# The Ore Bin


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**STATE OF OREGON**
**DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES**

# The Ore Bin

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State of Oregon
Department of Geology
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1069 State Office Bldg.
Portland Oregon 97201

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# OREGON'S MINERAL AND METALLURGICAL INDUSTRY IN 1973

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

The value of minerals produced in Oregon in 1973 increased a healthy 8.77 percent over the previous year. Higher production of sand and gravel, nickel, clays, and cement accounts for the increase. Production of stone declined somewhat from 1972. The dollar value of all minerals produced in the State amounted to $83,231,000, according to a preliminary estimate prepared by the U.S. Bureau of Mines. This figure reflects the pit price of the minerals only; it excludes any value added by beneficiation as well as the value of primary metals such as nickel, aluminum, steel, and the various exotic metals that are smelted and refined in Oregon.

In a year marked by rapid and large price increases for most commodities, it is interesting to observe that the sand and gravel unit cost rose only 4.9 percent, and the stone industries' yearly average showed no increases in unit costs whatsoever.

## Industrial Minerals

Sand and gravel and stone accounted for 64 percent of the State's total mineral production in 1973. On a per capita basis each person living in Oregon accounted for about $26.50 worth of these two commodities during the year. Very likely this expenditure represented the "best buy" made, since mineral aggregates produced in the State still sell at bargain prices. Just how long this situation will prevail is problematical since energy plays a large part in aggregate production and delivery costs. Production costs will undoubtedly increase as operators begin complying with the Mined Land Reclamation Act, which requires the eventual reclamation of the pit site as well as some changes in operational procedures.

Deposits of sand and gravel and stone are non-renewable; we are rapidly depleting them or removing them from mining by urbanization. As the demand increases and the supply shrinks, the price will inevitably rise. Careful planning will extend the useful life of the deposits, and more effort in this direction is imperative because no substitute has been found.

The per capita annual need for mineral aggregates for the manufacture of concrete in the United States amounts to 9,000 pounds of sand and gravel and 8,500 pounds of stone, to which might be added 800 pounds of cement and 600 pounds of clays, plus smaller amounts of other minerals. All of these products are low-value items in terms of their weight. Transportation from pit to market place represents a large part of the delivered cost, and with rising fuel costs, the need for local supplies becomes increasingly more important.

SOME OF OREGON'S MINERALS AT A GLANCE

| Mineral | 1972 | 1973 |
|---|---|---|
| Clays | $ 238,000 | $ 278,000 |
| Gem stones | 793,000 | 793,000 |
| Lime | 2,129,000 | 2,577,000 |
| Nickel | W | W |
| Pumice and volcanic cinder | W | 1,191,000 |
| Sand and gravel | 34,981,000 | 35,631,000 |
| Silver | 4,000 | ½* |
| Stone | 18,380,000 | 17,654,000 |
| Value of items that cannot be disclosed: Cement, diatomite, gold, talc, tungsten, and values indicated by symbol W | 19,991,000 | 25,107,000 |
| Total | $76,516,000 | $83,231,000 |

½* Less than ½ unit

## The Metals

Gold disappeared from the U.S. Bureau of Mines listing of commodities produced in Oregon during 1973, almost certainly the first time since records have been kept. Commercial gold production, troubled by increasing environmental restraints, has been declining for many years despite a firming of prices. Non-commercial, or recreational, gold mining has increased sharply in recent months but data on production is difficult if not impossible to obtain.

Whether or not the price of gold will stabilize at a price sufficiently high to attract major mining companies in the face of environmental restrictions remains to be seen.

Mercury production declined to the vanishing point during the year, following the general world-wide downward trend triggered by adverse reports on mercury published earlier.

As with gold and mercury, silver production decreased; in Oregon it is mineralogically associated with gold and produced largely as a co-product.

Nickel ore production at Riddle increased by 7 percent over the previous year, although the nickel content of the ore declined from 1.20 percent in 1972 to 1.17 in 1973. The Riddle operation produces the only primary nickel in the United States and accounts for roughly 8 percent of the total U.S. demand.

Aluminum production, despite a temporary shutdown at Reynold's Troutdale plant due to power shortage, increased 50 percent in the state over the previous year.

## Mined Land Reclamation

Although the Legislature passed a Mined Land Reclamation Act during the 1971 session, administration of the new law was hampered by lack of funding. During the year, one man was hired to inventory all mining operations in the State to develop an accurate data base for the Department's files. The 1973 legislative session revised the fee schedule, which provided extra funding to hire more personnel. Rules and regulations for administering the act were formulated and two public hearings were held during the year. Since that time, one additional geologist has been hired to assist in administering the act, and more personnel will be added to the staff when additional funds are acquired as a result of the new fee schedule. The inventory of mining operations, which is essentially complete, will place possibly 800 to 1,000 mining operations in the State under the act.

After much deliberation, the Department adopted Rules and Regulations for the administration of the act, and these, together with copies of various forms, were printed and made ready for distribution. A separate office was opened at Albany to handle the various phases of the Mined Land Reclamation Act. Correspondence concerning the act should be sent to Department of Geology and Mineral Industries, P.O. Box 1028, Albany, Oregon 97321; telephone number is (503) 926-5571, ext. 277. Copies of the act, rules and regulations, and the various forms may also be obtained at the Department offices in Portland, Grants Pass, and Baker.

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# OIL AND GAS EXPLORATION IN 1973

Vernon C. Newton, Jr.
Petroleum Engineer, Oregon Dept. Geology and Mineral Industries

There is still potential for finding deposits of oil and gas in Oregon in spite of many past drilling failures. No commercial production has been discovered thus far in nearly 200 attempts. However, only 32 deep holes have been put down onshore in Oregon since 1945 and only 8 holes drilled offshore since activity began there in 1965. Deep drilling has greatly increased knowledge of subsurface conditions in this geologically complex region. Results of deep drilling have been generally discouraging, but they have shown that there is a thick section of marine sedimentary rocks and that at many locations porous and permeable sands exist within the stratigraphic section.

## Exploration activity

Three major oil companies continued geologic studies in Oregon in 1973. The work is believed to have consisted of surface mapping subsequent to geophysical surveys made a year or two earlier.

Standard Oil Company of California drilled an 8,414-foot test hole in southeastern Malheur County this past summer. The hole was drilled on the 100,000-acre Blue Mountain Federal Unit (see Figure 1) 25 miles north of McDermitt, Nevada. Rocks on the surface in the vicinity of the site are mapped as Miocene volcanics and some areas of younger terrestrial sediments. Standard plugged and abandoned the Blue Mountain test in August and released the drilling equipment. Statistics on the well are as follows:

STATE DRILLING PERMIT NO. 64

| | | | | |
|---|---|---|---|---|
| Standard Oil Co. of Calif. | Blue Mtn. Fed. Unit No. 1 | SW$\frac{1}{4}$, sec. 34 T37S, R41E Malheur County | 8,414 TD | Abandoned August 8, 1973 |

## Leasing

Acquisition of oil and gas leases in 1973 continued to be substantially slowed by the moratorium on Federal lands declared in December 1971 by Secretary of the Interior Morton because of environmental questions raised by the Oregon Environmental Council and supported by the State Department of Environmental Quality and Senator Packwood. Action on applications in the state for 447,000 acres of Federal leases was postponed

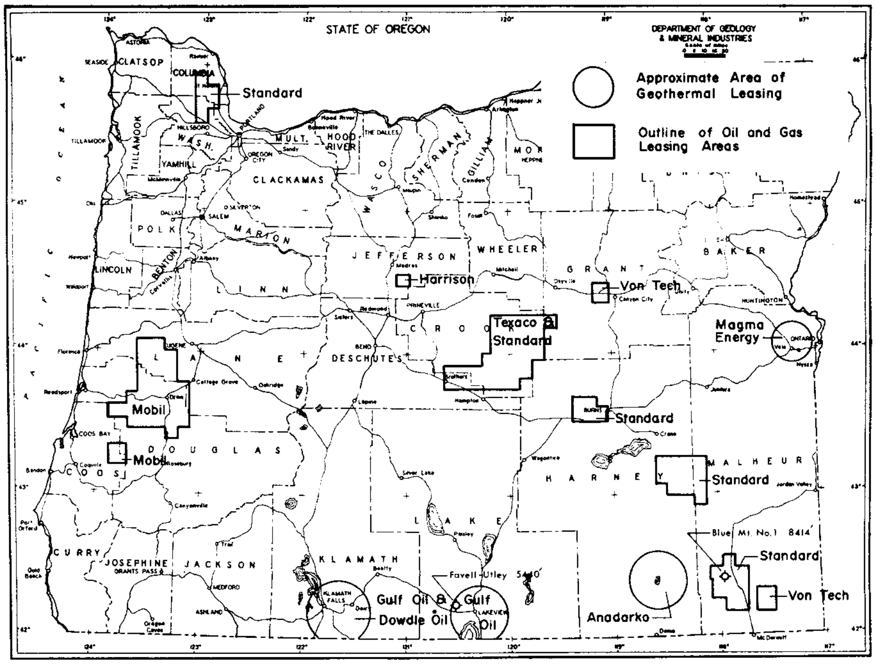


Figure 1. Map showing location of petroleum and geothermal lease areas, 1973.

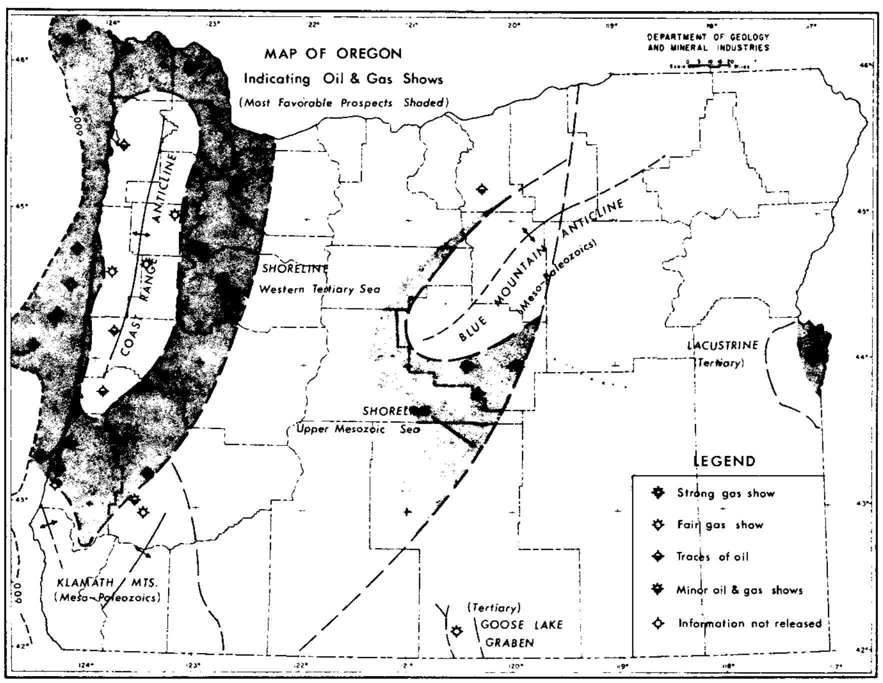


Figure 2. Map indicating favorable drilling prospects and wells with hydrocarbon shows.

until a determination of environmental effects of drilling could be made. With nearly 56 percent of the State owned by the Federal government, Federal policies have a significant influence on leasing activity. Early in January 1974, Governor McCall contacted Secretary Morton and urged that the impact study controversy in Oregon be resolved to allow reopening of Federal lands to leasing. Processing of applications for Federal oil and gas leases will probably be resumed in the near future.

Texaco renewed existing Federal leases in central Oregon following abandonment of its wildcat near the town of Paulina in November 1971. Gas shows were logged in what appeared to be Cretaceous sandstone. The Wolf Brothers, independent operators from Denver, and AMOCO Production Company withdrew applications for more than 200,000 acres of Federal leases, which were shelved by the moratorium. Leases on public lands for petroleum and geothermal resources are shown in Figure 1. Federal lands under lease as of January 1, 1974 were 232,000 acres.

## Favorable areas

Past drilling has delineated regions of the State where more exploration could be done to find oil and gas deposits. Geologic features are greatly simplified in Figure 2 to portray regional conditions. A large area of the western Tertiary marine basin onshore is still open to more testing, and much of the adjacent continental shelf has never been explored by drilling. The prospective shelf areas include a deep sedimentary basin off Coos County.

Geology of the central State region is complicated by a thick cover of Tertiary volcanic rocks, and until more deep drilling is done subsurface conditions cannot be well understood. The mantle of volcanic rocks is penetrated with difficulty or not at all by present geophysical tools. Most of the surface seeps of oil and tar found in the State occur in this region, but even in central Oregon surface indications of petroleum are rare. The Mesozoic prospects shown in Figure 2 probably could be extended if deep holes were put down a distance from the Mesozoic outcrop areas.

The eastern Oregon Tertiary lake basin has had numerous interesting gas shows. This sedimentary basin is several thousand feet deep and has a potential for gas production, providing permeable sands can be found in the stratigraphic section. Tests on gas samples from a well in the Idaho portion of the basin showed that it contained petroleum condensate. Gas shows have been encountered in Goose Lake graben also, but producing possibilities in that area appear to be quite limited.

Deep wells which encountered shows of oil or gas have been plotted in Figure 2. For the most part, the oil shows were in trace amounts. Gas shows plotted rate a "fair show" classification; either they were obtained in a water-saturated zone or they were found in beds with low permeability. An exception is the Reserve Oil and Gas Company gas show, which is classed as strong since a formation test on the zone between 7,055 and 7,106 feet in volcanic rock yielded 2,000 B/D of very gassy saltwater with a bottom-hole flow pressure of 4,482 psi. Oil shows in the Uranium Oil and Gas Co. and Oil Developers wells on the southeastern border of the Tertiary basin were better than trace amounts; the first was probably found in Cretaceous sandstone and the latter obtained in lower Eocene sandstone. Gas shows were recorded from 1,700 to 3,600 feet in Cretaceous sandstone in the Texaco well drilled in central Oregon in 1971 (Figure 3).

Shaded areas in Figure 2 show prospective regions of sedimentary basins where it is believed the thickness of rocks is great enough and the geologic structure suitable for accumulation of hydrocarbons. Several good drilling plays should be found in these areas, depending upon the results of supporting geological and geophysical data.

Private industry should be encouraged to explore in Oregon, as a discovery of oil or gas at this time would be very beneficial to the state. Dangers of oil and gas development have been greatly exaggerated since

Figure 3. Texaco "Federal No. 1," drilled in Crook County during 1971, logged gas shows in Cretaceous sandstone between 1700 and 3600 feet.

the Santa Barbara incident. Even though this blow-out is commonly referred to as a catastrophe, no one was killed in the accident and the birds and aquatic life re-established their prior natural balance within a year of the accident (Steinhart and Steinhart, 1972). Beaches along the bordering coastline and the boat harbor were restored essentially to normal conditions 45 days after the well blew wild in spite of severe storm conditions which prevailed at the time.

The physical property of oil preventing it from mixing with water should make it less hazardous to aquatic life than soluble pollutants. Crude oil is only moderately toxic as compared to some refined products transported in coastal waters (Holt, 1969). The increasing pollution of coastal water by waste effluents is a much greater threat to aquatic life than infrequent oil spills (Steinhart and Steinhart, 1972). Ocean spills are dissipated by dispersion, evaporation and bacterial degradation.

Oil development has been successfully conducted in metropolitan centers, exclusive residential areas, and wild life reserves. Screens, buried facilities, and subsea installations can be used to preserve aesthetic values while essential resources are recovered.

There are some risks involved in obtaining underground fluids. These include the possibility of subsidence in certain geologic circumstances, induced slippage along active faults, accidental spills, and contamination of water resources. Under existing regulations in most states, including Oregon, occurrence of any of these detrimental side effects will be rare.

At the present time, there are no substitutes for fossil fuels. They supply 95 percent of our present energy needs and very likely will continue to be the main supply for at least the next few decades.

All energy sources produce some measure of undesirable environmental side effects, but with planning and wise control, energy resources can be used without destroying or seriously impairing the environment.

## References

1. U.S. Geological Survey, 1969, Pictures of the oil spill in Santa Barbara channel, 1969: U.S. Geol. Survey Pacific Region Branch of Oil and Gas Operations, January to May 1969.
2. Holt, D. P., 1969, Oil on the Sea; Proceedings of Symposium on Technology; Massachusetts Institute of Technology and Woods Hole Oceanographic Institute, May 16, 1969: New York, Plenum Press.
3. Steinhart, C. E., and Steinhart, J. S., 1972, Blowout, a case study of the Santa Barbara oil spill: North Scitaute, Mass., Duxbury Press.

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# GEOTHERMAL ACTIVITY IN 1973

Richard G. Bowen
Economic Geologist, Oregon Dept. of Geology and Mineral Industries

The beginning of a new level of activity in geothermal exploration was seen in 1973. Awareness of the potential of geothermal resources has finally begun to penetrate the ranks of governmental and industrial decision makers, helped a great deal by the "energy crisis."

The Final Environmental Statement for the Geothermal Leasing Program was released during 1973 and a summary on page III-85, Vol. I, capsulized the results of the 3-year effort:

"While geothermal development will impose some unavoidable adverse environmental impacts, it appears to have the potential of being less environmentally damaging than other power generation systems using coal, oil, or nuclear energy sources. To the extent that there are net reductions in air, water, or land adverse impacts, such differences represent a positive benefit from use of geothermal resources."

As a result of the environmental study, Secretary of Interior Rogers C. B. Morton announced the decision of the Department to open all areas outside of the Known Geothermal Resource Areas (KGRA's) for filing and to take application on lands within three KGRA's in California at the Clear Lake-Geysers KGRA, Mono-Long Valley KGRA, and the East Mesa KGRA.

On the national level, the Atomic Energy Commission has started moving agressively to enlarge its sphere of interest in its drive to become the Energy Agency. Consequently it has been able to preempt nearly all the Federal research and development funds allocated to geothermal studies.

U.S. Geological Survey studies have expanded modestly and are including geothermal-related research in Oregon, Idaho, and Nevada, in addition to the more extensive studies in California.

Several significant test wells were drilled in 1973. The most extensive program was that of Gulf Oil Company, which drilled five slim-hole geophysical evaluation tests to depths greater than 5000 feet. Four of these wells were drilled in northern California, two near Susanville and two near Cedarville, and one well in Oregon near Lakeview. Gulf announced these wells were all drilled to evaluate geophysical exploration methods and consequently no information other than drilling depth has been released on any of the wells. Subsequent to the drilling in Lakeview, a representative of Gulf told a meeting of the local Lions and Rotary Clubs that they were "not discouraged" from the test and would be continuing work in the area next summer.

Other specific developments have been the increasing of leasing on private lands in many western states; the drilling of two exploration tests near Chandler, Arizona by Geothermal Kinetics Systems, which are still being evaluated; the continuation of drilling by Union Oil and Dunigan Enterprises in the Valles Caldara, New Mexico area; and the continued drilling activity in the Imperial Valley and at The Geysers in California.

At The Geysers several successful wells were drilled during the year, and by late fall five drilling rigs were enlarging the field. Another power plant containing units 9 and 10 came on line, increasing output to 396,000 kw, thus making it the largest geothermal facility in the world. Construction on unit 11 is underway, with operation scheduled in 1974.

The current shortages and increasing costs in the energy field are causing a reevaluation of geothermal potential, and many firms are now giving serious consideration to its use for space and process heating. This use broadens the application and greatly increases the usefulness of the resource.

* * * * *

## GEOTHERMAL LEASING PROCEDURE FOR STATE LANDS

The Oregon Division of State Lands introduced a draft of leasing procedures for geothermal resources at the December 21, 1973 meeting of the State Land Board. Copies of the draft have been sent to industry and to environmental organizations for review. Hearings on the new regulations are scheduled for February 1974, and final approval is expected by March. Present applications for geothermal leases on State lands total approximately 25,000 acres. The Oregon leasing procedures differ from the Federal regulations in that they set no maximum on acreage and competitive bidding is not initiated until a discovery is made.

<u>Leasing summary</u>

Stage 1.
- A. Exploration Lease - Two years of any exploration method except deep drilling. Developer determines the possibility of a discovery; if good, he submits:
- B. Land use environmental impact analysis - With facts to be used by the Lands Division before devoting land to geothermal use. Then the Division requests additional information from the public at a:
- C. Public hearing - If the Division then decides to go ahead:

Stage 2.
- D. Deep Drilling Lease - Five years of additional exploration including at least one 4,000 foot well; if the well is a:
- E. Discovery - When proven, it vests a right to a Production Lease subject to:

Stage 3.
- F. Development environmental impact analysis and plan;
- G. Geothermal Production Lease - For a ten (10) year primary term renewable to fifty (50) years.

## GEOTHERMAL LEASE REQUIREMENTS

| | Exploration Lease | | Deep Drill Lease | | | | | Production Lease | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 1st | 2nd | 3rd | 4th | 5th | 1st-10th | Later |
| Rent/Acre/Year | $1.00 | $1.00 | $1.00 | $2.00 | $3.00 | $4.00 | $5.00 | $5.00 Appl. to royalty | Reappraise |
| Exploration expense/Acre/Year | $1.00 | $1.00 | $1.00 | $2.00 | $3.00 | $3.00 | $3.00 | -0- | |
| Drilling requirement | --- | --- | | | to 4,000 feet | Carry | Carry | Per development plan | |
| Royalty | --- | --- | --- | --- | --- | --- | --- | 10% | |
| Bond | $10,000 | Same | $10,000 | Same | Same | Same | Same | $100,000 | Same |
| Insurance | $20/40/20,000 to $50/100/50,000 | Same | $100/200/ 100,000 | Same | Same | Same | Same | $100/200/ 100,000 | Same |
| Environmental analysis | | Land use - data costs and pub. | | | | | Develop-ment -- data costs | | |
| Environmental protection | Restoration costs | Restoration costs | Negotiated agreement | --- | ---- | --- | --- | Negotiated agreement on plan | As required by law |

# FIELD WORK IN OREGON DURING 1973

John D. Beaulieu
Stratigrapher, Oregon Dept. Geology and Mineral Industries

During the 1972 field season, approximately 90 geologic field studies 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 roughly divided into six sections.

The list is probably not complete and the Department would appreciate receiving information about other studies in progress in this State. The resumés received thus far have been invaluable in completing this list, and the Department is grateful for these contributions. Unless stated elsewhere, no reports on the following studies are available through this Department.

## Northwestern Oregon

1. Geologic hazards of Bull Run Watershed: John D. Beaulieu
2. Environmental geology of western Linn County: John D. Beaulieu and Paul W. Hughes, Dept. of Geol. and Mineral Industries
3. Erosion processes of the Willamette Valley: W. M. Brown and S. A. Vickers, U.S.G.S., Portland
4. Biostratigraphy of the type Nestucca Formation: A. D. Callender, graduate student, P.S.U.
5. Ground water of Harrisburg-Halsey area: F. J. Frank, U.S.G.S., Portland, in coop. with State Engineer
6. Ground water of coastal Lincoln County: F. J. Frank and A. Laenen, U.S.G.S., Portland, in coop. with State Engineer
7. Micropaleontology of type Yamhill Formation: Larry Gaston, graduate student, P.S.U.
8. Oregon coastal landforms: David Greene, U of O graduate student, geography
9. Portland earthquake potential: Paul Hammond, professor, P.S.U.
10. Volcanic hazards of Mount Hood: Paul Hammond, professor, P.S.U.
11. Bauxite trace elements: R. L. Jackson, graduate student, P.S.U.
12. Ground water in north Clackamas County: A. R. Leonard, U.S.G.S., Portland, in coop. with State Engineer
13. Amphibole-bearing volcanic rocks of the Cascades: G. L. Millhollen, professor, U of South Carolina
14. Micropaleontology of the Nestucca: Daniel McKeel, Mobil Oil Corp.
15. Volcanic chronology: A. McBirney, professor, U of O, and J. Sutter, professor, Ohio State U
16. Keasey Formation: Kris McDougall, graduate student, U.S.C.

17. Field relations of Tyee and Yamhill Formations: Robert McWilliams, professor, Miami U.
18. Astoria Formation: Al Niem, professor, O.S.U.
19. Oil and gas investigations in Columbia and Clatsop Counties: V. C. Newton, Dept. of Geol. and Mineral Indus.
20. Environmental geology of Marquam Hill, Portland: R. A. Redfern, graduate student, P.S.U.
21. Micropaleontology of Alsea Formation: W. W. Rau, geologist, State of Washington
22. Central Oregon Coast field check: P. D. Snavely and others, U.S.G.S. Menlo Park
23. Alsea Formation: P. D. Snavely and others, U.S.G.S., Menlo Park
24. Continental Margin: P. D. Snavely and others, U.S.G.S. Menlo Park
25. East Portland water quality: F. M. Tawfik, graduate student, P.S.U.
26. Zeolites in Goble volcanics: R. Tschernich, and W. S. Wise, U.Calif.
27. Pioneer Summit foraminifers: R. Thoms, professor, P.S.U.
28. Columbia River Gorge: A. C. Waters, professor, U. Calif., Santa Cruz
29. Cenozoic floras: J. A. Wolfe, U.S.G.S., Menlo Park

## Southwestern Oregon

1. Miocene stratigraphy: W. O. Addicott, U.S.G.S., Menlo Park
2. Sedimentation: H. E. Clifton, U.S.G.S., Menlo Park
3. Eocene synthesis: E. W. Baldwin, professor, U of O
4. Alpine ultramafic petrology: R. Coleman, U.S.G.S., Menlo Park
5. Rogue Formation and related rocks: Mike Garcia, graduate student, U.C.L.A.
6. Graywackes, C. E. Hedge, U.S.G.S., Menlo Park
7. Geology of NW¼ Roseburg sheet: Z. Huq, graduate student, U of O
8. Cretaceous of Canyonville and Days Creek quadrangles: D. Jones, U.S.G.S., Menlo Park
9. Quaternary sedimentation: R. J. Janda, U.S.G.S., Menlo Park
10. Geology along South Fork of Umpqua: A. Kays, professor, U of O
11. Alpine type ultramafics: R. A. Loney, U.S.G.S., Menlo Park
12. Soils of Siuslaw National Forest: H. A. Legard, U.S. Forest Service, Eugene
13. Aeromagnetic survey: D. R. Mabey, U.S.G.S., Menlo Park
14. Cenozoic marine vertebrates: C. Repenning, U.S.G.S., Menlo Park
15. Ground water of the Sutherlin area: J. H. Robison, U.S.G.S., Portland, in coop. with Douglas County
16. Geologic hazards of coastal Lane County: H. G. Schlicker, Dept. of Geol. and Mineral Indus.
17. Geology of SE¼ Dixonville quadrangle: W. Seeley, U of O
18. Lower Tertiary orbitoids: R. Thoms, professor, P.S.U.
19. Josephine Peridotite: Scott Vail, graduate student, O.S.U.

## North-central Oregon

1. Mineralogy of John Day tuffs: D. W. Baggs, graduate student, P.S.U.
2. Stratigraphy of Columbia River Basalt: R. D. Bentley, professor, Central Washington State College
3. Volcanic thermal studies: J. D. Friedman, U.S.G.S., Menlo Park
4. Picture Gorge Basalt: J. S. Fruchter, graduate student, U of O, and G. Goles, professor, U of O
5. Flat-topped volcanic landforms: B. Gannon, graduate student, P.S.U.
6. Quartzville mining district; F. R. Johnson, graduate student, O.S.U.
7. ERTS imagery: R. Lawrence, professor, O.S.U.
8. Clarno Formation: P. C. Owen, graduate student, O.S.U.
9. Deschutes County mineral resources: N. Peterson, Dept. of Geol. and Mineral Indus.
10. Water resources of Warm Springs Indian Reservation: J. H. Robison, U.S.G.S., Portland, in coop. with U.S. Federated Tribes
11. Clarno Formation: A. Rollins, graduate student, O.S.U.
12. Paleobotany: R. A. Scott, U.S.G.S., Menlo Park
13. Glacial geology: W. E. Scott, graduate student, U of O
14. Strain of volcanoes: D. A. Swanson, U.S.G.S., Menlo Park
15. Regional volcanology: R. L. Smith and H. R. Shaw, U.S.G.S., Portland
16. Broken Top: E. Taylor, professor, O.S.U.

## South-central Oregon

1. Pliocene basalts: J. C. Avent, professor, Fresno State College
2. Volcanic geology near Klamath Falls: G. Davis, and G. MacPherson, graduate students, U. Calif., Santa Cruz
3. Pleistocene shorelines: Charles Forbes, graduate student, U of O, geography
4. Mineralogy and geology, Paisley Mountains: J. W. Hammitt, graduate student, O.S.U.
5. Inventory hot water uses in Klamath Falls: N. Peterson, Dept. of Geol. and Mineral Indus.
6. Warner Valley lakebeds: D. L. Weide, U. Nevada, Las Vegas

## Northeastern Oregon

1. Mineral deposits of Big Lookout Mountain area: G. M. Cox, graduate student, O.S.U.
2. Platinum group metals: G. A. Desborough, U.S.G.S., Menlo Park
3. Banded rhyolites - trace elements: G. B. Hallock, graduate student, P.S.U.
4. Jurassic of North America: R. Imlay, U.S.G.S., Menlo Park
5. Columbia River Basalt of Imnaha Canyon area: W. Kleck, graduate student, P.S.U.

6. Grande Ronde dike swarm: S. A. Price, Atlantic Richfield Hanford Co.
7. Columbia River Basalts, Imnaha to Grande Ronde River area: S. Reidel, graduate student, W.S.U.
8. Columbia River Basalt, Grande Ronde River: M. Ross, graduate student, W.S.U.
9. Columbia River Basalt: D. A. Swanson, U.S.G.S., Menlo Park
10. Geology of chromium: T. Thayer, U.S.G.S., Menlo Park
11. Pre-Tertiary of John Day area: T. Thayer, U.S.G.S., Menlo Park
12. Geology Snake River Canyon: T. Vallier, professor, Indiana State U.
13. Eagle Cap Wilderness: P. Weis, U.S.G.S., Spokane
14. N$\frac{1}{2}$ Bates quadrangle: G. Wheeler, graduate student, U of W

### Southeastern Oregon

1. Geothermal studies: R. Bowen, Dept. of Geol. and Mineral Indus.
2. Volcanic stratigraphy of the Cordera quicksilver area: R. C. Greene, U.S.G.S., Menlo Park
3. Hydrologic reconnaissance of geothermal areas: E. A. Sammel, U.S.G.S. Menlo Park
4. Geothermal resources: J. H. Sass and A. H. Lachenbruch, U.S.G.S., Menlo Park
5. Zeolitic tuffs near Durkee: R. Sheppard, U.S.G.S., Menlo Park
6. Geothermal reconnaissance: G. Walker, N. MacLeod, E. McKee, U.S.G.S., Menlo Park
7. Oregon State map: G. Walker, U.S.G.S., Menlo Park

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## NORMAN S. WAGNER RETIRES

N. S. Wagner, district geologist in charge of the Department's Field Office in Baker, retired on December 31 after 31 years of service. "Wag" came to the Department during World War II after working as a geologist and assayer for the Idaho-Maryland mine in the Grass Valley area of California and at the West Coast mine near Winnemucca, Nevada. During his time with the Department, he has authored or co-authored at least 40 reports on the geology and mineral resources of eastern Oregon, including stratigraphic and ground-water studies, geologic mapping, articles on mining history, and surveys of innumerable mineral commodities. He has rendered particularly valuable service to the mining industry by contributing his broad knowledge on the mineral potential of this large region.

Wag's recent acquisition of some top-notch photographic equipment, his keen interest in mining lore, and his knack for writing it down, lead us to anticipate seeing some interesting results in the publications field .

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## GEOLOGIC HIGHWAY MAP OF OREGON AND WASHINGTON

The Department has received for sale "Geologic Highway Map of the Pacific Northwest Region -- Washington and Oregon" published in 1973 by the American Association of Petroleum Geologists. The sheet, measuring 28 by 36 inches, is printed in multicolor on both sides and folds to a standard highway map size. A small-scale map of Oregon and Washington shows the geology and the main towns and highways. The sheet includes considerable other information such as cross sections, time scales, index maps of special subjects, and texts describing the stratigraphy, geomorphology, and historical geology. The map can be obtain from the Department's offices in Portland, Baker, and Grants Pass for $2.50.

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## LINCOLN COUNTY BULLETIN PUBLISHED

"Environmental Geology of Lincoln County, Oregon" is the latest in the Department's bulletin series. The bulletin (No. 81) describes the characteristics of the bedrock units and surficial materials, the topography, and the geologic and climatic processes at work in the area. Geologic hazards that result from the complex interplay of these factors, influenced by man's activities, are the chief concerns of the bulletin.

Most of Lincoln County's population is concentrated along its coastal terraces, where seaward-tilted bedrock overlain by sands and silts are subject to severe wave erosion and landsliding. Housing is increasing along the major valleys which, unfortunately, are fequently threatened by flooding and landslides. Very recently, development has moved into the low coastal dune areas, which are highly vulnerable to the ravages of high tides and storm waves. Demand for more land on which to build recreational facilities has resulted in many poor site selections and financial losses to individuals who have invested in the property.

Bulletin 81 is the work of four geologists, all authorities in their special fields. It is illustrated with many photographs and diagrams, and is accompanied by a set of six multicolored maps showing distribution of geologic units and areas of current or potential geologic hazard. The publication should be of great service to county planners and the concerned public.

Bulletin 81 is for sale by the Department's office in Portland, Baker, and Grants Pass. The price is $7.50.

* * * * *

## 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
58. Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass . . . . 5.00
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75. Geology, mineral resources of Douglas County, 1972: Ramp . . . . . . . . 3.00
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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
81. Environmental geology of Lincoln County, 1973: Schlicker and others . . . . . 7.50
82. Geol. hazards of Bull Run Watershed, Mult. Clackamas Cos., 1974: Beaulieu . . .in press

### GEOLOGIC MAPS

Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck . . . . . . 2.15
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# ECONOMICS OF GEOTHERMAL DEVELOPMENT

> The following article by Dr. Robert W. Rex is the text of his remarks to the Sub-Committee on Energy, Committee on Science and Astronautics, U.S. House of Representatives, on September 18, 1973. This text was previously published in Geothermal Energy, vol. 1, no. 4, December 1973. We are reprinting it in this issue of The ORE BIN because we believe the thoughts expressed are pertinent to Oregon at this time and should have as wide dissemination as possible.
>
> Dr. Rex is the President of Republic Geothermal, Inc., Playa del Rey, California. He was formerly Exploration Manager of Pacific Energy Corporation, and prior to that he headed the geothermal energy studies at the University of California, Riverside.
>
> For many years, Dr. Rex has been one of the nation's most articulate spokesmen for geothermal power development and a leader in applying the multipurpose concept to development of geothermal resources.

## Hearing on Geothermal Energy

### Introduction

Mr. Chairman, members of the Sub-Committee:

I am honored to be invited to present comments on H.R. 9658* and to discuss the potential for geothermal energy in the U.S.

The previous witnesses have given you a picture of Federal effort in geothermal energy research and of the potential both at home and abroad. Dr. Smith** has also informed you of the very exciting and remarkably successful program at the Los Alamos Scientific Laboratory to extract useful heat from hot dry rock. It is my intention to brief you on my determinations

*Bill for funding geothermal studies

**Morton Smith, A.E.C. Los Alamos Scientific Laboratory, Project on Extraction of Power from Hot Dry Rock on the relationship between resource price and the quantity of potentially available resources. Then I intend to present an analysis of the revenue accruing to the government from geothermal development of Federal lands by private industry.

## U.S. resource size - price relationship

It is my opinion that most of the variations in the estimates of U.S. geothermal potential are caused by variations in the assumed market price for this energy. Most of the conservative estimates were the result of assuming energy prices fixed at the 1970, 1971, or 1972 levels. Clearly this is unrealistic. The National Petroleum Council clearly states that their most recent reserve estimates were based on "current market prices", whatever that means. There is a logical and overweaning reason for this. County government places a property tax on reserves in the ground called the ad valorem tax. No energy extraction company is going to allow an exploration manager to gather data on presently non-marketable reserves because any such action would most probably trigger ad valorem taxes on such marginal reserves. Consequently, the geothermal, oil, and natural gas industries assiduously avoid bankrupting themselves by gathering data on currently non-profitable energy reserves. This means that the public sector has great difficulty in obtaining a realistic appraisal on the relationship between total U.S. recoverable reserves and a reasonable market price for those reserves. I view this head-on conflict between Federal and county interests to be the overwhelming fundamental cause of the present energy crisis. Without this conflict we would long ago have had the necessary information to develop a rational national energy policy and could have avoided the present dislocations.

My colleagues and I have attempted to model many hundreds of geothermal ventures including dry steam, various types of hot water, and hot dry rock. These models suggest the energy price which would be required to sustain a viable corporate venture. Then I have tried to make regional estimates of resource size. The combined results of these analyses are given in Table 1, which compares known, probable, and undiscovered reserves as a function of cost. In order to keep within the areas of maximum data available at the time of preparation of this table, I focused on steam, hot water, and hot dry rock in the states west of the Rockies. The addition of the Gulf Coast potential for the geopressured geothermal resource would serve to substantially increase the present figures.

The two primary points that I would like to make in this area are as follows:

First, the data available suggest that large scale utilization of the U.S. geothermal resource is very close to economic feasibility. Small scale use is developing rapidly at present. Consequently, positive action by the Federal government has the potential for major leverage by the private sector.

By this I mean that the forces of the marketplace are bringing geothermal energy into the U.S. energy portfolio. Congress, however, has the ability, by providing seed money for technology demonstration, to accelerate by from ten to twenty years the pace of development of the U.S. geothermal potential and in this way save substantial foreign exchange liabilities and help control inflation.

Second, there is a large amount of dissolved natural gas in the geopressured Gulf Coast geothermal waters. The dollar value of this gas is about double the value of the thermal and pressure energy. However, the wells to develop this resource will be deep (often 14,000 feet or more) and expensive. The threshold price for this gas is about $1.00 per mcf [thousand cubic feet]. The Federal Power Commission is presently rejecting sales prices above $0.50 per mcf. Consequently, the FPC is preventing development of this gas reserve by its pricing policy. It should be noted that imported natural gas costs the U.S. more than $1.00 per mcf, as does synthetic natural gas. Current fuel oil prices are the equivalent of from $0.90 to $1.10 per mcf. This FPC pricing policy is therefore blocking the development of the geopressured natural gas resource.

The Resource Appraisal Panel of the National Science Foundation Conference on Geothermal Energy in September 1972 made a preliminary calculation of the size of the recoverable resource on the Gulf Coast. It is 2,700 trillion cubic feet or enough gas to meet U.S. needs for 50 years.

It is my recommendation that high national priority be given to a research and development program to appraise this resource, demonstrate the technology necessary to utilize it, and develop an understanding of the environmental problems associated with its development. I view this need as so great that I would prefer to see it handled by existing entities such as the non-nuclear activities group of the A.E.C., the National Science Foundation, and the U.S. Geological Survey rather than wait for a new entity. House bill H.R. 9658 is a partial step in this direction, but by itself it is less important than adequate program funding within the present National Science Foundation structure. If H.R. 9658 comes into law, it will be a positive move. If not, it is imperative that present programs be funded at increasing levels to permit acceleration of the pace of development of geothermal technology.

## Revenue accruing to government from development of Federal lands

It is clearly evident that development of geothermal plants in the U.S. displaces imported petroleum. This means that the fuel bill for the generation of electricity can either be a foreign exchange burden or it can result in economic growth of the U.S. economy and yield tax, royalty, and rental revenue to the government.

In order to illustrate the large contribution that development of Federal lands for their geothermal potential makes to the U.S. taxpayer, I have

Table 1. Amount of producible geothermal energy in the United States (Mwcen* of electricity)

| Energy price (mill/kwhr)[a] | Known reserves | | Probable reserves | | Undiscovered | |
|---|---|---|---|---|---|---|
| | Amount | Areas** | Amount | Areas** | Amount | Areas** |
| 2.9- 3.0 | 1,000 | 1 | 5,000 | 1 | 10,000 | 1 |
| 3.0- 4.0 | 30,000 | 1-2 | 400,000 | 1-4 | 2,000,000 | 1-5 |
| 4.0- 5.0 | --- | --- | 600,000 | 1-6 | 12,000,000 | 1-7 |
| 5.0- 8.0 | --- | --- | --- | --- | 20,000,000[b] | d |
| 8.0-12.0 | --- | --- | --- | --- | 40,000,000[c] | d |

[a] Mills per kilowatt hour in 1972 dollars

[b] Hot, dry rock at less than 6.1 km (20,000 ft.) depth

[c] Hot, dry rock at less than 10.7 km (35,000 ft.) depth

[d] Development of hot, dry rock energy is assumed over 5 percent of the area of the western third of the U.S. Hot, dry rock systems development is based on hydraulic fracturing or cost-equivalent technology. Present drilling technology is assumed; new low-cost deep drilling could substantially improve these economics.

* Megawatt-Century: steam reserves sufficient to generate one megawatt of electricity for one century using efficiencies of present technology.

** Areas: 1. Clear Lake-The Geysers; 2. Imperial Valley; 3. Jemez area, N.M.; 4. Long Valley, Calif; 5. remainder of Basin and Range area of western U.S.; 6. Hawaii; 7. Alaska

Table 2. Revenue to the public sector from 1,000 megawatts for 30 years from Federal land (including depletion allowance at 22 percent)

| | | |
|---|---|---|
| Lease rental | $ 45,000 | |
| Royalty | 244,887,000 | |
| Federal income tax | 482,998,000 | |
| Total Federal | | $ 727,930,000 |
| State income tax | 107,578,000 | |
| County ad valorem tax | 177,154,000 | |
| Total other governments | | 284,732,000 |
| Total government revenue | | $1,012,662,000 |

## Appendix to Table 2

1. Plant factor = .909 (100 MW for each 110MW capacity)
2. Well size: 7.5 MW (150,000 lbs/hr)
3. Disposal: 1 disposal well for each producing well (first dry hole used as a disposal well)
4. Drilling program for each 55 MW unit:

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 12 |
|---|---|---|---|---|---|---|---|---|---|
| Exploratory wells | 2 | - | - | - | - | - | - | - | - |
| Development wells | - | 3 | 3 | - | - | 1 | 1 | 1 | 1 |
| Dry holes | 1 | 1 | 1 | - | - | - | - | - | - |
| Disposal wells | 1 | 3 | 3 | - | - | 1 | 1 | 1 | 1 |

5. Cost of wells:

| | Tangible | Intangible | Total |
|---|---|---|---|
| Exploratory | $117,000 | $273,000 | $390,000 |
| Development | 116,000 | 174,000 | 290,000 |
| Dry holes | 117,000 | 273,000 | 390,000 |
| Disposal | 36,000 | 54,000 | 90,000 |

6. Gathering lines: $15.5/KW capacity ($852,500 for 55 MW unit)
7. No operator fee
8. No production or severance taxes
9. Overhead at $50,000 per year per unit plus a percentage of land, drilling, and operating expense
10. Depreciation: straight line
11. Geology/Geophysics: $20,000 in each year of drilling plus $7,000 per year every year
12. Acreage: 560 acres per 55MW unit
13. Royalty: 10 percent
14. Lease rental: $1/acre in years 1-4
15. Working capital: $200,000 per 110 MW capacity
16. All equity capital: no debt structure; no interest accrual
17. Inflation: 5 percent per annum on all costs
18. Steam production begins in year 5
19. Gathering lines constructed in year 4
20. Steam sales price: 4.5 mills/kwhr in year 1; 5 percent yearly increase
21. State income tax at 9 percent
22. Federal income tax: 22 percent on total taxable income
    26 percent on taxable income over $25,000
23. Ad valorem tax: 10 percent of assessed value (25 percent of market value determined by discounting net income before taxes)

* * * * *

analyzed the economics of development of ten 100 megawatt units on Federal lands and considered the income stream accruing to the public sector from the 1,000 megawatts of power over 30 years. The various assumptions that went into these calculations are given in the appendix to Table 2. The calculations are based on development of hot water fields such as are found in many places in the western U.S. There is a possibility of some latitude in local cost factors that vary from field to field but this will have relatively small impact on the tax income stream. The results are given in Table 2.

Every 1,000 megawatts of geothermal development on Federal lands yields about one billion dollars of public revenue; 73 percent to the Federal government, 11 percent to State governments which have income taxes, such as California, and 18 percent to county governments.

I strongly recommend that the enormous return on investment to the government on Federal geothermal research be acknowledged in national energy planning and budgeting. Furthermore, it becomes obvious that the slow pace of implementing the Federal lands leasing program is depriving the Federal government of a significant income stream. It illustrates that the earlier arguments concerning grandfather rights and a possible "give-away" of rights by granting grandfather leases is without basis. The income stream from royalties completely swamps any conceivable lease rental considerations.

If the projections for development of from 40,000 to 90,000 megawatts of geothermal energy in the next decade are realized, we will add 40 to 90 billion dollars in tax revenue to the public treasuries which would otherwise have been lost.

I seriously doubt that any other Federal investment in energy technology stimulation offers a better promise than does geothermal energy in all of its aspects, including hot waters, geopressured resources, and hot dry rock.

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## ENERGY FORUM PROCEEDINGS TO BE PUBLISHED

Authorities on wind power, solar power, geothermal power, conversion of oil shale, and coal gasification and liquefaction spoke to a capacity audience at the "Citizens Forum on Potential Future Energy Sources" held January 17, 1974, at Portland State University. Because of the great interest shown in these possible supplementary energy resources, the speakers have agreed to submit their reports to the forum sponsors (this Department and the Portland State University College of Science) for publication in a proceedings volume. Availability of the forum proceedings will be announced in The ORE BIN upon publication.

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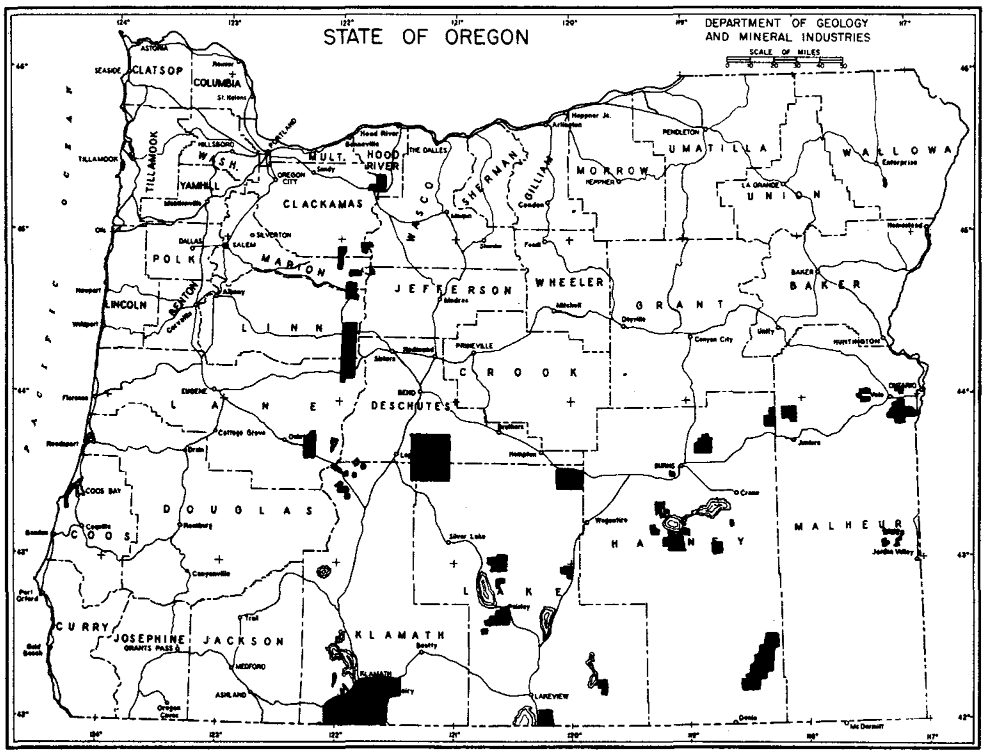
# GEOTHERMAL LEASING IN OREGON

February 1, 1974, was the first drawing of wildcat lease applications for geothermal exploration on Federal land in Oregon. Sixty-one companies and individuals filed for a total of nearly one million acres in the western Cascades and southeastern Oregon. In the Cascades, leasing was confined to Hood River, Clackamas, Marion, Linn, and Lane Counties. East of the Cascades, leasing was in Deschutes, Klamath, Lake, Harney, and Malheur Counties with about 200,000 acres filed for in Deschutes, Harney and Mal-Heur Counties. Heaviest filing occurred around Klamath Falls, the Alvord Desert, Glass Buttes, Newberry Crater, and along a north-south band near Belknap Springs.




Approximate locations of geothermal leasing on Federal lands in Oregon.

In some areas of the Alvord Desert, lease filings by three or more companies and individuals overlapped, raising the possibility that the area may be declared a KGRA (Known Geothermal Resource Area), which will require an environmental impact statement before leasing by competitive bidding can begin.

It is unknown whether or not lease applications will be approved in the Newberry Crater, since it is primarily a recreation area.

Sun Oil Co., the largest filer in Oregon, applied for about 158,271 acres. Next largest filer was California Geothermal Inc., with about 99,493 acres, followed by Chevron Oil Co. with about 94,849 acres. However, since the maximum acreage allowed per company or individual is 20,480, many applications will be withdrawn.

Other filers include several individual Oregonians, the Hunt family of Texas, Magma Power Co., Earth Power Co., Gulf Oil Co., and the City of Burbank, California.

Further information on leasing can be obtained from the Bureau of Land Management office in Portland.

* * * * *

## OREGON BLM OFFICER APPOINTED

E. J. Petersen has been named Oregon Associate State Director for the Bureau of Land Management by BLM Director Curt Berklund, effective January 1, 1974. Petersen, who joined BLM in 1949 as a forester in Coos Bay, Oregon, was transferred to California as a district director in 1955 and progressed to the position of Associate BLM Director for California. Archie Craft, BLM Director for Oregon, said that Petersen's broad previous experience will make him a valuable member of the BLM staff, and that he will be particularly helpful in managing recreational use of the national resource lands in Oregon.

* * * * *

## AGE DATES OF OREGON ROCKS TABULATED

Two open-file reports tabulating radiometric ages of Oregon rocks are available for inspection at the Department's library in its Portland office.

One of the reports, entitled "Radiometric ages of Oregon and Washington through June 1972," was compiled by Jennie M. Laursen and Paul E. Hammond, Portland State University, from published and unpublished material. The information in this report is arranged according to geographic areas outlined on accompanying index maps, and specific sample sites are located on state geologic maps.

The second report consists of a series of datings for rocks within the United States compiled from data published from 1956 through 1971. The compilations are by Richard F. Marvin, U.S. Geological Survey, Branch of Isotope Geology, Denver, Colorado. The information is systematized according to year and state. The material available in the Department library is limited to Oregon.

* * * * *

# A NEW LOOK AT TEKTITES

Erwin F. Lange
Portland State University

In The ORE BIN (vol. 27, no. 4, April 1965), the writer called attention to certain similarities and differences that exist between tektites and Oregon's volcanic glasses. At that time there was considerable scientific agreement that tektites were formed by melting and outward splashing of material during the explosive impact of an asteroid, comet, or large meteorite. The main area of disagreement was whether the impact occurred on the earth or the moon. Scientists interested in tektites were about evenly divided between a lunar and terrestrial origin of tektites.

Since that time, tektites have undergone much research based on new and interesting techniques. Also since that time six successful manned moon missions have brought back some 800 pounds of lunar material which has been widely distributed and investigated. Two other areas of the moon were sampled by Russia's unmanned space crafts, Luna 16 and 20, which returned a few ounces of lunar soil to the earth. The careful and intensive investigations of the rocks and soil from the moon do not support a lunar origin of tektites. Many recent studies point more and more to a terrestrial origin.

Tektites are small glassy objects of unusual shape, rarely more than 4 inches in diameter or length. Most of those found are in the shape of spheres, discs, teardrops, and dumbbells (see accompanying photographs). Their form indicates that at one time they were in a hot molten condition and then solidified rapidly after having been aerodynamically shaped. The outer surface is often pitted or covered with worm-like grooves resulting from etching and abrasion. Many of the Australian tektites are encircled with a band or flange of glass, indicating a second period of heating and cooling. Many tektites contain inclusions of air bubbles and of particles, the most common being tiny fused quartz grains called lechatelierites. More recently tiny nickel-iron spherules and the mineral coesite have been detected in tektites, providing evidence that the tektite origin is related to meteoritic impact and explosion.

Unlike meteorites, tektites have never been seen falling, and they are not randomly distributed over the earth's surface. Also, unlike meteorites, they are not being deposited continuously on the earth; instead, they have arrived on at least four separate occasions in four widely separated areas. Today scientists usually refer to the four major tektite areas as strewn fields.

The largest strewn field is in the southwest Pacific region involving Australia, part of China, Indochina, Indonesia, and the Philippine Islands. The associated tektites are generally black but usually appear brown with transmitted light. Dating studies indicate that they are among the youngest


Large tektites from Thailand with teardrop and dumbbell shapes (E. F. Lange collection).


Large button-shaped tektite from Thailand (E.F. Lange collection).

known, with an age of about 700,000 years. A second field is that of the Ivory Coast of Africa, where dating studies show the tektites to be about 1.5 million years old. The third strewn field is a small area in southern Bohemia and southern Moravia, where the tektites, known as moldavites, are generally green and have an age of about 14.8 million years. The moldavites have been known since 1788, when tektites were first referred to in the scientific literature. The oldest tektites are those of Texas and Georgia; they are about 34 million years old.

Much of the newer tektite research deals with a variety of dating studies and with the analysis of trace elements. By using these techniques, attempts have been made to associate the tektites of each strewn field with the formation of a specific meteoritic crater. The Nordlinger Ries, an old meteoritic crater in south-central Germany, has been associated with the moldavite tektite field of Bohemia-Moravia. Impact glass from the crater has about the same age and chemical composition as the moldavites, indicating that both were formed from the same parent material. Africa's Ivory Coast tektites have the same age as impact glass from the great Ashanti Crater, also commonly known as Lake Bosumtivi in Ghana, considered to be a meteoritic crater. These studies strongly indicate that the crater and the tektites were formed at the same time. Glasses from the Henbury, Australia craters have been shown to have a chemical composition similar to the Australian tektites. The Henbury craters cannot, however, account for all of the tektites of the South Pacific. No crater has yet been found for the American tektites.

Deep-sea sediment cores from off the Australian Coast, off the Ivory Coast, and in the Caribbean Sea have resulted in the discovery of a limited number of tiny glassy objects less than a millimeter in size with the characteristic shapes of tektites. These are called microtektites. On the basis of their chemical composition and physical properties they are believed to be a part of the respective Australian, Ivory Coast, and American strewn tektite fields.

In spite of these many studies, which strongly suggest a terrestrial origin, no specific parent materials from which tektites might have originated have yet been identified.

An extraterrestrial origin of tektites is doubtful because tektites are lacking in isotopes that would be formed in space by cosmic ray bombardment. Such isotopes are found in exposed moon rocks and in meteorites that have spent millions of years in space.

The chemical composition of tektites is wholly different from that of meteorites, volcanic rocks, or lunar rocks. Chemically they resemble some terrestrial sandstones such as arkose and graywackes. Many of the moon rocks resemble basalts with some striking differences, these being a lower content of light elements such as sodium and potassium, higher amounts of titanium, zirconium, and yttrium, and low silica concentrations ranging from about 40 to 45 percent. Tektites have high silica content varying from about 60 to 80 percent, with alumina the next most common mineral, ranging


Small tektites (1 to 2 inches) from Thailand. E.F. Lange collection.

from about 11 to 15 percent. The rare earth distribution in tektites is wholly different from that in moon rocks.

One of the surprises of the lunar missions was the large number of glassy objects of various colors in the lunar soil. These small objects, mostly less than 1 millimeter in diameter, like microtektites, have many of the usual tektite shapes. The presence of these glassy objects has been explained both as a by-product of meteoritic bombardment and as a scorching phenomenon during a great solar flare. While they resemble tektites, their chemistry is characteristic of moon rocks rather than that of known tektites.

Schnetzer (1970) summarized the origin controversy as follows, "The lunar origin of tektites, a controversial and stimulating theory on the scientific scene for almost 75 years, died on July 20, 1969. The cause of death has been diagnosed as a massive overdose of lunar data."

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## IMPORT MINERALS IN JEOPARDY?

In the January 18, 1974 issue of Science, Nicholas Wade warns of the possibility that Third World countries might eventually deny not only oil but other necessary raw materials to the U.S. and other nations. The following excerpts and the accompanying table are from his article entitled "Raw Materials: U.S. Grows More Vulnerable to Third World Cartels." Additional pertinent publications are listed at the end of these excerpts.

Pessimists argue that America's growing dependence on imports for a number of key industrial minerals is making the threat of producer cartels more and more likely. Others believe that as far as nonfuel minerals are concerned, there is at present no commodity whose producers have the right combination of economic strength and political hostility to form a cartel against the United States. Whichever view is correct, the nation's position on nonfuel minerals is an intricate amalgam of diplomacy, economics, and technology, its importance largely unrecognized until the present oil crisis.

But, although rich in minerals, America began in the 1920's to be a net importer. According to the Department of the Interior, U.S. imports of all nonfuel minerals cost $6 billion in 1971 and are estimated to rise to $20 billion by 1985 and $52 billion by the turn of the century.

For 20 nonfuel minerals, including chromium, aluminum, nickel, and zinc, the U.S. already derives more than half of its supply from abroad (see Table 1), and this dependence seems certain to increase. Because of the uneven distribution of minerals in the earth's crust, a handful of countries have dominating positions in several metals. Four countries control more than four-fifths of the world's exportable supply of copper. Malaysia, Thailand, and Bolivia together provide 98 percent of U.S. imports of tin.

Even before the oil crisis broke, concern was expressed for America's vulnerability to group action by producing countries. Collective bargaining by raw materials producers is a "real possibility" in the case of copper, tin, and lead, wrote L. R. Brown of the Overseas Development Council in 1972. More recently, C. F. Bergsten, a former assistant to Henry Kissinger on the National Security Council and now with Brookings Institution, has argued that the U.S.'s neglect of the third world is dangerously myopic in view of the nation's growing dependence on the raw materials controlled by these countries. "Third World countries...have sizeable potential for strategic market power," Bergsten noted in an article in Foreign Policy. If foreign producers lack clout now, they will not always do so. Third world countries expect a rise in standards of living but, while their per capita gross national product has increased somewhat, so has the gap between rich countries and poor. Growth in both affluence and population cannot but intensify the competition for a finite quantity of natural resources. In 1970 the U.S. possessed 5 percent of the world's population but consumed 27 percent of its raw materials, a share difficult to maintain.

Table 1. Percentage of U.S. mineral requirements imported during 1972. (Data derived from Mining and Minerals Policy 1973, a report by the Secretary of the Interior to the Congress)

| Mineral | Percentage imported | Major foreign sources |
|---|---|---|
| Platinum group metals | 100 | U.K., U.S.S.R., South Africa, Canada, Japan, Norway |
| Mica (sheet) | 100 | India, Brazil, Malagasy |
| Chromium | 100 | U.S.S.R., South Africa, Turkey |
| Strontium | 100 | Mexico, Spain |
| Cobalt | 98 | Zaire, Belgium, Luxembourg, Finland, Canada, Norway |
| Tantalum | 97 | Nigeria, Canada, Zaire |
| Aluminum (ores and metal) | 96 | Jamaica, Surinam, Canada, Australia |
| Manganese | 95 | Brazil, Gabon, South Africa, Zaire |
| Fluorine | 87 | Mexico, Spain, Italy, South Africa |
| Titanium (rutile) | 86 | Australia |
| Asbestos | 85 | Canada, South Africa |
| Tin | 77 | Malaysia, Thailand, Bolivia |
| Bismuth | 75 | Mexico, Japan, Peru, U.K., Korea |
| Nickel | 74 | Canada, Norway |
| Columbium | 67 | Brazil, Nigeria, Malagasy, Thailand |
| Antimony | 65 | South Africa, Mexico, U.K., Bolivia |
| Gold | 61 | Canada, Switzerland, U.S.S.R. |
| Potassium | 60 | Canada |
| Mercury | 58 | Canada, Mexico |
| Zinc | 52 | Canada, Mexico, Peru |
| Silver | 44 | Canada, Peru, Mexico, Honduras, Australia |
| Barium | 43 | Peru, Ireland, Mexico, Greece |
| Gypsum | 39 | Canada, Mexico, Jamaica |
| Selenium | 37 | Canada, Japan, Mexico, U.K. |
| Tellurium | 36 | Peru, Canada |
| Vanadium | 32 | South Africa, Chile, U.S.S.R. |
| Petroleum (includes liquid natural gas) | 29 | Central and South America, Canada, Middle East |
| Iron | 28 | Canada, Venezuela, Japan, Common Market |
| Lead | 26 | Canada, Australia, Peru, Mexico |
| Cadmium | 25 | Mexico, Australia, Belgium, Luxembourg, Canada, Peru |
| Copper | 18 | Canada, Peru, Chile |
| Titanium (ilmenite) | 18 | Canada, Australia |
| Rare earths | 14 | Australia, Malaysia, India |
| Pumice | 12 | Greece, Italy |
| Salt | 7 | Canada, Mexico, Bahamas |
| Cement | 5 | Canada, Bahamas, Norway |
| Magnesium (nonmetallic) | 8 | Greece, Ireland |
| Natural gas | 9 | Canada |
| Rhenium | 4 | West Germany, France |
| Stone | 2 | Canada, Mexico, Italy, Portugal |

According to Vincent E. McKelvey, chief of the U.S. Geological Survey, the country is in fair shape to supply its needs of most key metals out of its own reserves, if necessary, until the end of the century and beyond. Surveys of the country's mineral resources are far from complete, and there is still the chance that important deposits remain to be discovered. For some commodities, such as manganese, tin, and chromite, the United States must look to foreign sources for future supplies, McKelvey concludes. For others, such as vanadium and tungsten, the ores are there and could be profitably mined with suitable advances in technology and rises in world price. Resources of materials such as iron, molybdenum, copper, lead, zinc, and aluminum are "nearly equivalent to potential demand over the next few decades, and the prospects for new discoveries are reasonably good."

Improving domestic supply is one major approach to increasing self-sufficiency. Others are recycling and substitution. With each of these strategies the room for maneuver appears to be if anything shrinking as new constraints emerge, such as environmental protection and the rising cost of energy. Increasing production is, of course, not the only way to achieve a balance, but there is an evident reluctance in government reports to consider the alternative of reducing demand. This gap has been filled by a committee of the National Materials Advisory Board of the National Academy of Sciences. In a report of 1972 entitled "Elements of a national materials policy," the board criticizes the entire existing system for materials decision-making as "so biased in favor of production and consumption that one can hardly overstress the need for temperance and foresight in monitoring and controlling wasteful and nonessential uses."

Besides improving domestic supplies and reducing waste, the academy committee recommends that technology should be adapted to depend on widespread and abundant basic commodities such as iron, aluminum, magnesium, and the silicates. Failure to adapt will lead, within decades, to the erosion of the mineral position of the United States, "growing economic colonialism, international frictions, steadily deteriorating balance of trade, and a tarnished global image of the nation."

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# WRIGHT'S POINT, HARNEY COUNTY, OREGON AN EXAMPLE OF INVERTED TOPOGRAPHY

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## Abstract

Wright's Point, a 250-foot-high, sinuous, flat-topped ridge, projects eastward into Harney Basin, Harney County, Oregon. This 6-mile-long feature ranges from 200 to 600 yards wide and merges with a broad mesa at its western end. The nearest topographic highs are Dog Mountain, 2 miles southwest, and foothills of the Blue Mountains near Burns, 12 miles northwest. The point is composed of a fluvial* sequence of tuffaceous channel sandstones, mudstones, and conglomerates (Pliocene-Pleistocene Harney Formation) capped by two thin, early Pleistocene diktytaxitic olivine basalt flows. The configuration of the ridge and the paleocurrent pattern, sedimentary structures, fossils, and stratigraphic relations of the rocks to nearby topographic highs suggest that the fluvial sequence and capping basalts were deposited in a narrow valley of an eastward flowing meandering stream(s). The basalts acted as a protective cap while the less-resistant valley walls were eroded away to produce an inverted topography.

Remnants of the valley walls consist of a Plio-Pleistocene palagonite tuff ring at Dog Mountain and ignimbrites and tuffaceous sediments of the middle Pliocene Danforth Formation in the Blue Mountain foothills. Reworked palagonite tuff, pumice sands, and Danforth ignimbrite pebbles compose the sandstone and conglomerates of Wright's Point. Measured elevation differences at the base of the lower flow, orientations of filled and open lava tubes, and increasing number of flows to the west suggest that the basalt flowed from west to east down the stream valley. Probable sources of the basalts are several vents 6 miles west of Wright's Point near the Palomino Buttes.

*Definitions of terms in glossary at end of article

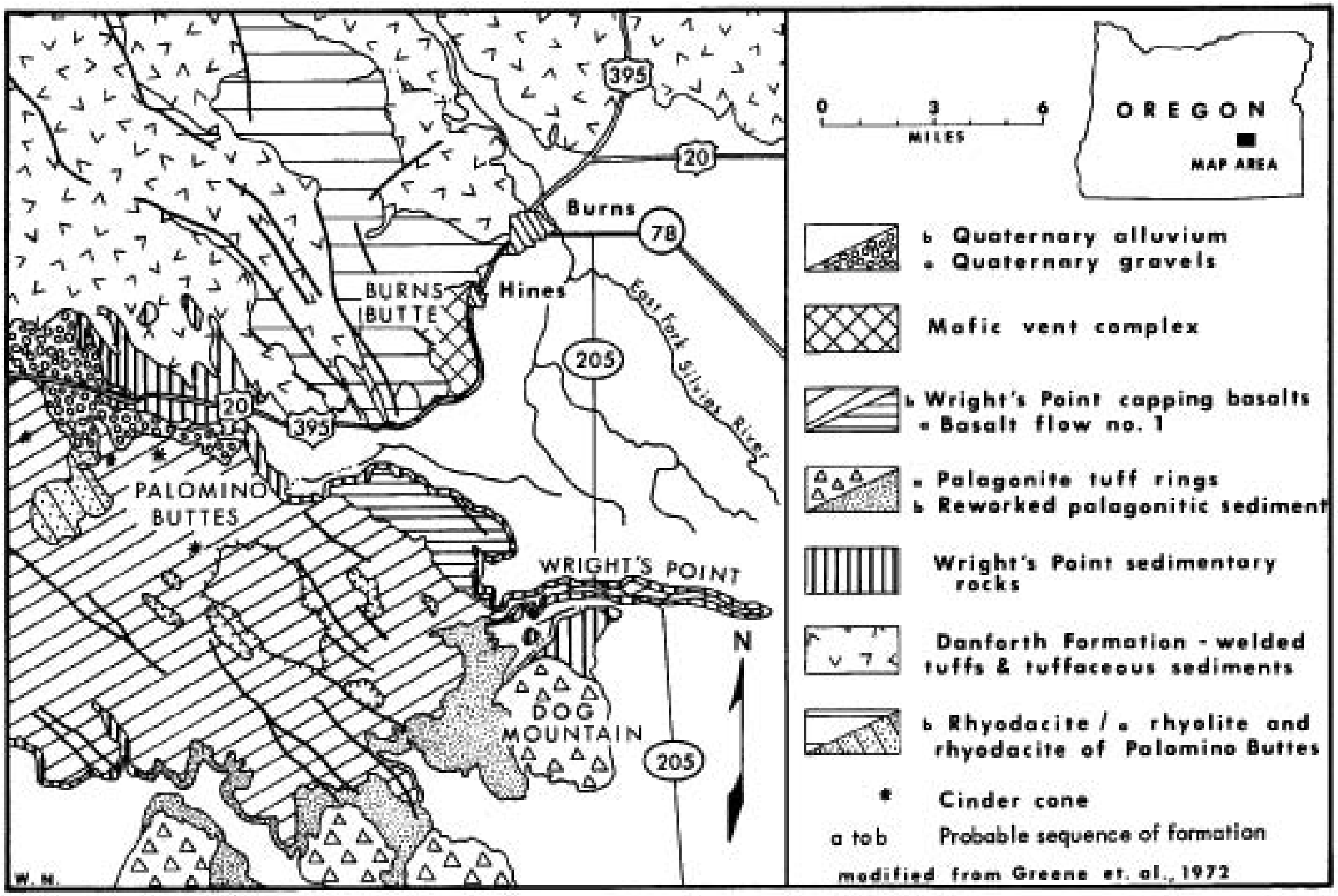


Figure 1. Geologic map of northwestern part of Harney Basin.

## Introduction

Intracanyon lava flows are a familiar sight on the high lava plateaus of eastern Oregon. Equally familiar are the elongate sinuous basalt-capped ridges produced when "softer" canyon walls are eroded away, leaving an erosion-resistant, narrow, high-standing ridge composed of stream valley fill with an intracanyon basalt cap. Yet this familiar topographic feature, commonly referred to as inverted topography (Thornbury, 1969, p. 217), has received little more than brief mention in general geomorphology texts. A perusal of the geologic literature indicates that little is reported about the anatomy or origin of inverted topography. According to Aaron Waters (1960), western North America contains hundreds of examples of this distinctive landform.

An easily accessible classical example of inverted topography occurs at Wright's Point in southeastern Oregon. Wright's Point is a long, narrow finger-shaped ridge approximately 12 miles south-southeast of Burns, Oregon (Figure 1). It appears on the U.S. Geological Survey Dog Mountain and Lawen 15-minute topographic maps. This sinuous flat-topped ridge is 6 miles long, 200 to 600 yards wide, and rises 250 feet above the surrounding basin floor (Figure 2). The point merges with a broad basalt-capped mesa at its western end. The nearest topographic highs are Dog Mountain, 2 miles to the southwest, and the foothills of the Blue Mountains, which include Burns Butte near the city of Burns.

Oregon State Highway 205 crosses Wright's Point and provides a series of nearly continuous roadcuts from the basin floor to the top of the ridge. Although the roadcuts on the north side of the ridge have slumped extensively, those on the southern margin are relatively fresh and undisturbed. Two thin basalt flows overlie a well-exposed, nearly horizontal sedimentary section approximately 200 feet thick (Figure 3).

## General Geologic Setting

Wright's Point is located in the northwestern part of the Harney Basin. The Harney Basin is approximately 50 miles in diameter and is bounded on the east by the continuation of the fault-block Steens Mountains and on the west by the high lava plateaus of central Oregon. The Blue Mountains form the northern boundary. Streams flowing into the basin empty into the shallow ephemeral Malheur and Harney Lakes. The basin is floored with lake sediments and alluvium. Although marsh and wet ranch lands cover much of the area, sand dunes are locally developed along the eastern shore of Harney Lake.

The geology of the Wright's Point area is varied. North of Burns, ignimbrites, tuffaceous and pumiceous sandstones, and mudstones of the middle Pliocene Danforth Formation crop out in the foothills of the Blue Mountains (Figure 1). The ignimbrites form thick resistant ledges which dip gently southward into the basin.

Figure 2. Oblique aerial view of Wright's Point looking westward.

Figure 3. Roadcuts on south side of Wright's Point expose dark basalts capping light-colored sedimentary section.

A flow-banded rhyodacitic mass (7.82 ± 0.26 m.y., Greene and others, 1972) with abundant obsidian at the surface, a Quaternary mafic vent complex, and Pliocene pumiceous strata comprise Burns Butte immediately west of Burns and Hines.

Dog Mountain, 2 miles southwest of Wright's Point, is a 520-foot-high palagonite tuff ring (Figure 1). From the air, it appears as a roughly circular topographic high with a central depression. The orange-brown palagonite is easily eroded, and the slopes of Dog Mountain have a distinctive "badlands" topography that is strewn with a variety of basalt boulders from fist size to 8 feet in diameter. The tuff ring is massive to well-bedded, commonly consisting of alternating thin beds of ash falls and base-surge deposits similar in appearance, composition, and structures to the palagonite tuff rings at Fort Rock, Oregon, and Diamond Head, Hawaii.

The flat surface of the basalt mesa at the western end of Wright's Point is interrupted by several partly eroded cinder cones, irregular to circular and elongate depressions infilled with thin recent playa deposits, and a 300-foot-high rhyolitic and rhyodacitic domal mass that forms the Palomino Buttes. A thin mantle of gravels and tuffaceous sandstones overlies the northern part of the mesa. The broad mesa, the nearby Blue Mountain foothills, and Burns Butte are cut by numerous northwest-trending normal faults with minor displacements.

## Stratigraphy

The sedimentary rocks of Wright's Point were mapped by Piper and others (1939) as part of the Harney Formation, which they named for a section measured on the east face of Dog Mountain, 4 miles south of Wright's Point. Their work preceded the construction of State Highway 205 in its present position; and, therefore, the exposures available to this writer were not in existence at that time. The correlation of Piper and others (1939) from Dog Mountain to Wright's Point was based on a 5-foot-thick basaltic scoria which they considered to be equivalent to the basalt cap of Wright's Point. Although this unit occurs approximately at the same elevation as the Wright's Point basalt, these two units apparently are not equivalent. The basaltic scoria feathers out along the north-northeast flank of Dog Mountain, whereas the Wright's Point basalt actually consists of two separate flows that can be traced westward. In addition, the Dog Mountain section bears little resemblance to the section along Highway 205. The former is composed of dark black scoria and yellowish-brown palagonite tuff and breccia, a typical tuff ring assemblage; the latter contains cross-bedded pale olive-gray ignimbrite pebble conglomerates, yellow-gray tuffaceous channel sandstones and mudstones with abundant plant rootlets, and a 6-inch-thick white tuff bed. Therefore, the name Harney Formation is not used in this paper. Greene and others (1972) refer to the Wright's Point strata on the Burns quadrangle geologic map as tuffaceous sedimentary rocks and differentiate these strata from the palagonite tuff at Dog Mountain.


Figure 4. Roadcut on Oregon State Highway 205 exposes a large light-colored mudstone-filled channel truncating darker tuffaceous strata. Several smaller channels also occur in this roadcut. Bar scale is 5 feet high.

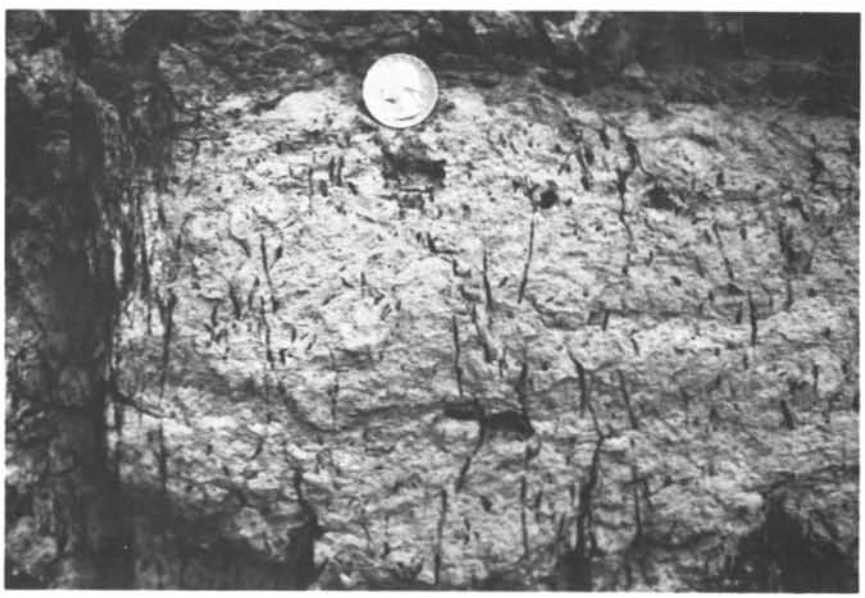

Figure 5. Fossil plant rootlet impressions in tuffaceous mudstones exposed in roadcut on Wright's Point.

Semi-consolidated yellowish-gray mudstone-filled channels and planar to trough cross-bedded conglomerate and tuffaceous sandstone lenses are abundant in the sedimentary sequence of Wright's Point. Relief of the channels ranges from 1 foot to 9 feet; the width ranges from 3 feet to 42 feet (Figure 4). Commonly the base of a channel is filled with cross-bedded conglomerate that grades abruptly upward into buff mudstone with abundant plant rootlet impressions. The impressions are less than 1/8 inch in diameter, up to 2½ inches long, and are stained black. They are in growth position and closely resemble the rootlets of reeds found in the mud and silt banks of the modern Silvies and Donner und Blitzen Rivers that flow into the Harney Basin (Figure 5).

Fairly well-sorted to poorly sorted fine- to medium-grained tuffaceous sandstone beds are faintly laminated or contain well-developed trough cross-lamination (Figure 6), and many grade laterally over 40 to 150 feet into conglomerate or mudstone units. The sandstone beds are generally 1 foot to 3 feet thick although lenses and 2- to 3-inch beds are present. Several fossil fish bones, including vertebrae and ribs, were collected from some of the coarser-grained sandstone beds. Thin, uniform sandstone beds contain ripple marks and some carbonaceous plant fragments. The upper few inches of several sandstone beds contain concentrically filled burrows that may have been produced by worms or mollusks. Extensive burrowing has obliterated internal stratification in many mudstone beds. The semi-consolidated sandstones consist of mixtures of glass shards, pumice, plagioclase grains, subangular basalt fragments, minor quartz, and rare ignimbrite and palagonite clasts.

The volcanic conglomeratic units of Wright's Point are a distinctive pale olive-green color. They are cross-bedded, poorly sorted, and many units are lens-shaped. The subangular to subrounded pebble- to cobble-sized clasts range in composition from obsidian to ripped-up clasts of the underlying tuffaceous mudstones. The most common clasts are very irregular, knobbly,"vuggy" pale olive-green ignimbrite fragments (Figure 7). Rounded white to yellow pumice, basalt, and sandstone clasts also are present. Numerous fossilized fish bones are oriented along the cross-beds in the conglomerates. The tooth of a large Plio-Pleistocene camelid (identification by Charles Repenning, U.S. Geological Survey) and a fresh-water pelecypod were collected from a conglomerate bed.

Approximately 25 to 50 feet of bedded yellow-brown palagonite tuff and breccia underlie the two capping basalt flows and overlie the yellow-gray channel sandstones, cross-bedded sandstones, and mudstones in the extreme southwestern part of Wright's Point (Figure 8). It is not clear if this material is current-reworked palagonite tuff derived from Dog Mountain or if this is an original part of the palagonite tuff ring. The occurrence of bedding sags (Figure 9) and antidune structures suggests a primary base-surge origin. This suggestion is further supported by the fact that this palagonite deposit can be traced continuously beneath the broad mesa of Wright's Point basalts to the palagonite rims of Dog Mountain, where it thickens to 200 to 400 feet.

Figure 6. Trough cross-bedded pebbly sandstone of Wright's Point.

Figure 7. Irregular, "vuggy," caliche-encased ignimbrite pebbles from conglomerate of Wright's Point strata.

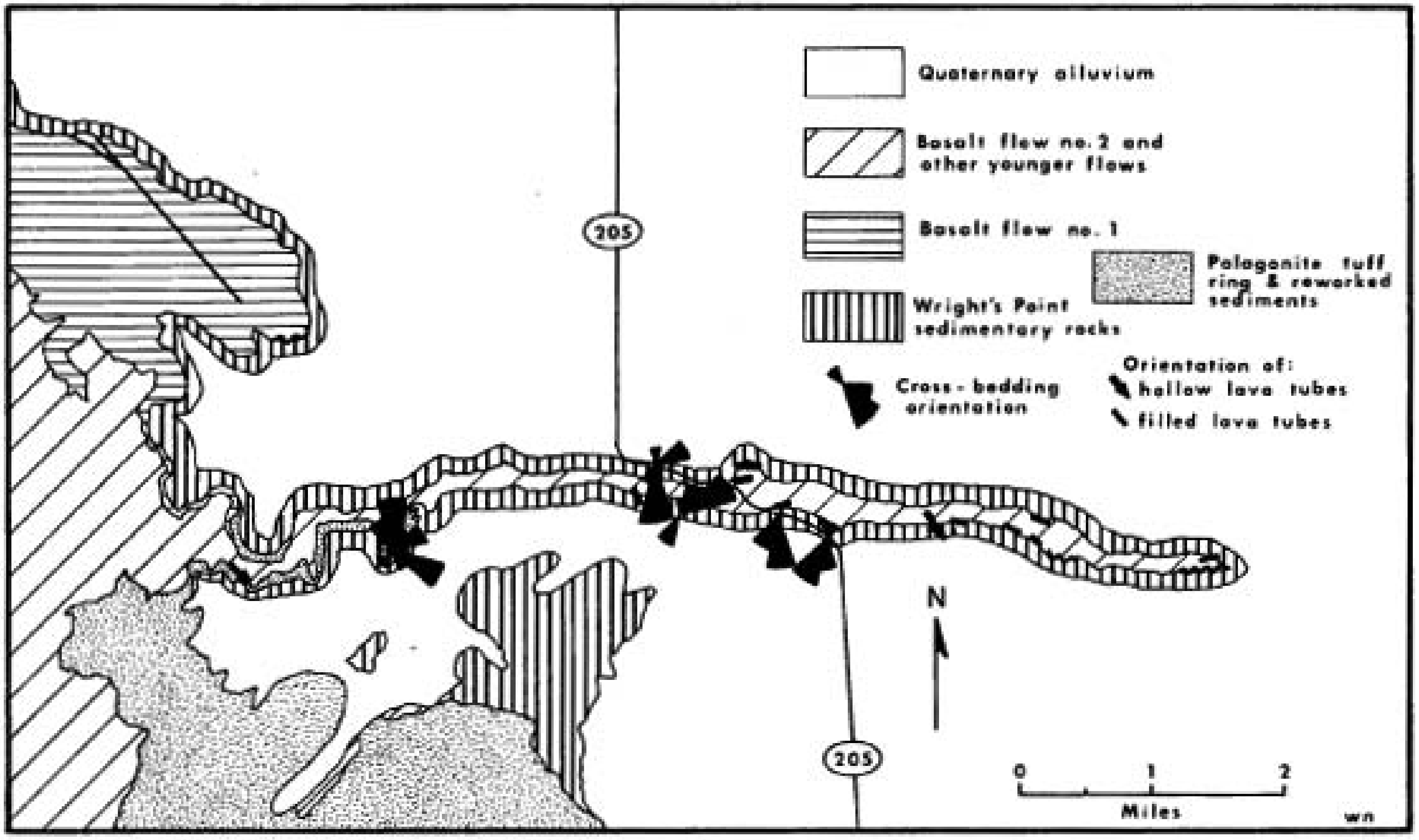


Figure 8. Geologic map of Wright's Point.

Paleocurrent directions indicated by cross-beds are bimodal to the north-northeast and south-southwest and were probably produced by a meandering or braided stream (Figure 8). The directions of the channel axes are in a similar bimodal pattern.

## Basalts

Wright's Point is capped by two thin (10 to 30 feet thick), diktytaxitic olivine basalt flows of Pleistocene age (2.4 m.y. according to Greene and others, 1972). A thin baked zone occurs at the contact of the basalt with the underlying sedimentary rocks. Both flows are vesicular, locally dense or platy, and display well-developed columnar jointing. Where the upper surfaces of the flows are exposed, the polygonal pattern of the jointing is apparent. A third basalt flow, 15 feet thick, occurs some 55 to 75 feet below the two capping flows of Wright's Point at the extreme northwestern side of Wright's Point and forms a cap in the northeastern part of the broad mesa that joins Wright's Point (Figure 8). This flow contains abundant small plagioclase phenocrysts.

The upper surface of the youngest flow capping Wright's Point is covered with a thin soil, ant hills, and sage brush. Locally the two capping flows of Wright's Point are separated by 4 to 6 feet of thinly bedded white tuff. In general, however, the younger flow rests directly on the red rubbly undulating upper surface of the older flow with a relief of 1 to 4 feet. Both filled and open lava tubes occur near the base of both flows. Filled lava tubes were recognized by the distinctive "war bonnet" radiating pattern of columnar jointing described by Waters (1960, p. 354). Individual "war bonnets" are 15 to 20 feet in diameter (Figure 10). Curving platy joints and bands of vesicles in concentric zones (Waters, 1960, p. 354) locally form arcs suggesting filled lava tubes in which columnar jointing did not form.

In general, the sinuous filled lava tubes are oriented parallel to the edge of the east-west ridge, and in many places their margins form the resistant edge of the ridge. Most of the open lava tubes also have a west to east orientation (Figure 8). The elevation of three widely separated points at the base of the older flow were measured with plane table and alidade from a bench mark on Wright's Point. Using the three-point method of Billings (1954), the paleoslope of the base of the older flow was determined to be 12 feet per mile eastward.

### Source of capping basalts

The broad mesa that lies to the west of Wright's Point most probably contains the source of the Wright's Point lavas. A western source is suggested by the orientation of filled and open lava tubes and increasing number of flows in that direction. Several possible sources on the mesa were

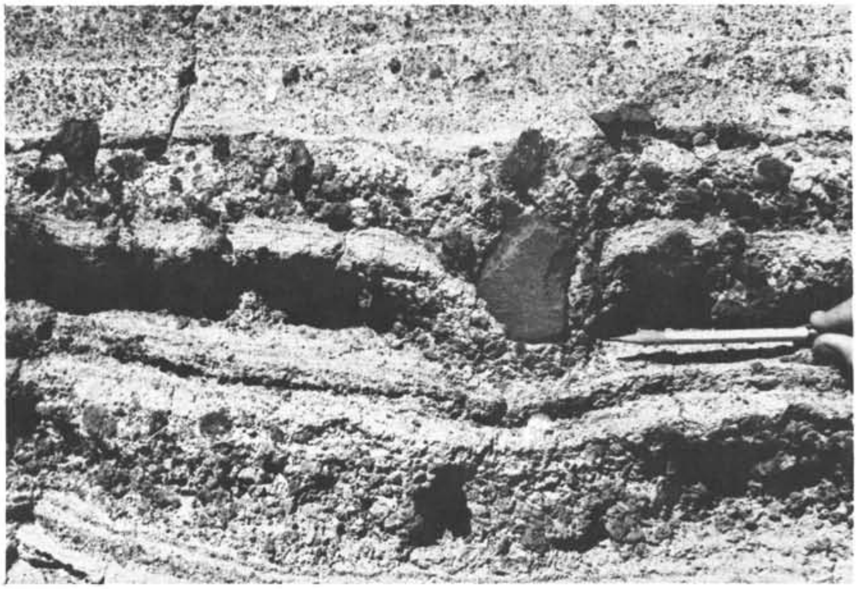

Figure 9. Bedding sag structure in palagonite tuff 10 feet below capping basalts of Wright's Point.

Figure 10. Filled lava tube with "war bonnet" pattern of columnar jointing, south side of Wright's Point.

investigated. Northeast of the Palomino Buttes, two old eroded cinder cones rest on the lower capping basalt of Wright's Point (Figure 1). Other cones occur northwest and southeast of the buttes. Five miles southeast of Palomino Buttes, several lava flows form a broad, local topographic high. This mound, $1\frac{1}{2}$ miles wide, 4 miles long, and rising 200 feet above the mesa, is another possible source of the Wright's Point lava flows.

Circular to elongate depressions on the basaltic surface of the broad mesa may be surface expressions of collapse features such as grabens produced by draining of underlying lava tubes or, as interpreted by George Walker (U.S. Geological Survey, personal communication, 1972), may be deflation basins. Islands of fine tuffaceous sediment surrounded by lava were later more rapidly eroded (by wind?) than the basalt, thereby producing a depression. More recently these shallow depressions have acted as catchment basins for rain water and have been partly infilled with mud.

## Geologic Interpretations

The abundance of channels, trough and planar cross-bedding, poor sorting, and subrounded nature of the clasts in the conglomerates, lens-like shape of the conglomerates and sandstones, and rapid lateral grading of conglomerate-sandstone-mudstone facies in the Wright's Point strata indicate that the sedimentary rocks were deposited in a fluvial environment. Fossilized fish bones, a fresh-water pelecypod, and the tooth of a camelid are further evidence for a stream depositional environment. The repeated reduction in grain size in the channels from cross-bedded conglomerates to mudstone is the typical sequence observed in modern meandering river deposits (Selley, 1970).

The channels and ripped-up sandstone and mudstone clasts in the channel conglomerates were probably produced during erosive flood stages. The planar and trough cross-bedded conglomerates and sandstones at the base of the channels represent high-flow regime deposition with migrating megaripples and sand waves. The gradation upward into finer sandstone and tuffaceous mudstone, which are the major constituents of the channel fill, possibly reflects settlement of finer sediment from suspension during a period of diminished stream velocity, as in low-river stage. More probably it represents the gradual infilling of abandoned channel meanders (e.g., oxbow lakes) during periods of overbank flow of the active channels. The abundance of reed-like plant rootlet impressions in the mudstones and abundant burrows in the sandstones also suggest a flood-plain environment similar to that observed in the nearby modern Silvies River.

The laminated and rippled sandstones are probably the coarser flood-plain deposits. The rapid lateral facies changes in the deposit, channel truncations, and ripped-up clasts of sandstone and mudstone in the conglomerates may be attributed to erosion and deposition during lateral channel migration. Some of the conglomerate and sandstone lenses in channels appear to be point bars. The bimodal cross-bedding orientations and the somewhat sinuous shape of Wright's Point ridge also suggest that the stream meandered. The Silvies River, just north of Wright's Point, shows a meandering river pattern (Figure 11) similar to the hypothetical stream that deposited the Wright's Point strata. The valley fill accumulated to at least 200 feet as the streams meandered laterally and inundated the flood-plain periodically.

The source areas of the Wright's Point strata as indicated by thin-section petrography were nearby and ranged from welded ash-flow tuff (ignimbrite) to obsidian to palagonite tuff. The ignimbrite clasts have distinctive hollowed shapes indicating an origin from the weathering of a lithophysal zone of an ignimbrite, probably from the older middle Pliocene Danforth ignimbrites. Near Burns the Danforth ignimbrites contain abundant lithophysae. Abundant glass shards and pumice in the tuffaceous sandstones were probably derived from the thick, older, pumiceous and shard-rich lacustrine, fluvial,

Figure 11. Aerial view looking eastward down the meandering course of the Silvies River, a quarter of a mile north of Wright's Point.

and ash-fall interbeds of the Danforth Formation in the foothills of the Blue Mountains to the northwest of Wright's Point. The nearest sources of obsidian occur in the rhyodacitic domes (middle Pliocene) at Burns Butte to the northwest and Palomino Buttes to the west. The palagonite tuff ring at Dog Mountain contributed palagonite, scoria, and a variety of basalt clasts to the sediment, particularly to the western part of Wright's Point.

Erosional remnants of these potential source areas are still exposed in sharp contact with the Wright's Point strata and capping basalts (Figure 1), suggesting that they may have acted in part as source areas and as valley walls for the streams that flowed down the Wright's Point paleoslope. The palagonite tuff ring is Pliocene-Pleistocene in age based on a fossilized horse's tooth (identification by Repenning), and the palagonite tuff may have been erupted just before or contemporaneously with the Wright's Point lava because the tuff underlies the capping basalts at the western end of Wright's Point and overlies most Wright's Point stream-deposited strata. Orientation of cross-bedding and channels and slope of the base of the older lava flow suggest that the paleoslope of Wright's Point valley was from west to east.

Early Pleistocene lavas flowed down the ancient stream valley from the west, as evidenced by the dip of the base of the older flow, orientation of lava tubes, and increased number of flows to the west. The flows may have been partly funneled down a stream channel within the flood plain. As the "softer" valley walls and flood-plain deposits were stripped away in the last 2.5 million years (age of Wright's Point flows), the erosion-resistant basalt-capped ridge remained to produce an example of inverted topography.

## Acknowledgments

The writer gratefully acknowledges help from his wife, Wendy Niem, for field assistance, drafting, and typing of the manuscript. Also thanks are extended to George Walker, U.S. Geological Survey, and to Donald Parker, Oregon State University, for helpful discussions concerning Wright's Point, and to Charles Repenning, U.S. Geological Survey, for identifications of vertebrate fossils. Research was supported by grants from the Oregon State University Graduate School General Research Fund.

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## Glossary

Antidune structure: a form of cross-bedded ripple that appears to have moved up-current rather than with the current.

Base-surge deposits: volcanic material which spreads outward at hurricane speeds from the base of vertical eruption clouds; commonly deposited in very thin layers.

Bimodal: grain size distribution in which there are two maxima.

Bimodal pattern: On a paleocurrent diagram, the two most frequently occurring directions of flow.

Breccia: a rock composed of angular fragments.

Camelid: a camel-like animal.

Channel truncations: abrupt ends of sedimentary layers due to erosion by stream channels.

Clasts: transported fragments of any size in a sedimentary rock.

Cross-bedding and cross-lamination: the arrangement of layers of sediment within a sedimentary bed at an angle to the upper and lower surfaces of the bed.

Diktytaxitic: a descriptive term for basalt with numerous very small angular cavities.

Fluvial: deposited by a stream or river.

Grabens: depressions formed by downdropping of a block of earth between two faults.

Ignimbrite: rock composed of small volcanic fragments erupted in dense fiery clouds; as the deposit cooled, some fragments were "welded" together, hence the name commonly used, "welded tuff."

Lacustrine: deposited in a lake.

Lithophysae: large hollows infilled with aggregates of minerals found in volcanic rocks.

Lithophysal zone: the portion of an ignimbrite that contains lithophysae.

Palagonite: yellow to orange mineraloid formed when lava flows into water.

Palagonite tuff ring: a volcanic cone composed of tuff (fine-grained volcanic rock) containing yellowish brown palagonite, commonly well bedded.

Paleocurrent: direction of flow of water, air, lava, etc in geologic past.

Paleoslope: the direction of the slope of the land in the geologic past.

Phenocrysts: crystals in igneous rocks.

Planar cross-bedding: sedimentary cross-bedding in which the layers lie more or less parallel [as opposed to curved (trough cross-bedding) layers] and are inclined from the top to the bottom of a sedimentary bed.

Playa deposits: very fine-grained sediment deposited in the lowest portions of basins.

Pleistocene: the period of geologic time between approximately 3 million years ago and 10,000 years ago - popularly called "The Ice Age."

Pliocene: the period of geologic time extending from approximately 10 million years ago to approximately 3 million years ago.

Quaternary mafic vent complex: an area of numerous small volcanic cones composed of dark igneous material that was erupted sometime during the last 3 million years.

Rhyodacitic mass: a fine-grained light-colored igneous rock body, commonly showing flow structures.

Scoria: a dark-colored porous volcanic rock composed of cinders.

Shard: a curved fragment of volcanic glass, usually sand-sized or smaller.

Thin section petrography: a detailed study with a microscope of rocks cut in thin slices.

Tuffaceous: formed of volcanic fragments.

Tuff ring: a type of maar; a circular, shallow, flat-floored crater usually less than a half mile in diameter surrounded by a rampart of volcanic ejecta containing abundant palagonite.

Vesicular: containing many small cavities.

* * * * *

## WALKING TOURS TO SEE ROCKS AND MINERALS

Walking tours around Portland and its environs are becoming increasingly popular as a way to conserve gas, get some exercise, and learn some interesting facts about the city.

One type of walking tour recommended by the Department is to see the unusual variety of rocks and mineral products that constitute the exteriors of Portland's buildings. The following pamphlets provide self-conducting tours and describe these decorative building materials; they are available at the Department's Portland office in the State Office Building:

"The Lloyd Center Collection of Fine Stones," by R. S. Mason ..... 35¢
"Portland State University - Park Blocks Area Tour of Walls,"
by R. S. Mason ......... Free; by mail 10¢
"Walls of Portland," by R. S. Mason (ORE BIN, April 1965) 25¢

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## CONGRESS SHOWS CONCERN OVER MINERALS SHORTAGES

Concern over impending shortages of domestically produced minerals is being evidenced in the U.S. Congress. Two bills have been introduced in the House. Rep. Elwood H. Hillis introduced H. Res. 907 with 17 co-sponsors creating a select committee of seven House members named by the Speaker "to conduct a full and complete investigation and study of the shortages of materials and natural resources." A bill by Rep. Edward R. Madigan (H.R. 13202) would create a National Commission on Raw Materials to study and recommend programs to prevent shortages of raw materials in the U.S.

* * * * *

## GEOTHERMAL FIELD TRIP IN JUNE 1974

The Oregon Department of Geology and Mineral Industries will conduct a field trip through parts of Oregon and Washington to show the relationship of thermal manifestations to regional and local geology.

Present plans are to make this a 6-day trip, starting in Portland on June 24 and returning on June 29. Participating in the organization and leading segments of the trip will be Paul Hammond, Portland State University; Oregon Department of Geology staff members R. G. Bowen, Howard Brooks, R. E. Corcoran, and N. V. Peterson; and Washington Division of Geology and Earth Resources staff members Ted Livingston and Eric Schuster.

The planned itinerary is as follows:

Day 1. Start from Portland. Proceed into area of Pleistocene to Holocene volcanism between Mount St. Helens and Mount Adams; overnight in Pendleton, Oregon.

Day 2. Pendleton through Blue Mountain belt to La Grande-Baker area; overnight at Ontario.

Day 3. Vale-Owyhee Uplands to north side of Harney Basin; overnight in Burns.

Day 4. Southern Harney Basin, Alvord Valley, Fields, Denio to Warner Valley-Crump Lake area via Highway 140; overnight in Lakeview.

Day 5. Lakeview thermal area, Klamath Falls thermal areas with stops at Oregon Institute of Technology and other heating installations; overnight at Bend.

Day 6. Holocene geology of High Cascades, volcanic stratigraphy, and structural geology of Western Cascades thermal spring area; return to Portland.

This trip will be limited to the first 35 persons applying. Cost will be about $250, to include bus transportation, lodging away from Portland, and noon lunches. A $25 non-refundable fee, which will be applied to total cost, is required with each application.

Send application and fee to Geothermal Trip, Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon, 97201.

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## MINED LAND RULES AND REGULATIONS

Copies of the Rules and Regulations for the Mined Land Reclamation Act are now available from the Department. All known operators of open pits in the State are being supplied with copies, but others interested in obtaining this information may get copies from any of the Department's offices for $1.50.

* * * * *

## GEOTHERMAL REPORT ON OPEN FILE

The U.S. Geological Survey has just released an open-file report on chemical analyses of thermal springs in Oregon. The 27-page report, entitled "The Chemical Composition and Estimated Minimum Thermal Reservoir Temperatures of Selected Hot Springs in Oregon," is by R. H. Mariner, J. B. Rapp, L. M. Willey, T. S. Presser. The report describes 32 hot springs in the State, detailing their major element composition, geologic setting, and probable reservoir temperatures.

Copies of the report are available from the Oregon Department of Geology and Mineral Industries for $2.70.

* * * * *

## SLOSSON NAMED HEAD OF CALIFORNIA DIVISION OF MINES

James E. Slosson has been named State Geologist and Chief of the California Division of Mines and Geology, under the Department of Conservation. He succeeds Wesley Bruer.

Slosson joined the California Division of Mines and Geology in 1973. He is a graduate of the University of Southern California and holds master's and doctorate degrees from U.S.C. He has worked for the U.S. Geological Survey, the Department of Water Resources, and Gulf Oil Corporation. Before entering the state service, he formed his own consulting geological firm. He was recently appointed to the scientific panel of the Earthquake Engineering Research Institute and to the landslide mitigation panel by the National Academy of Science.

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## FALKIE NAMED BUREAU OF MINES DIRECTOR

Interior Secretary Rogers Morton administered the oath of office to Thomas V. Falkie, 39, newly confirmed by the Senate as Director of the Bureau of Mines, at a ceremony February 28 in the Secretary's office.

Dr. Falkie, a professor of mining engineering, headed the Department of Mineral Engineering at Penn State University from 1969 until his nomination by President Nixon as head of the Bureau of Mines on January 25. At Penn State he was also chairman of the inter-disciplinary graduate program in mineral engineering management. Since 1971 he has been a consultant to the United Nations on mining economics and mine management, with recent assignments in Chile.

From 1961 to 1969 he was employed by International Minerals and Chemical Corporation, holding various managerial and technical positions.

* * * * *

## SECOND GEOTHERMAL LEASE OPENING HELD

The U.S. Bureau of Land Management opened, on March 1, 242 geothermal lease offers from 43 companies in the second geothermal lease opening in the state since Federal regulations became effective January 1.

The applications were for more than a half million acres in Oregon and Washington. Oregon offers totaled 460,121 acres. In Washington the applications were for 68,981 acres.

Greatest interest was for lands in southern Lake County, Oregon, where almost 100 applications were filed. Members of the Dallas, Texas based Hunt Oil Company, filing as individuals, had 96 applications in Oregon, most of which were in Lake and Klamath Counties.

Applications in both states generally followed patterns of offers filed in February. There was some increase in activity in Marion and Clackamas Counties in the vicinity of Breitenbush Hot Springs.

In Washington, most filings were in Skamania County.

About a third of the applications were for land within national forests.

BLM is processing these applications, many of which overlap with ones filed in February. It is expected to be several months before the first leases are offered and actual development of geothermal energy begins.

* * * * *

## GOLD MINE PRODUCING IN BAKER COUNTY

The Bald Mountain gold mine near Sumpter in Baker County recently began shipping crude ore to the American Smelting and Refining Company smelter in Tacoma. Shipments are at the rate of about 50 tons per day. Renovation and new development work at the old mine began in 1970, and rehabilitation of 2700 feet of haulage adit and construction of new surface facilities has been done to Federal safety standards.

The mine property incorporates workings of the Bald Mountain and Ibex mines, which were first operated prior to 1900. The vein, which is 5 to 25 feet wide, dips steeply and is in argillite near the contact with younger quartz diorite of the Bald Mountain batholith. Haulage level is about 900 feet below surface outcrops of the vein, and present mining widths are 6 to 8 feet. The ore is highly siliceous; values are about 65 percent gold and 35 percent silver.

Owner of the mine is Tony Brandenthaler, and the present work force of 15 men includes Mirko Skripsky, mine manager, and Vern Jacobson, engineer.

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### GEOLOGIC MAPS

| | |
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| Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck . . . . . . | 2.15 |
| 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 |
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April 1974

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DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

# The Ore Bin

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The ORE BIN
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# RECYCLE TO EXTEND OUR RESOURCES

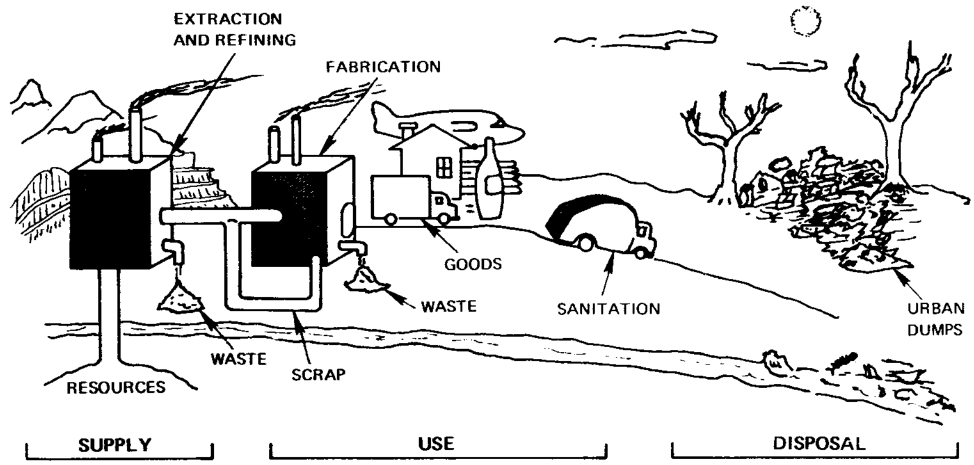
In the late nineteenth century, the mineral industry was concerned with discovering new deposits of ore and mining them. The demands of the manufacturer and of the consumer were not great, and only the easy, high-grade ores were mined. As these dwindled, improved mining technology made it worthwhile to mine lower-grade ores, often at a higher cost. Meanwhile, our escalating demands for more material conveniences at a cheaper price encouraged importation of increasing quantities of minerals.

This century has brought widespread manufacturing of an endless array of mineral products ranging from gigantic jet planes to tiny transistors, including millions of automobiles, miles of aluminum foil, and mountains of tin cans -- not to mention ditches full of beverage bottles. Our technology concentrated on the "throw it away, there's more where it came from" philosophy, or what we have come to call planned obsolescence.

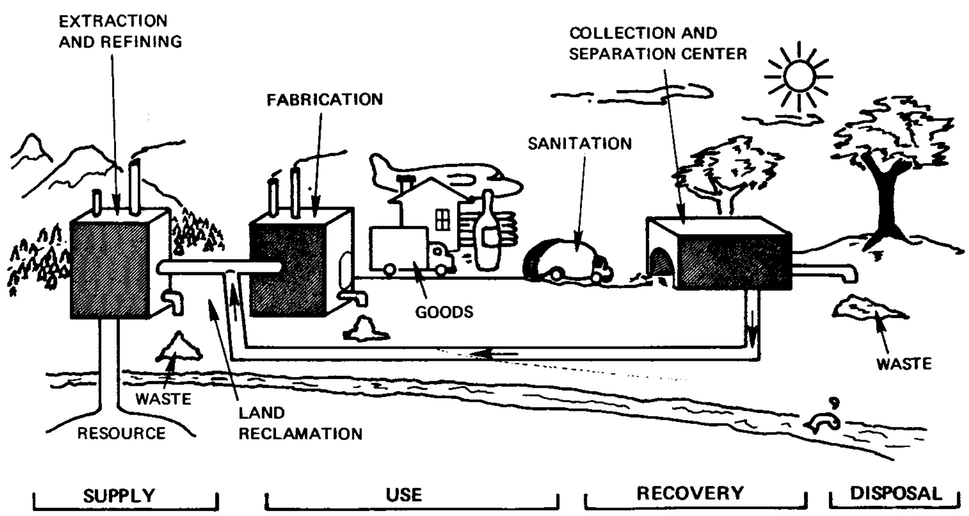
Now almost suddenly industries are discovering what the geologist has been saying -- there is a limit to the earth's mineral and fuel resources available for exploitation. We are entering an era of accepting the necessity to extend the life of our resources, including recycling of discards. The National Center for Resource Recovery, Washington, D.C., estimates that our yearly industrial and residential waste contains $5 billion worth of metals.

According to a 1972 report by the Environmental Protection Agency, "Report to Congress on Resource Recovery," complete recycling of metallic wastes would have a dramatic impact on a number of environmental problems. Making 1,000 tons of steel from scrap rather than ore would result in a 90 percent savings in natural resources, a 74 percent savings in energy consumption, an 86 percent reduction in air pollution, a 40 percent reduction in water use, a 76 percent reduction in water pollution, a 97 percent reduction in mining wastes, and a corresponding reduction in consumer wastes generated. Recycling of other products would likewise have a significant effect.

In this issue of The ORE BIN, we consider recovery and reclaiming of discarded mineral products. In doing so, we have borrowed freely from the Phoenix Quarterly, published by the Institute of Scrap Iron and Steel, Inc., especially for the first four articles that follow. To report what is going on in Oregon, particularly in Portland, Carol Brookhyser has gathered information from such local sources as the Recycling Switchboard of the Oregon Department of Environmental Quality and the companies involved in recycling.




OPEN-ENDED MATERIALS SYSTEM. Mineral resources are mined, go to a refinery, are made into consumer goods, which are used, discarded, and hauled to a dump where they contribute to environmental degradation.




CLOSED MATERIALS SYSTEM. Mineral resources are combined with recycled materials, are refined, and made into consumer goods which are used, saved, hauled to collection and separation centers, and are returned to the refinery. Completing the circle conserves energy and raw minerals and improves the environment.

From: Material Needs and the Environment Today and Tomorrow

## Is Steel the Only Thing You Recycle?

No, many metals and combinations of metals can be recycled. Steel is a combination of iron and carbon plus small traces of other elements. Because it contains iron, steel is a ferrous metal. Stainless steel is also considered a ferrous metal. Stainless steel has become nearly as ubiquitous in the late 20th century as steel, but it only came to prominence during the forties when its heat resistant properties made it important in war production. Then the development of the airplane assured its continued use. Now it is everywhere. Widely used in the home, particularly in the kitchen, because of its resistance to rust, stainless steel appears as cooking equipment, equipment parts and trim. Many of us eat with stainless steel "silverware."

There are many varieties of stainless steel. As an alloy - a mixture of two or more metals - its proportions can be varied in the melting to produce a stainless steel whose specific characteristics will make it exactly suited to the particular function the end product will perform. In general, however, there are two types of stainless steel - chrome stainless and nickel stainless. Chrome stainless is an alloy of chrome and steel. It is magnetic. A non-magnetic, more expensive stainless is made from nickel, chrome, and steel. There are hundreds of variations of these themes.

Like iron and steel scrap, stainless steel scrap can be recycled endlessly, taking on new forms as habits, styles, and technology change. Scrap firms who process stainless steel collect it from both household discards and industrial and manufacturing sources. Once gathered into the scrap plant, it must be carefully sorted so that the processor can provide the buyer with his exact needs. Because there are so many varieties of stainless, the sorting process is extremely important. Methods range from the most complex processes of the space age, such as spectrograph analysis, to sorting by hand. Other methods include testing by acids and spark testing. Scrap processors who handle large quantities of stainless say hand sorting remains the most widely used technique. Processors know that particular items - an airplane engine part for example - are usually made from the same grade of stainless. Once sorted, the stainless scrap is sold to those steel mills which melt and manufacture stainless steel.

Copper and its alloys form another branch of the recycling industry - a non-ferrous branch. Copper, a mined, natural resource, grows scarcer day by day. Recycling this essential metal is increasingly important, especially in an energy-tight era when recycling requires substantially less fuel than extraction of raw materials.

Neither copper nor its alloys are as visible in the home as stainless steel. Copper's heat-conducting properties make it popular for electrical wiring, and its corrosion resistance enables it to carry water well. However, the use of both copper and steel for pipe and plumbing fixtures in the home is being challenged by plastics.

Nor are the copper alloys - bronze and brass - frequently found in the home. Formerly brass candlesticks and chandeliers adorned homes and public buildings and bronze decorations were common. Today's brass candlestick is likely to be brassplate, and a crafty shopper would go armed with a magnet to be sure items labeled solid brass are in fact that. Brass materials will not take a magnet, brassplated material will.

Most recycled copper-based items are not household scrap. Electric utilities use quantities of copper in generators and turbines. Transmission lines are generally copper. The auto industry is a big copper user. These are some of the sources of copper and its alloys for recycling. In 1967, 49.7 percent of copper consumed in the U.S. was recycled copper.

These materials are sheared and baled or otherwise processed and sold either to brass mills which manufacture a product or to ingot manufacturers who melt the copper, bronze, or brass and make ingots conforming to precise specifications. These are in turn sold to the manufacturer for remelting and formation into the final product.

Aluminum is another recyclable metal. Some 18.3 percent of aluminum consumed in 1967 was recycled, and the percentages rise annually. Aluminum-can recycling is discussed on page 63. But aluminum appears in many guises in both industry and the consumer world. Lawn furniture, high-speed bicycles, automobile trim and components, foil, all are made of aluminum and can be recycled as easily as cans.

Many scrap processors have aluminum melting furnaces in their scrap plants where they condense bulky items into aluminum ingots. These furnaces separate aluminum from other substances and enable recovery of both materials. Once melted, the ingots are shipped to aluminum manufacturers or refiners to begin another trip on their endless recycling journey.

## Where Do You Get All That Scrap?

Scrap comes from everywhere. The automobile is an obvious rich source of scrap. So are the home, office buildings, industries, and manufacturing plants, railroads. Anything made from iron and steel or any other metal may be taken into the scrap cycle and used again. However, iron and steel scrap is found in the largest quantities.

Aside from the auto, the manufacturing industry is the largest source of scrap. If a manufacturer makes scissors, for example, or gears, or puts threads on screws, the metal left over once the principal operation has been performed is scrap - an industrial by-product. Sometimes industrial scrap is sheets of cutouts, sometimes millions of tiny fragments. Though it is usually clean and easily recyclable, occasionally it has picked up contaminants in the manufacturing process, oils and grease for example, which make that scrap more difficult to recycle.

Scrap processors who prepare industrial scrap use essentially the same machines and techniques used on other sorts of scrap. Once brought into

Old rusted automobile bodies enroute to the "Goldfinger Machine" for eventual reclamation of valuable metals.

Metal strips from the slicing machine on their way to the baler.

(Photos courtesy of Phoenix Quarterly)

the scrap processing plant, ferrous scrap is separated from non-ferrous and then prepared for shipment to the mills or foundries which will recycle the metal. Sheets can be baled into bundles; rods and bars may be cut to uniform lengths; smaller fragments may be converted into small units about the size of bricks that are called briquettes.

Industrial scrap is a very important part of the scrap processing industry. In manufacturing operations a significant percentage of the metal used generally is left over when the product is finished. Without the highly organized reclamation system, enormous quantities of steel and other metals would have been wasted over the years and brought the nation much closer to the edge of natural resources depletion.

Railroads are a source of scrap - old rails, freight cars themselves, and much of the paraphernalia that enables a railroad to function are made from steel. These all can be and are recycled through the scrap processing system to become new rails, freight cars, signal lights, foundry castings, and iron and steel products for other uses.

Obsolete, as contrasted with industrial scrap, old autos, obsolete household appliances and miscellaneous metals find their way to the scrap processor by various routes. Some cars and appliances are brought by their owners to the scrap plant; others are sold to an auto wrecker who removes the salable parts. He sells the remaining hulks to scrap processors.

Another source of scrap is the junk collector. Not so prominent a feature of the modern landscape as he was in former times because of current economic conditions, the junk collector gathers up papers, rags, and metallic items such as old radiators, fencing, appliances, sorts them, and sells them to those who process them - paper to a paper mill for manufacture into recycled paper, metallic items to a scrap processor to be prepared for use in mills, refineries, and foundries. When buildings are demolished, the steel that made up the structure generally passes through the scrap plant enroute to recycling in steel mills and foundries.

Everything metallic is potentially scrap. It can come from anywhere to the scrap processor who can turn it into a valuable resource. This role will become increasingly important as the United States and other nations learn to live within the limited resources of the earth.

## Do Scrap Dealers Use That "Goldfinger Machine"?

Yes, the baler, "that Goldfinger Machine," operates just as was graphically demonstrated in the James Bond film. It hydraulically compresses autos into a bundle about the size of a console television set which conforms to a precise specification in the scrap market - a No. 2 auto bundle.

Scrap dealers are often said to be conserving the future. And so they are. Millions of automobiles are lying around America rusting into oblivion; the scrap processor can reclaim their valuable metals and get them back into the economic stream. In so doing, he performs the vital service of conserving natural resources. Each time scrap iron and steel is used instead of ore, the day of mineral exhaustion is postponed.

When an auto arrives at a scrap processing plant, it may already have been stripped of usable parts for resale by auto wreckers. What is left is prepared for sale to the steel or foundry industries, and the baler is the best known equipment used for this.

Another method of auto processing is flattening cars and passing them through a giant slicing machine known as the hydraulic guillotine shear. The shear produces a sliced material of a predetermined size.

A relative newcomer to the scrap processing industry is the shredder. A shredder is a very expensive, sophisticated machine, ranging in cost from $1 million to $5 million.

The shredder does just what its name implies. It ingests automobiles from which tires and gas tanks have been removed and, sometimes in much less than a minute, reduces it to pieces of steel, glass, plastic, and other metals about the size of a fist. These shredded particles are then passed over a series of magnetic drums and separation systems until the final ferrous product is virtually pure steel.

A problem for auto scrap processors which promises to worsen is the increasing percentage of an automobile which is not steel. Through auto industry efforts to lighten auto weights or to attract consumer tastes with design additions, the steel portion of an auto has dropped from over 90 percent to 74 percent in 1972. And many signs point to a continuing decrease in the use of steel in cars. Consequently, scrap processors will have less steel per auto coming out of their shredder or in their bundle or slab and more non-ferrous or non-metallic products with which to deal. Some are valuable, such as aluminum, zinc, and copper, if separated economically. However, upholstery, glass, and plastic have as yet little or no place in the recycling system. Methods for recycling of even these materials are being developed. For instance, a pilot project by the U.S. Bureau of Mines recently investigated the use of waste glass in the manufacture of glass wool.

All scrap processing machines can be used to process other types of scrap besides autos. The baler can be used on a variety of materials, from cans to wire; the shear slices sections of steel plate and pipe as easily as an auto; and the shredder can rip most metals to recyclable size. But all are important in processing that most obvious article of recyclable steel - the automobile. Each time they bale, slice, or shred, they help extend the nation's limited supply of natural resources.

## How Many Cans To Make a Ton?

It depends on what kind of can you are collecting. If it is "tin" cans, which are actually tin-plated steel cans, you will need to collect 18,000 to 20,000. If you are collecting aluminum cans you will need 40,000. That is a lot of cans.

Usually Scout troops, civic groups, or environmental organizations collect cans in somewhat smaller quantities, by the bag or the stationwagon full. Some groups have centrally-placed dumping bins whose contents are collected regularly. Hardly anyone piles up a ton of cans before disposing of them. Most people just don't have the room.

Since the dawn of the environmental era, many people have tried to recycle cans. These efforts have been frustrated by the distance of most urban centers from the markets - the steel mills and aluminum manufacturers - and the above-mentioned quantities in which cans must be collected to be significant in the marketplace.

Aluminum is a more expensive metal to extract and produce, so aluminum companies are willing to pay a relatively high price for aluminum cans for recycling.

Tin cans are less valuable but equally recyclable. (First, they are usually detinned.) Detinning plants collect cans and other tin-plated scrap - the latter including waste material from factories that produce the cans themselves. Once collected, the cans are shredded and thrown into a detinning solution; a caustic, alkaline solution which removes the tin on the cans. One producer estimates he recovers 7 pounds of tin from a gross ton (2,240 pounds) of cans. After detinning, the shredded steel is washed to remove any dissolved tin, compressed into a bundle of high quality scrap and shipped to a steel mill for recycling into new products. The tin, meanwhile, is recovered in a pure form and also sold for manufacturing. Tin-plated cans may be added directly to steel furnaces in limited quantities but the industry says it prefers to take detinned cans.

Easy as it sounds, there are some stumbling blocks. For one, not all the cans are clean. Consider the can which once held stewed tomatoes or macaroni and cheese. Once its contents have been emptied, into a trash bag it goes, unwashed, uncrushed. All those food particles show up in the detinning solution with resultant difficulties for the detinner. For this reason as well as the problem of rodent and insect infestation in each phase of handling, most recycling centers require that cans be clean.

Steel cans also are used for copper precipitation. There the cans are placed in a copper sulphate solution which is the result of copper extraction. The steel replaces the copper in the sulphate solution, leaving behind the more valuable copper.

Using tin cans for either copper precipitation or to make new steel extends limited supplies of natural resources and encourages resource self-sufficiency. And with energy growing scarcer every day, it is important to note that the Environmental Protection Agency has found that using scrap rather than iron ore to make steel uses 74 percent less energy. Other environmental problems - air pollution, water pollution, mining wastes and water use - all are significantly reduced when steel is made from scrap instead of ore. So as the nation looks for ways to stretch its energy and solve its environmental problems, even the humble can has a role to play.

## What is being Recycled in Oregon?

### Autos and household appliances

The biggest car shredder installation in the Pacific Northwest has been pulverizing cars in Portland at the rate of about 250 to 300 cars a day for the past 4 years. Cars, however, are not the only material recycled by the Schnitzer Steel Products Co. machine. The company buys discarded household appliances from junk dealers. Items such as stoves, laundry equipment, refrigerators, hot water heaters which cannot be handled by a scrap baler can be fed into the shredder and reduced to fist-sized pieces of scrap.

The local pulverizing operation accepts only cars which are beyond rebuilding - literally wrecks. Before these are processed, the interior padding such as seats and rugs is removed. Window glass becomes part of waste debris since there is currently no local recycling use for this type of glass. Motor blocks may be left in or may be sent to steel mills as a separate scrap item.

The cars are fed through powerful rollers which flatten them, then into the drum pulverizer where sixteen hammers chop through metal and glass. Contaminants are sucked from the conveyor as the metallic remains move to magnetic separators. Originally the non-ferrous (and therefore non-magnetic) materials were picked out by hand from the scrap, but now a more economical mechanical system separates the valuable copper and zinc from the ferrous scrap.

The shredder operation produces the almost-pure ferrous scrap needed for mixing with iron ore in the oxygen furnaces developed in the 1950's for use in steel mills. It was the need for this purer scrap that led to the development of the shredder to replace the baler previously used almost entirely for processing auto scrap. Since the baler crushed the entire car, the percentage of contaminants was generally high, and although the new shredders can handle the baled car (No. 2 car bundle discussed earlier), the operator must be certain it is "clean" scrap in the bale and that upholstery, dirt, rocks, etc., are not included.

The cars and other scrap being processed at the Portland shredder may come from all over Oregon, eastern Washington, Idaho, and even western Montana. The freeway system in Oregon is one important factor in the economics of hauling scrap from long distances. As the price of scrap rises, longer hauls become feasible.

Dr. Leonard E. Schnitzer, Vice President of the steel company, reports that cars being scrapped locally now might be termed current production, that the accumulated "old junkers" of the past were cleaned up in the first few years the shredder was operating. He says it is possible that the northern United States is now being covered rather thoroughly by truckers hauling scrap; some from western Montana is being brought here, and that from eastern Montana and the Plains states is going into Chicago and Kansas City.

Crushed car bodies ready for shredding machine at Schnitzer Steel Products Co., Portland.

"End of the Trail" at the dismantling yard of Schnitzer Steel Products Co., Portland.

(Photos by Sherman Washburn, Oregon State Health Division)

Recycling of metallic scrap materials is dependent on a geographically convenient source of supply, proximity to scrap markets, and freight rates which make it possible for scrap to compete with virgin materials. The coast areas become the natural locations for these operations because of population density and the lower cost of moving scrap by water to steel mills both in this country and abroad. The major market for much of U. S. scrap has been Japan, but steel mills in this country are increasing their consumption of recycled materials, and the industry is working with railroads to improve freight rate competition. At the present, ore moves at a lower rate than does iron and steel scrap, and the inequities tend to increase as hauling distances increase.

## Aluminum cans, foil, and TV dinner trays

Aluminum is a metal that can be recycled endlessly; so far as is now known, there is no weakening with reuse. Since much aluminum production goes into consumer goods, the average person is important in the reuse cycle.

The Reynolds Metals Company has a recycling depot at its guard office at the Troutdale plant, where, each Saturday, groups or individuals may resell their discarded aluminum. Reynolds will take aluminum beverage cans, pie pans, TV dinner trays, aluminum wrap, lawn or house furniture frames with upholstery, webbing, and bolts removed. Food contamination must be cleaned from containers and foil. Car parts and cooking utensils are a different alloy and cannot be accepted by the Troutdale plant.

In Oregon 30,000 to 40,000 pounds of aluminum are recycled per month. From Reynolds it is shipped to Seattle for shredding and then sent east to a smelter. The in-plant scrap at Troutdale is reused at the plant.

Aluminum production is a high consumer of energy; about 15,000 kw of electricity is needed to produce one ton, but recycling that ton requires only about 450 kw. Amounts now being recycled in the U.S. are equal to one year's production of new metal from one potline. Since aluminum is one of the most valuable metals, it is estimated that municipal garbage containing 1 percent of aluminum waste could be economically processed for the recovery of that metal alone.

## Tin cans

Tin cans are a component of the average household garbage and are easy to recycle. They should be rinsed out first (see page 60 regarding need for rinsing cans), have labels removed, and be flattened.

The Continental Can Co. is the largest handler of recycled tin cans in the Portland metropolitan area. Their suppliers are mainly non-profit groups and individuals. The company records amounts brought by groups and when any one group has accumulated deliveries totaling a ton, payment is made. Weight of cans brought in by individuals is combined with that of company scrap, and a contribution to cover the total is made by the company to an environmental or charitable organization.

Over 900,000 pounds of scrap cans were received by the Portland plant during 1973 and shipped to steel mills or to copper refineries.

Cans which contained pesticides should never be recycled. The Department of Agriculture warns that many pesticides remain highly toxic for a long period of time. What is considered an empty can or bottle may actually contain a lethal dosage of pesticide. Even when buried it will eventually break or rust away, allowing the contaminant to soak into the ground. Only a commercial pesticide operator should handle the recycling of pesticide containers.

## Glass bottles

Glass bottles originate from a melt of raw materials (sand, limestone, soda ash, and feldspar) that have to be mined out of the ground, shipped to the glass factory, and processed. The making of glass not only uses up mineral resources, it consumes energy in all steps from mine to finished product. Energy resources, like mineral, are finite.

Glass is the one product most frequently and most easily recycled by the individual. Recycling of glassware is becoming a routine in most households and a source of income for many non-profit groups and for some small businesses.

The Owens-Illinois Glass Co. of Portland started a redemption center in midyear of 1970 and in the first month of operation recycled approximately 5,000 pounds. In February 1974 the center accepted over 1,200,000 pounds and expects about a million pounds per month, mainly from the Portland area, but loads also are brought in by groups from as far as Medford, the Tri-Cities area in Washington, and from the nearest Idaho towns.

Broken glass, called cullet, is a necessary part of the glass-making process and is used at a ratio of 20 percent cullet to 80 percent virgin minerals in a given batch. At the Portland plant 6 to 8 percent recyled glass and 12 to 14 percent rejected glass from the production line make up the cullet. At the present time all of the recycled glass received is being used in in the plant's production of 8,000 to 10,000 tons of glass containers per month, and the percentage of cullet could be increased appreciably if more recycled glass were received.

Any glass turned in for recycling must be free of metal lids or the metal rings sometimes left on necks of bottles after removal of certain types of lids. The possibility of any contamination from metal debris is the reason the Portland plant cannot now use glass residue from a garbage processing operation. Although there is more sophisticated machinery available to handle this possible contamination, the Portland plant does not yet have it. Metal contamination causes defects in the glass product, such as gas bubbles, or settles to the bottom of the furnace, creating hot spots.

A ton of tin cans?

Environment-conscious householders wash, flatten, and collect their tin cans for the local recycle center which sells them by the ton to the Continental Can Company. (Photo from The Oregonian)

Bottles and more bottles!

Non-returnable glass bottles are gathered, crushed, and trucked to the Owens-Illinois glass plant in Portland for recycling. (Photo from The Oregonian)

The Portland plant was closed recently for a short period because of a shortage of soda ash, an essential ingredient in the making of glass. Nearly half of the yearly U.S. production of soda ash goes into the manufacture of glass, and in recent years soda ash production has not increased in proportion to the increased demand for glass products. The Wyoming trona deposits, main source of natural soda ash, are being mined more intensively, but Solvay-processed soda ash decreased because of closure of some older plants due to stricter limitations on chlorides in plant effluents.

Since Oregon's "Bottle Bill" went into effect, a definite change has been seen in container use. There has been a 62.8 percent increase in use of returnable bottles for beer and a 31 percent increase for soft drinks. Beer bottles are re-used about 15 times and soft drink bottles 19 times.

## How Can I Get Into The Recycling Act?

Return your returnables and save your recyclables. For a copy of the Recycling Handbook or for information on recycling centers (locations, hours of operation, kind of materials), and for answers to other questions, contact the Department of Environmental Quality, 1234 S. W. Morrison, or phone their information number in Portland:

RECYCLING SWITCHBOARD
229-5555

Information on where to take your recyclables is also available from DEQ district offices in Salem, Eugene, Roseburg, Bend, and Pendleton.

## Where Can I Get More Information?

RECYCLING HANDBOOK: Free on request from Recycling Information Office, Oregon Dept. of Environmental Quality, 1234 S.W. Morrison, Portland, Oregon, 97205.

PHOENIX QUARTERLY: Published quarterly by the Institute of Scrap Iron and Steel, Inc., 1729 H Street N.W., Washington, D.C. 20006.

STEEL FACTS: Published quarterly by American Iron and Steel Institute, 1000 16th St. N.W., Washington, D. C. 20036.

SOLID WASTES: Contains 25 articles reprinted from Environmental Science & Technology. Order from Special Issues Sales, American Chemical Society, 1155 16th St. N.W., Washington, D.C. 20036, price $2.00.

MATERIAL NEEDS AND THE ENVIRONMENT TODAY AND TOMORROW: Report to the National Commission of Materials Policy, June 1973. For sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Paper cover, postpaid $3.20.

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## PROPOSED U.S.F.S. MINING REGULATIONS QUESTIONED

Rep. John Melcher (MT), chairman of the Public Lands Subcommittee of the House Interior Committee, stated at hearings held March 7 and 8 on the proposed Forest Service mining regulations that his subcommittee would take a careful look at the authority of the Forest Service to promulgate these regulations. He also said that he had been assured by Forest Service Chief John R. McGuire that the regulations would not be published in final form until the House Public Lands Subcommittee has had a chance to thoroughly review the regulations.

Stanley Dempsey, general attorney, western area, American Metal Climax, Inc., and chairman of the Forest Service Regulations Subcommittee of the American Mining Congress Public Lands Committee, presented the association's views on the proposed Forest Service regulations.

Dempsey stated that AMC believes that the Forest Service is without authority to promulgate any regulations that may preclude access and mineral development on the national forests. He listed specific problems created by the regulations, including the conflict between the regulations and state mining-claim location laws, the possible delays in approval of a plan of operations, the necessity for filing an environmental impact statement, and the inadequacy of the draft environmental impact statement filed with the proposed regulations. Dempsey emphasized that implementation of the regulations will discourage exploration for and development of mineral resources in the national forests, with the result that the U.S. will be forced to rely even more on imports.

Under questioning, Dempsey indicated that it would be most difficult for the small miner, who is most essential in mineral exploration, to secure the bond required by the regulations. As to the impact the regulations would have on his company, Dempsey said that exploration efforts would be slowed significantly. He emphasized that the regulations are aimed at regulating mining, whereas they should be self-executing, aimed at protecting the forest resources.

Forest Service Chief McGuire was questioned in regard to the authority of the Forest Service to promulgate mining regulations on national forest lands. Rep. Sam Steiger (AZ) said to McGuire, "I'm convinced you've got a problem...and that in your approach you have compounded the problem." Questions then shifted to whether the Forest Service has adequate funds and manpower to administer the regulations. Other members of the subcommittee expressed to McGuire their concern with the present minerals shortage and the dampening effect of the regulations on mineral exploration and development. Concern was also expressed that the regulations would eliminate the small miner, especially with regard to the unreasonable bonding provision.

Rep. Harold Johnson (CA) expressed his concern whether the impact and intent of laws enacted by Congress can be modified drastically by administrative regulation. He said he was convinced that the regulations are most unreasonable and will work extreme hardship upon the minerals industry, especially upon the small prospector and miner.

-- American Mining Congress News Bulletin No. 74-6.

* * * * *

## REPEAL OF HARD MINERALS DEPLETION ALLOWANCE PROPOSED

On April 1 the House Committee on Ways and Means, during its deliberations on the windfall profits tax bill, voted 18 to 7 to eliminate the percentage depletion allowance for oil and gas over a three-year period.

During the discussion on this subject, Chairman Wilbur D. Mills (AR) stated that it was his intention to end the depletion allowance for all other minerals in connection with tax reform. The following day, April 2, an amendment to eliminate the depletion allowances on all minerals barely failed of passage in the Ways and Means Committee by a tie vote, 12 to 12. However, the committee will again consider mineral depletion allowances.

-- American Mining Congress News Bulletin No. 74-7.

* * * * *

## GEOTHERMAL POTENTIAL IN SOUTH-CENTRAL OREGON INDICATED

"Some Implications of Late Cenozoic Volcanism to Geothermal Potential in the High Lava Plains," by George W. Walker, has been released as an open-file report by the U.S. Geological Survey. Volcanic rocks related to the Brothers fault zone extending from Harney Basin to Newberry Volcano show decreasing age westward, with probable greater geothermal potential at the western end.

The 14-page report has an index map, structure map, and table of potassium argon dates. Copies of the report are available for $1.50 each from the Oregon Department of Geology and Mineral Industries at its Portland office.

* * * * *

## FIELD-STUDIES REPORT ON OPEN FILE

"Field-oriented geology studies in Oregon, 1973," prepared by John D. Beaulieu has been placed on open-file in the Department's library. The report is a listing and brief summary of all known geologic projects that were conducted in the field in Oregon during the past year. In addition to aiding the Department in planning programs, the report enables the interested geologist to keep informed of recent research.

* * * * *

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# ROCK UNITS AND COASTAL LANDFORMS BETWEEN NEWPORT AND LINCOLN CITY, OREGON

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The coast between Newport and Lincoln City is composed of sedimentary rock punctuated locally by volcanic rock. Where the shore is on sedimentary rock, it is characterized by a long, sandy beach in front of a sea cliff. Perched above the sea cliff is the sandy marine terrace that fringes most of this segment of the Oregon coast. Where volcanic rock interrupts the continuity of sedimentary rock, the regularity of the coastline is broken by jagged promontories, rocky shores, and sea stacks (Figure 1).

Figure 1. Yaquina Head composed of volcanic rock; Moloch Beach is on sedimentary rock. (State Highway Division photo by Kinney)

Figure 2. Landslide at Jumpoff Joe in Newport destroyed about 15 acres of coastal frontage and involved a number of houses.

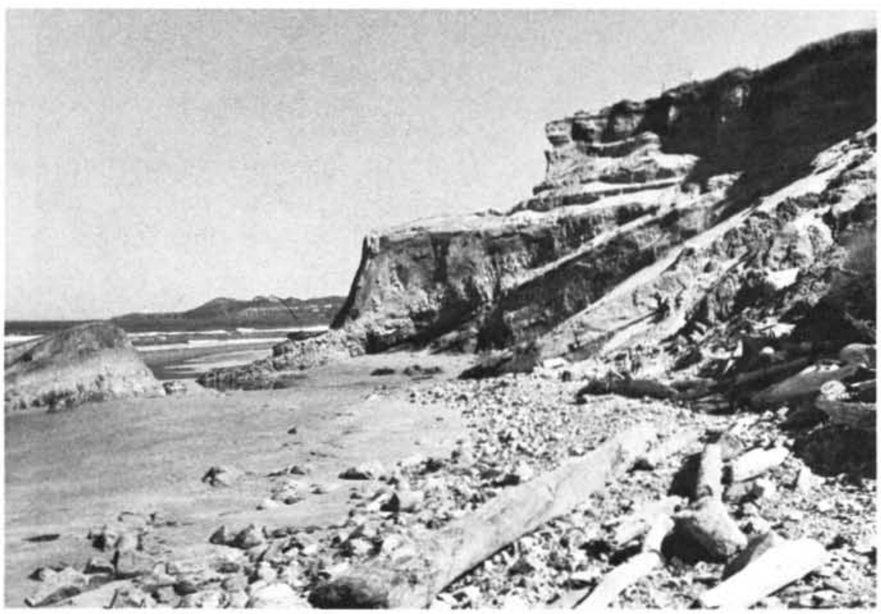


Figure 3. Seaward dipping beds of Astoria Formation are exposed at Jumpoff Joe.

A number of different rock units (geologic formations) are exposed along this part of the Oregon Coast (see accompanying geologic map). Each unit is characterized by a kind of rock or suite of rocks that distinguishes it from other units. For this reason, each unit plays a different role in shaping the coastal landforms.

In the following text, the geologic formations are discussed from oldest to youngest beginning with those of Eocene age, dating back 40 or 50 million years ago, to those of Quaternary age, some of which are forming today. The distinctive landforms associated with each unit are described and also illustrated in the photographs.

## Eocene formations

Siletz River Volcanics: This formation, consisting of basalt flows and pyroclastic rocks, is not exposed along the shore but crops out east of Devils Lake and is responsible for the rugged topography in the Coast Range to the east.

Nestucca Formation: These late Eocene siltstones and interbedded sandstones are the bedrock beneath the marine terrace north of Siletz Bay. They underlie the beach sand at Lincoln City and are often exposed during the winter and early spring after storm waves have swept away the sand. The Nestucca Formation is described in more detail by Snavely and others (1969).

## Oligocene formations

Siltstone of Alsea: This formation, named informally by Snavely and others (1969), consists of massive to thick-bedded tuffaceous siltstone and very fine-grained sandstone. It is the bedrock along the east side of Siletz Bay and is exposed in a roadcut along U. S. Highway 101 just south of Schooner Creek at the north end of Siletz Bay.

Yaquina Formation: The Yaquina Formation is of diverse composition, consisting mainly of sandstone but also of conglomerate and siltstone (Snavely and others, 1969). It is the bedrock beneath the marine terrace south of Siletz Bay and is exposed in a roadcut at the south end of the bay, but neither it nor the siltstone of Alsea is exposed along the shore in this segment of the coast.

## Miocene formations

Nye Mudstone: The Nye Mudstone, of lower Miocene age, is described by Snavely and others (1964) as a "...mixture of clay, silt, and very fine sand-size particles in varying proportions; the lithologic designation differs from place to place, but commonly is mudstone and siltstone, and less commonly silty, very fine-grained sandstone." The Nye crops out along

Figure 4. View south from Cape Foulweather toward terrace promontories on Astoria Formation; Yaquina Head in distance. (State Highway Division photo)

Figure 5. Devils Punchbowl in Astoria Formation is the collapsed roof of two sea caves. (State Highway Div. photo by Kinney)

the sea cliff at Newport beneath the Astoria Formation and is exposed in contact with the Astoria Formation at Jumpoff Joe, 1½ miles north of Yaquina Bay. It does not crop out along the shore north of Yaquina Head but underlies the terrace south of Gleneden Beach.

Beds of the Nye Mudstone have a high clay content and therefore have low shearing strength, especially when wet; areas underlain by this formation are subject to landslides along cliffs and in steep terrain. Along the shore between Yaquina Bay and Yaquina Head, the beds have a seaward inclination of as much as 30 degrees, which increases the threat of landslides in this formation. Much of the slumping along this part of the coast is attributed to yielding of weak beds along inclined bedding planes, and bedrock slumps are numerous. The largest slumped area is at the Jumpoff Joe locality in Newport; it involves about 15 acres along a quarter mile of the shore (Figure 2).

Astoria Formation: The middle Miocene Astoria Formation, which overlies the Nye Mudstone, is described by Snavely and others (1969) as consisting "...principally of olive-gray, fine- to medium-grained micaceous, arkosic sandstone and dark carbonaceous siltstone. The sandstone beds range from massive to thin-bedded and generally are thicker in the upper part of the sequence." The Astoria Formation contains many fossils.

Between Yaquina Bay and Yaquina Head, the Astoria Formation is exposed above the Nye Mudstone in the sea cliff (Figure 3). From Yaquina Head to Cape Foulweather it is the bedrock below the terrace sediments, and it crops out extensively in the sea cliff and on the wave-cut platform between these points. It is exposed at inner Depoe Bay, in the sea cliffs at Boiler Bay, and at the mouth of Fogarty Creek. It underlies the terrace at Lincoln Beach but is not exposed along the beach.

From Yaquina Head to Otter Rock, a continuous, gently sloping beach lies in front of the sea cliff on the Astoria Formation and overlying terrace sandstone (Figure 4). The northern part is Beverly Beach and the southern part Moloch Beach.

Two promontories (Figure 4) south of Cape Foulweather are segments of a marine terrace developed on the Astoria Formation. The terrace is capped by a layer of sandstone, which gives the flat surface to these points of land. The Astoria Formation is exposed along the outer edges of the promontories where wave erosion has removed the terrace sandstone. It forms the present-day wave-cut platform, where marine gardens with many tidal pools support a luxuriant and varied assemblage of plants and animals.

The southernmost of the two promontories, at Otter Rock community, is the site of the famed Devils Punchbowl (Figure 5). This hole in the terrace was formed by collapse of the roof where two sea caves met, one from the north and the other from the west. Water enters the bowl at high tide, and during storms it churns and foams as in a boiling pot.

One of the most remarkable features in the Astoria Formation is the inner Depoe Bay (Figure 6). This very small and secure harbor lies behind

Figure 6. Basaltic wall shelters inner Depoe Bay from storm waves and erosion. (State Highway Division photo by Kinney)

Figure 7. Government point is a wave-cut platform on volcanic rock; Boiler Bay to north is eroded into sedimentary rock. (State Highway Division photo by Kinney)

a wall of basalt lava rock, and its access to the sea is a narrow chasm through the basalt wall. The basin is a low area in the topography formed principally by stream erosion along North and South Depoe Creeks. Much of the shaping of this small basin was done during the most recent glacial stage, the Wisconsin, when sea level stood several hundred feet lower than it does now. At that time the passage through the wall was a gorge through which the ancestral Depoe Creek flowed. With melting of the glacial ice, the sea rose to a level that caused flooding at the lower end of the drainage basin of Depoe Creek. In this respect, the origin of this small bay has something in common with large water bodies such as Yaquina Bay, where rise in sea level has "drowned" their lower parts and formed estuaries.

Boiler Bay (Figure 7), about 1½ miles north of Depoe Bay, is eroded in the Astoria Formation, which is exposed beneath a thick terrace deposit along the inner cliffs of the bay. Boiler Bay was formed where wave erosion breached a layer of the same basalt as that at Depoe Bay. A fault and other fractures trending at nearly right angles to the shore helped direct the erosion.

A short distance north of Boiler Bay there is a cove in the Astoria Formation at the mouth of Fogarty Creek (Figure 8). This indentation is defended on both north and south sides by remnants of the basalt.

<u>Depoe Bay Basalt:</u> This middle Miocene basalt flow was described by Snavely and others (1965) and named by the same writers (1973). The flow is exposed along the shore at Depoe Bay and forms the wall that separates the inner and outer bays (Figure 6). Here the rock is a pillow basalt breccia consisting of more or less dense ellipsoidal masses (pillows) of basalt enclosed in a matrix of angular basaltic glass fragments formed by the sudden chilling of hot lava coming in contact with sea water (Figure 9). Snavely and co-workers state that the 75-foot thick breccia at Depoe Bay grades into a 50-foot subaerial (deposited on land) flow to the south. Numerous dikes and sills of this type of basalt cut the Astoria Formation just east of Depoe Bay, and it is believed that lava erupted from local fissures and flowed into the ancient sea (Snavely and MacLeod, 1971).

At Depoe Bay, the lava flow forms a jagged, steeply sloping surface along the water's edge, and in places trenches and small caves have been eroded along fractures. One of the caves has an opening at its landward end through which the force of waves causes water to erupt, at times in columns several tens of feet high. These features, called spouting horns, are common along parts of the Oregon coast, and the one at Depoe Bay is one of the most spectacular (Figure 10).

The Depoe Bay Basalt extends northward from Depoe Bay but lies inland from the shore until it appears again at Boiler Bay, where small isolated masses, through their superior resistance to erosion, impart an irregularity to the inner edge of the bay. It lies along the shore north of Boiler Bay as far as Lincoln Beach. The rock knob at the mouth of Fogarty Creek (Figure 8) and the sea cliff northward to Fishing Rock (Figure 11) are of this basalt, and an isolated remnant of the flow forms a reef opposite Lincoln

Figure 8. Fogarty Creek enters a small cove protected by basalt shoulders. (State Highway Div. photo by Kinney)

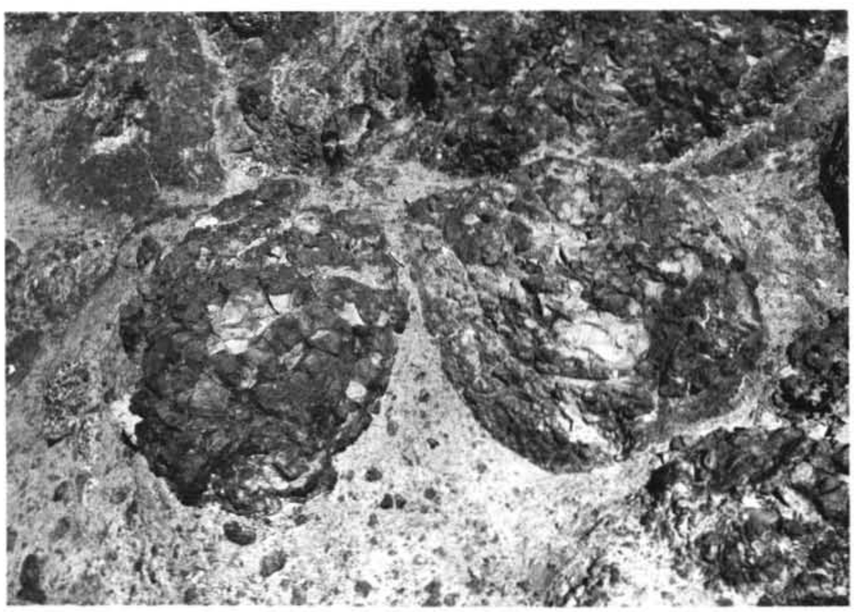


Figure 9. Pillow structure formed when hot lava of Depoe Bay Basalt poured into seawater.

Figure 10. Spouting Horn at Depoe Bay shoots up through a hole in the roof of a sea cave. (State Highway Division photo)

Beach Wayside, just north of Fishing Rock. Off Neptune Beach, a reef and two small islands, Otter Rock and Whaleback, are remnants of subaerial flows of this formation.

Sandstone of Whale Cove: An unnamed middle Miocene unit of sandstone 200 to 300 feet thick lies between the Depoe Bay Basalt and the slightly younger Cape Foulweather Basalt in the Whale Cove-Depoe Bay locality. This unit, informally referred to as the sandstone of Whale Cove, is described by Snavely and others (1969), who state, "Massive to thick-bedded medium- to fine-grained arkosic sandstone and thin-bedded micaceous carbonaceous siltstone to fine-grained sandstone constitute the bulk of the unit."

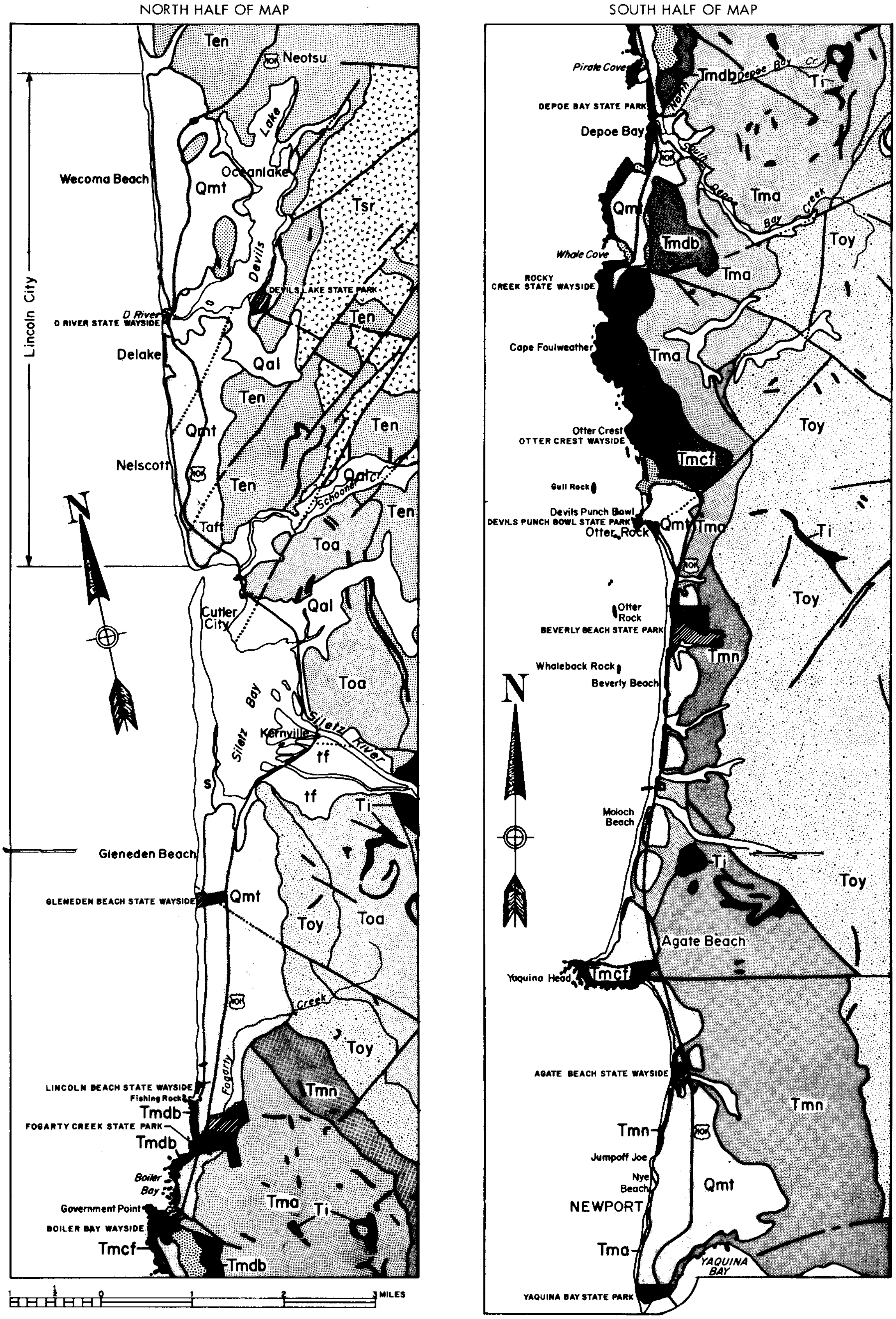
Whale Cove (Figure 12) was eroded in this sandstone, which forms the sea cliffs along the east and north edges of the cove. The erosion was probably directed initially along an east-west fault that cuts across the sandstone and the basalt that lies between it and the ocean. Once erosion breached

Figure 11. Fishing Rock at south end of Lincoln Beach is a remnant of Depoe Bay Basalt. (State Highway Div. photo by Kinney)

Figure 12. Whale Cove in the foreground and outer Depoe Bay in the distance. (State Highway Div. photo by Kinney)

Figure 13. North end of outer Depoe Bay (lower left of photo) and Pirate Cove (center left of photo) carved into sandstone and basalt. (State Highway Div. photo by Kinney)

Figure 14. Otter Crest on Cape Foulweather rises abruptly out of sea and provides spectacular views from its top. (State Highway Div. photo)




EXPLANATION

- Qal tf — Alluvium and estuary deposits
- s — Beach, sandspits, and dunes
- Qmt — Marine terrace deposits
- Tmcf — Cape Foulweather Basalt
- Tmwc — Sandstone of Whale Cove
- Tmdb — Depoe Bay Basalt
- Tma — Astoria Formation
- Tmn — Nye Mudstone
- Toy — Yaquina Formation
- Toa — Siltstone of Alsea
- Ten — Nestucca Formation
- Tsr — Siletz River Volcanic Series
- Ti — Intrusive rocks

Geologic map of coastal Lincoln County between Newport and Lincoln City. Adapted from maps by Snavely and MacLeod, published in Schlicker and others (1973).

the wall of basalt, the cove was enlarged in the softer sandstone. North-trending faults and fractures in the rock helped promote the cove's enlargement, and sea caves and small re-entrants formed along some of the fractures.

From Whale Cove, the sandstone formation extends northward beneath the terrace sandstone and is the rock in which the wide outer Depoe Bay was formed (Figures 12 and 13). It forms the sea cliffs at the north and south ends of this bay, and, as at Whale Cove, the sea cliffs are irregular and penetrated by small coves and sea caves.

Pirate Cove (Figure 13), a short distance north of Depoe Bay, is partly in the sandstone of Whale Cove, and the sea cliffs along the inner edges of the cove have caves, chasms, and other features characteristic of this sandstone. The sandstone ends just south of Boiler Bay.

Cape Foulweather Basalt: The Cape Foulweather Basalt, named by Snavely and others (1973), is the younger of the two middle Miocene basalt units along this part of the Oregon Coast. It is more extensive than Depoe Bay Basalt and is the major contributor to the shore's irregularity. The unit includes several textural varieties of volcanic basalt but consists predominantly of breccia and water-laid fragmental debris (Snavely and others, 1969). It also contains massive subaerial flows and submarine pillow lavas. Volcanic necks and feeder dikes that cut through the layers of erupted rock indicate that the eruptions were from local centers. Particles that went into the ocean were reworked into poorly sorted and crudely stratified deposits that fringe the main body of erupted rock.

The main center of eruption of this basalt was at Cape Foulweather, where layers of basalt breccia and dense lava accumulated to a great thickness. The Cape, with cliffs and precipitous seaward slopes that rise to a height of 500 feet at Otter Crest (Figure 14) is one of the most ruggedly beautiful headlands on the Oregon Coast. From the viewpoint at Otter Crest, one can see miles of coastline to the south (Figure 4). North of Otter Crest the shoreline around the Cape is very irregular, with numerous small coves and smaller promontories (Figure 15).

The Cape Foulweather Basalt extends along the shore as far as Boiler Bay, and north of the Cape the rock consists mostly of fragmental types. It is the bedrock beneath the terrace along the shore between the Cape and Government Point (Figure 7). The basalt helps to enclose and protect Whale Cove, outer Depoe Bay, and Pirate Cove.

At Rocky Creek Wayside the Cape Foulweather Basalt is an unsorted and crudely stratified breccia (Figure 16) overlying dense flow basalt. The strata are fairly steeply inclined and are the accumulations of volcanic fragments and flows on the flank of a volcanic cone. North-trending fractures in the rock at this locality have directed the wave erosion that has shaped a picturesque setting of a chasm, sea caves, trenches, and isolated wave-washed rocks (Figure 17).

At Government Point the fragmental rock is roughly size-sorted and

Figure 15. Rugged shore of Cape Foulweather north of Otter Crest.

Figure 16. Basalt breccia of Cape Foulweather Basalt at Rocky Creek Wayside was erupted from a volcanic cone in Miocene time.

Figure 17. Rocky Creek Wayside is situated on a small marine terrace composed of basalt. (State Highway Div. photo by Kinney)

Figure 18. Waves and turbulent water at Government Point, a marine terrace eroded on fragmental volcanic rock. (State Highway Div. photo)

stratified, which suggests a submarine site of deposition. Much of the material is about the size of pebbles. Volcanic fragments of this size are called lapilli, and the rock is designated a lapilli tuff; the coarser textured rock is classed as breccia. These rocks are part of the apron of water-deposited fragmental volcanic debris that formed a fringe around the seaward edge of the main center of eruption at Cape Foulweather.

Government Point is a favorite viewpoint for wave-watchers. During storms, waves strike the rocks with eruptive violence (Figure 18) or rush plunging into adjacent Boiler Bay (Figure 7), at times causing the surface of the bay to turn white with foam and seething water. Though the turbulence of the water in Boiler Bay during storms is not the basis for the name, the condition does lend appropriateness to it. The bay gets its name from the boiler of a wrecked ship which was visible for many years, until it finally rusted away.

Yaquina Head (Figure 1) is composed of the same kind of basalt as that at Cape Foulweather, and the breccias and dense flows are similar to those at the Cape. Dikes and sills cutting the extrusive layers indicate a local center of eruption. The flows at Yaquina Head overlie the Astoria Formation, and in places the lava became intermixed with the sandstone. The contact is clearly exposed in the cliffs at the ends of the beaches on both sides of Yaquina Head (Figure 19).

This point of land was once much more extensive and is slowly but steadily being worn away by the waves. Because of more rapid erosion in areas of weakest rock, owing to either hardness difference or fracturing, the outline of Yaquina Head is very irregular. As erosion has progressed, more resistant parts have become separated from the mainland and are now small stacks and rock knobs.

The steep-sided island (Figure 20) lying offshore about half a mile southwest of Otter Crest is an isolated remnant of the Cape Foulweather Basalt. This island is referred to as both Gull Rock and Otter Rock.

Dikes cropping out on the wave-cut platform between Otter Crest and Otter Rock headland are related to the Cape Foulweather Basalt and were probably part of the feeder system for the flows. Dikes and sills in the hills and on the beach north of Cape Foulweather are of middle Miocene age but have not been correlated with either the Depoe Bay Basalt or the Cape Foulweather Basalt.

A row of rock knobs at the north end of Siletz Bay near the mouth of Schooner Creek is along a dike that is also exposed in the nearby roadcut. Another dike about a quarter of a mile to the south forms a rock knob on a point of land. The Inn at Spanish Head is built on a basalt sill which has two seaward projections that form natural breakwaters. Remnants of the sill are awash in the surf zone a few hundred yards to the north. A dike complex about half a mile north of Nelscott community forms a reef that projects seaward nearly at right angles to the beach.

Figure 19. Intermixed sedimentary rock and basalt on south side of Yaquina Head.

Figure 20. Gull Rock south of Otter Crest is a remnant of the former headland.

## Quaternary deposits

Terrace sediments: At times of higher sea level during the Pleistocene Ice Age, wave erosion cut platforms and benches on the bedrock along the shore the same way it does today, but at a higher elevation. After the platform was cut, sediments were deposited over it as the water level rose. When the sea level again lowered, a terrace was left behind.

The terrace sediments are mostly weakly consolidated sand, but in many places there is a gravel layer directly above the bedrock. Less commonly, gravel is interlayered with the sand. These gravel beds are a source of agates and other interesting rocks on the beaches. Agate hunting is best during the winter, when much of the sand has been removed by storm waves that leave exposed gravel. The source of the agates at Agate Beach is cavity fillings in the basalt at Yaquina Head and gravel layers in the terrace sediments. As the sea cliff is eroded, a new supply of agates is added to the beach.

Terraces are widest and longest where the bedrock is sedimentary, but they are well formed on the fragmental basalts north of Cape Foulweather and on the outer end of Yaquina Head. Pleistocene sediments along the shore range in thickness from a few feet to more than a hundred feet. Sea cliffs at Lincoln City reach heights of more than 100 feet and are mostly of terrace sandstone with a capping of dune sand.

River and estuary deposits: There are two estuaries in this stretch of the coast, Yaquina Bay (Figure 21) and Siletz Bay. Estuaries are formed where the sea has encroached on the lower ends of rivers because of a rise in sea level. In some of the larger rivers, they are affected by tides and the inflow of salt water for many miles upstream.

The flat plains along the estuaries are of sediments, mostly silt, sand, and clay, that were carried by the rivers and deposited in the quieter water of the bays. Most of the deposition took place at times when the sea level was higher and the bays were enlarged, but alluvium continues to be added to the plains whenever the rivers spill over their banks during floods.

Beaches and sandspits: The sand and gravel on the beach form a thin veneer over a wave-eroded surface on bedrock (the wave-cut platform). The beach is sometimes referred to as a river of sand because the sand moves along the shore with the longshore currents. Along the Oregon Coast, winter winds from the south and southwest give the currents a predominantly northward motion; summer winds from northerly directions drive the currents southward. Sand accumulates on the beach during summer, but most of it is swept away during the winter storms when the wave energy is high. In some places, the bedrock is swept clear, and in others the beach deposit becomes mostly gravel.

Sandspits are extensions of the beach that project into and terminate in open water (Figure 22). They are located at the mouths of bays, some projecting from the north and others from the south. Some bays may have

Figure 21. Entrance to Yaquina Bay, an estuary that formed by drowning of the river mouth with rising sea level. (State Highway Div. photo by Kinney)

Figure 22. Sandspits at entrance to Siletz Bay. Sandspit at right is more than 2 miles long. (State Highway Div. photo by Kinney)

both a north and a south projecting spit, as at Siletz Bay, but one will usually be longer than the other. A sandspit is in delicate balance with the waves, currents, tides, and sand supply; fluctuations in any one or a combination of these factors have an immediate and sometimes devastating effect, such as breaching during storms. A given sandspit may survive as a landform, but its position, size, outline, and contours will change.

Figure 23. Low dunes on Siletz Spit stabilized by grass. Basalt riprap provides temporary protection for houses until next assault by high tides and storm waves. (State Highway Div. photo by Kinney)

Sand dunes: Because most of the shore between Newport and Lincoln City has a sea cliff along it, preventing sand from blowing inland from the beach, there are few recent dunes. Old Pleistocene-age dunes composed of brownish-yellow sand are situated on the marine terrace at a number of places between Newport and northern Lincoln City. The old dunes are stabilized by soil and vegetation, but where exposed they are subject to erosion. They are visible in the higher sea cliffs, in highway cuts, and in excavations.

Dunes along the Siletz sandspit are the most recently active, but over most of the sandspit they have been stabilized with European Beach grass (Figure 23). On the seaward side at the end of the spit, sand is still being moved by the wind. Erosion by waves during storms and high tides of winter are constantly wearing away the outer margin of this spit, endangering houses built too near the edge and requiring the placement of rock (riprap) to retard the erosive undermining of the structures.

Devils Lake, the only large lake on this part of the Oregon coast, owes its origin to drowning of the lower part of a stream valley and blocking of the stream's mouth by dunes and beach deposits. Since the volume of water flowing in D River is not sufficient to keep the bottom of the river channel below sea level, a fresh-water lake results rather than a salt-water estuary.

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## OTHER COASTAL LANDFORMS ARTICLES AVAILABLE

Among the many articles previously published in The ORE BIN on landforms and geology of the coastal areas of Oregon are the following, copies of which are available at Department offices for 25¢ each:

Lund, Ernest H., Coastal landforms between Florence and Yachats, Oregon: Ore Bin, v. 33, no. 2, p. 21-44, Feb. 1971.

_____, Coastal landforms between Yachats and Newport, Oregon: Ore Bin, v. 34, no. 5, p. 73-92, May 1972.

_____, Coastal landforms between Tillamook Bay and the Columbia River, Oregon: Ore Bin, v. 34, no. 11, p. 173-194, Nov. 1972.

_____, Oregon coastal dunes between Coos Bay and Sea Lion Point: Ore Bin, v. 35, no. 5, p. 73-92, May 1973.

_____, Landforms along the coast of southern Coos County, Oregon: Ore Bin, v. 35, no. 12, p. 189-210, Dec. 1973.

Hunter, R. E., Clifton, H. E., and Phillips, R. L., Geology of the stacks and reefs off the southern Oregon coast: Ore Bin, v. 32, no. 10, p. 185-201, October 1970.

Snavely, P. D., Jr., and MacLeod, N. S., Visitor's guide to the geology of the coastal area near Beverly Beach State Park, Oregon: Ore Bin, v. 33, no. 5, p. 85-105, May 1971.

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## BULL RUN WATERSHED GEOLOGY PUBLISHED

"Geologic Hazards of the Bull Run Watershed, Multnomah and Clackamas Counties, Oregon" is the latest of the Department's bulletins dealing with environmental geology. The author is John D. Beaulieu, Department stratigrapher.

The Bull Run watershed, situated at the foot of Mount Hood in the Western Cascades, is Portland's sole source of water and is an excellent timber-producing area. As part of a comprehensive land management program, the geologic hazards study was initiated to provide basic data regarding the capabilities of the land and the types of natural hazards threatening water quality. The bulletin discusses geologic units, geologic hazards, runoff, and historic landslides.

Bulletin 82 has 86 pages, 71 photographs, 14 drafted figures, 6 tables, and two maps on a scale of 2 inches to a mile. The bulletin can be obtained from the Oregon Department of Geology and Mineral Industries at its offices in Portland, Baker, and Grants Pass. Price is $5.00.

* * * * *

## GEOTHERMAL DEVELOPMENTS

### Auction date set for Vale KGRA

The first competitive Federal auction for geothermal resources in Oregon has been scheduled for 10:00 a.m. June 21. The auction will be for a 1,347.17 acre leasing unit near Vale. Sealed bids will be accepted for the unit until sale time at the Bureau of Land Management office, 729 N. E. Oregon Street, P.O. Box 2965, Portland, Oregon 97208.

Information on specific details and terms of the offering can be obtained at the BLM office.

### Addition to Vale KGRA

An additional area of 11,535.27 acres has been added to the Vale Hot Springs Known Geothermal Resource Area. Location is as follows:

T. 18 S., R. 45 E., Sec. 34: all
T. 19 S., R. 45 E., Sec. 2-4, 9-15, 23-26, 36 inclusive
T. 19 S., R. 36 E., Sec. 19, 30: all

### New KGRA defined at Belknap-Foley Hot Springs

An area of 5,066.21 acres adjacent to Belknap and Foley Hot Springs has been identified as a Known Geothermal Resource Area by the Conservation Division of the U.S. Geological Survey. Location is as follows:

T. 16 S., R. 6 E., Secs. 14, 20-23, 26, 28, 29: all

### New KGRA defined at McCredie Hot Springs

An area of 3,658.60 acres adjacent to McCredie Hot Springs has been identified as a KGRA by the Conservation Division of the U.S. Geological Survey. Location is as follows:

T. 21 S., R. 4 E., Secs. 25, 26, 35, 36: all
T. 22 S., R. 4 E., Sec. 1: all
T. 21 S., R. 5 E., Sec. 31: all

Geothermal leases are for 10 years, with provisions for renewal to a maximum of 40 years. "Diligent exploration" is required and a rental fee of not less than $2 an acre per year will be charged prior to production. After five years, rentals will go up $1 an acre per year through the tenth year.

The Geological Survey identified 84,000 acres of Oregon land in seven areas as Known Geothermal Resource Areas (KGRA). Since January 1, there have been 693 applications filed for leases in Oregon for approximately 1.5 million acres of Federal land not previously identified for its geothermal potential.

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# TELLURIC CURRENT EXPLORATION FOR GEOTHERMAL ANOMALIES IN OREGON

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This study was supported in part by the U.S. Bureau of Mines grant No. SO122129 to the Oregon Department of Geology and Mineral Industries. Because of its timely interest, the article is being published in The ORE BIN rather than in a more technical journal in order to make the information immediately available to those involved in geothermal exploration in Oregon and elsewhere.

## Introduction

A reconnaissance telluric current* exploration program for geothermal anomalies in southern and eastern Oregon was initiated in 1971 by the Geophysics Group at Oregon State University. During 1971 and 1972, observational data were obtained from a total of 19 field stations. The program concentrated on the Klamath Falls area, where 10 stations were occupied, and on a profile including a total of 9 stations extending from Siletz at the Pacific Coast to the area around Vale in the extreme eastern part of the state. The locations of the stations are shown in Figures 5 and 6. The principal purpose of this program was to test instrumentation, field procedure, data processing methods, and the general applicability of the telluric current method in reconnaissance exploration for geothermal resources. The results obtained are to be applied to improve all aspects of our methodology and to prepare for a more substantial effort in this field.

The field procedure applied on the present program deviates from the standard telluric method in that the telluric data obtained at the field stations are compared with the magnetic field recorded at a fixed base station. Our method is therefore a variant of the standard magneto-telluric method,

* Natural electric currents that flow on or near the earth's surface in large sheets. Methods have been developed for using these currents to make resistivity surveys.

but since we are mainly interested in large-scale lateral variations of the earth's conductivity, we have preferred to refer to the method as a telluric rather than magneto-telluric method.

## Rationale for the Telluric Current Method

Regional reconnaissance exploration for geothermal resources is concerned with the initial detection and recognition of geothermal anomalies of economic interest. An elementary investigation (Bodvarsson, 1966) of resource energetics shows that the heat capacity of rock is such that in terms of electrical energy it is realistic to expect that very roughly about 1 kwhr can be generated per cubic meter of resource volume. This estimate is based on the assumption of the conditions in known fluid-phase, high-temperature geothermal systems where base temperatures of the order of 250°C are encountered and by using a recovery factor of 10 percent. Hence, the generation of 250 Mw at base-load condition for 50 years would require a resource volume of not less than 100 cubic kilometers. This volume could, for example, have the shape of a disk with a diameter of 8 km and thickness of 2 km. Invariably such a reservoir would be surrounded by a thermal halo of considerable extent and the total associated thermal anomaly could extend over areas of several hundred square kilometers and downward into the deeper crust. The exploration targets are, therefore, quite extensive features.

Most of the important known geothermal resources are leaky in the sense that they generate thermal surface manifestations such as hot springs and conspicuous thermal rock alteration. The high temperature character can be recognized on the basis of the physical and chemical characteristics of the surface display. In general, the leaky resources are easily recognized, and there is little need for sophisticated reconnaissance type exploration work.

There is, however, considerable evidence that geothermal systems of great economic potential may be totally concealed and display no surface leakage at all (Bodvarsson, 1961, 1970). In fact, geothermal fluids have a tendency to chemically seal outlets and thereby contribute to the eradication of surface manifestations (Bodvarsson, 1961). Resources of this type can be detected only with the help of more elaborate techniques, such as thermal and electrical exploration methods.

The thermal methods involve regional temperature probing or heat-flow mapping with the help of temperature data from very shallow boreholes. Large geothermal resources within drillable depths are invariably associated with conspicuous surface heat-flow anomalies and can therefore be recognized in regional heat-flow maps of sufficiently detailed nature.

The application of the electrical methods is based on the fact that the formations within geothermal systems have a low electrical resistivity (Bodvarsson, 1970). Values in the range of 1 to 10 Ωm have been observed within many high-temperature geothermal reservoirs. This is the consequence of high temperatures and high mineral content of reservoir interstitial waters.

The resistivity contrast between the hot formations and the surrounding country rock quite often involves factors ranging from 10 to 100. Most major geothermal systems are associated with large-scale electrical resistivity anomalies, and this is especially true with the fluid phase systems. Electrical methods are therefore important tools in geothermal exploration work.

Electrical exploration methods fall into two categories, those based (1) on controlled artificial current source fields, and (2) on natural current fields provided by magnetic micropulsations and other ULF natural activity. The second class of methods, which includes the telluric and magneto-telluric methods, has a considerable advantage in reconnaissance type exploration work involving exploration targets of relatively large dimensions and depths of more than 1 or 2 kilometers. The artificial current sources in such circumstances would require a considerable amount of equipment and field effort. The advantage of the second class of methods is obtained at the cost of less resolving power and greater ambiquity in interpretation, but since target dimensions and resistivity contrasts are unusually large, this disadvantage is not considered to be too important.

For the present purpose, the natural field electrical methods have a certain economic advantage over the thermal methods. Heat-flow mapping is based on the measurement of the vertical flow of heat, which usually has to be derived from temperature and heat conductivity data obtained from shallow boreholes. The minimum depth of such boreholes is 10 to 20 meters, and the selection of drilling locations has to be carried out with considerable care. The field effort required at each station to obtain one or two hours of telluric records is considerably smaller. Moreover, since the telluric currents are horizontal, each telluric station can sample a larger formation volume than the corresponding heat-flow station. In a given area it should therefore be possible to obtain useful reconnaissance type data with the help of fewer telluric field stations than thermal stations. It is clear that carefully measured heat-flow data can be more accurate and have a greater resolution than telluric data, but in reconnaissance type geothermal exploration work the economic advantage of the telluric method appears to outweight this disadvantage. These are the main reasons for selecting the telluric method for our work in Oregon.

In this study it was considered of advantage to install a fixed magnetic base station, rather than to rely on a telluric electrical field base station. The magnetic data allow us to obtain absolute conductivity values. The magnetic base station was installed at Corvallis, Oregon, some 280 km north of the Klamath Falls area. Investigations of micropulsation activity in southern California (Benioff, 1960) have indicated that the micropulsation field at moderate latitudes does not vary appreciably over such distances. On the other hand, the field stations at Vale in eastern Oregon are located almost 500 km from the base station, and the general magnetic coherency cannot be expected to be as good, although individual magnetic events with a good coherency appear to exist.

## Expected Resolution

It is important to raise the question as to the overall quality of the exploratory information which can be expected from a telluric current field program of the type described above. Unfortunately, the information content of the observational field data depends to a considerable extent on the local conditions at the individual field stations. Moreover, the theory of telluric currents in electrically non-homogeneous geological structures is a matter of great complexity and not much work of practical relevance has been devoted to the subject. We therefore limit ourselves to the following quite superficial remarks.

For the present purpose, the earth can be assumed to be a semi-infinite perfect reflector of the magnetic field generated by the oscillating ionospheric currents. The penetration of the induced telluric currents is limited by the skin effect which is measured by the skin depth, that is, the depth at which the current amplitude has been attenuated to $1/e = 0.37$ of its surface value (Keller and Frischknecht, 1966, p. 213). Relevant values of the skin depth for homogeneous isotropic half-spaces at various resistivities and at periods from 10 to 50 seconds are given in Figure 1.

Approximately 2/3 of the telluric current flows in the horizontal region above the skin depth. Hence, this depth gives a fairly good measure of the thickness of the formations sampled by the telluric currents and the associated electrical field. Assuming perfect source current conditions and a homogeneous half-space, the above described telluric method will give the true resistivity of the half-space regardless of the frequency. In a layered

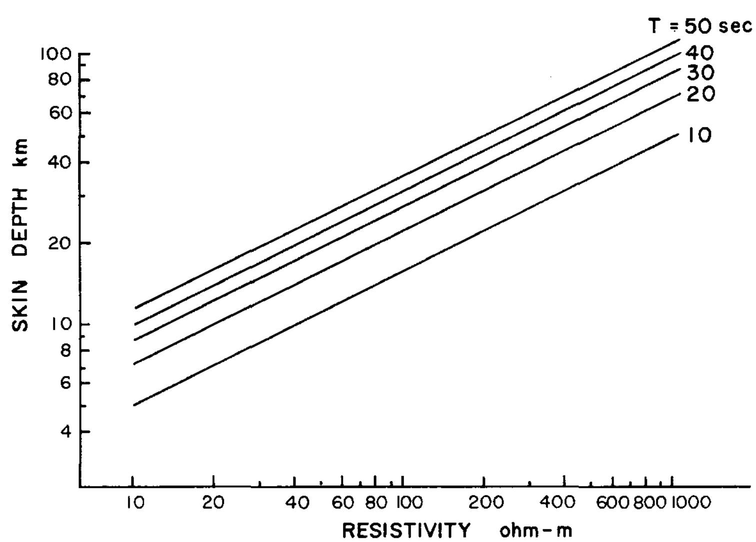



Figure 1. Data on the skin depth in a homogeneous half-space.

half-space, the method gives a certain weighted average of the vertical resistivity distribution in the region where the bulk of the telluric current flows. Obviously, the averaging is biased toward the shallower sections.

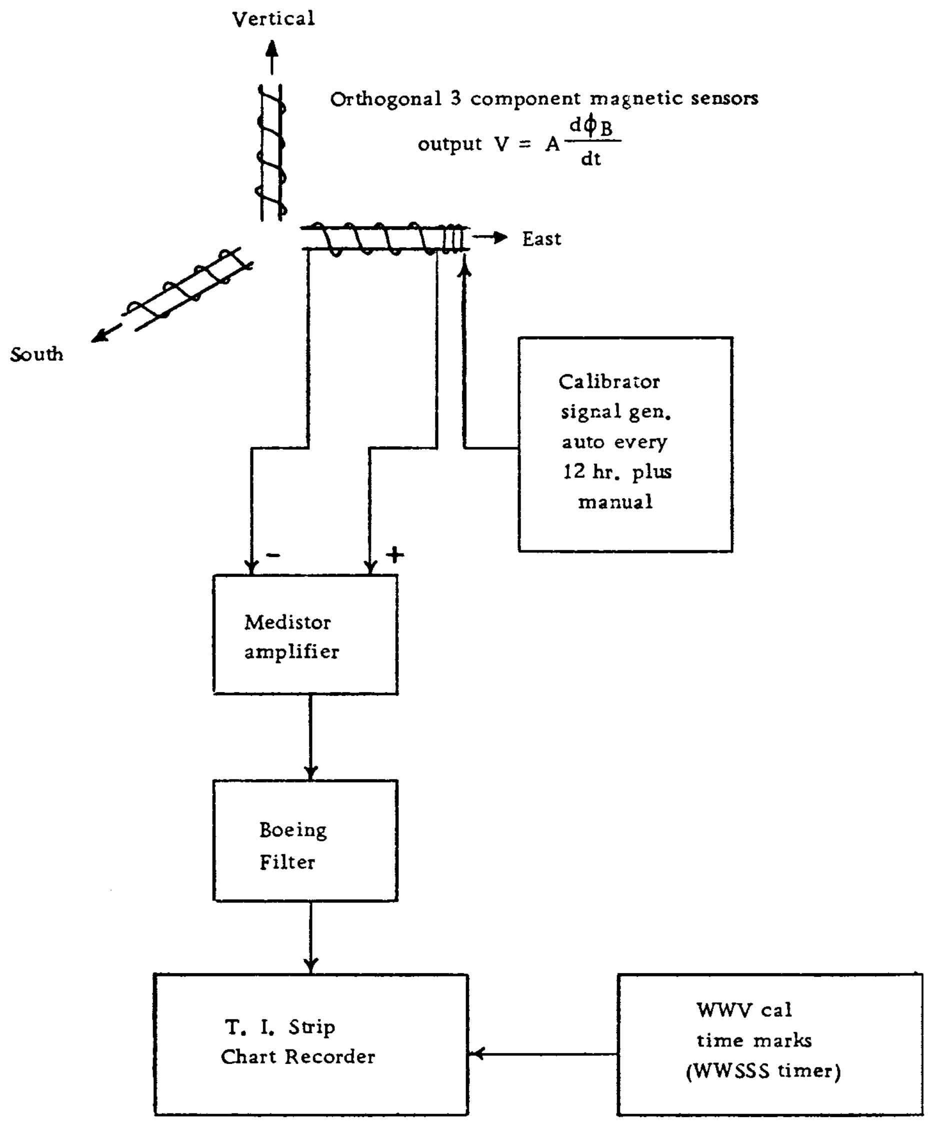
The telluric current pattern is distorted by lateral inhomogeneities and anisotropicities which commonly occur in the field. The conditions in the local region between and around the field electrodes are of primary importance, particularly where the electrodes have been placed within a local low resistivity anomaly. The electrical field readings are then abnormally low and the station yields an apparent resistivity value which can be grossly in error. Substantial apparent anisotropies may also be introduced by purely local conditions. Clearly, difficulties of this kind are common to all electrical methods using conductive contacts. The principal precautions against serious errors of this type are (1) to select the field stations with care to avoid local zones of low resistivity and anisotropicity, and (2) to scrutinize all conspicuously low and anisotropic apparent resistivity values by repeated measurements at several stations in the local area. This is of particular importance for the present project since the low resistivity anomalies are the primary exploration targets.

Directional and density inhomogeneities in the overhead ionospheric currents are further sources of errors. Usually, the interpretation of telluric and magneto-telluric data is based on the assumption of uniform and unidirectional source currents. Deviations from this idealized model lower the quality of the observational material and are perhaps the main cause of the often excessive scattering of observational magneto-telluric resistivity data. As indicated above, this matter is of particular concern with regard to the present project since such difficulties are likely to be enhanced by the distance between the magnetic base station and the electrical field stations. To minimize this effect, it is important to obtain field records for sufficiently long periods of time and to edit the data by rejecting sections with low magnetic-telluric coherency.

## Instrumentation and Field Procedure

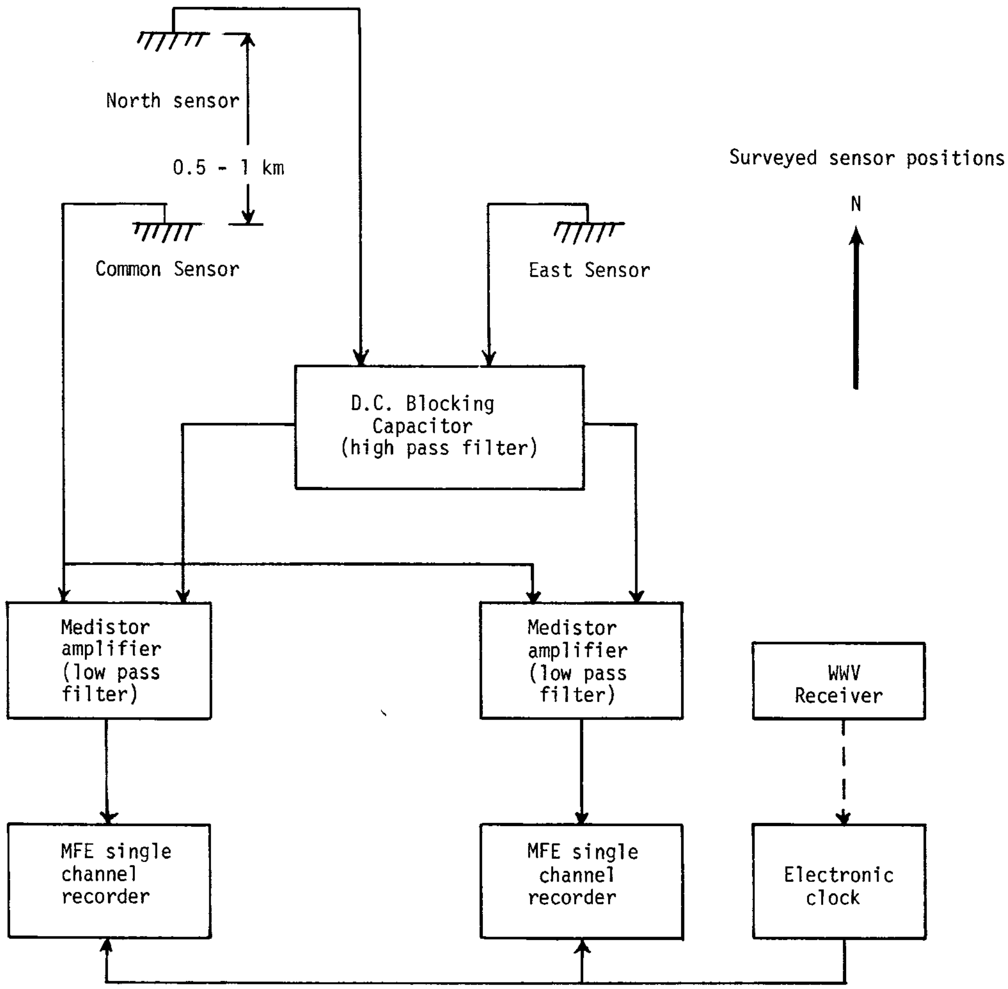
The instrumentation used on the present project consists of two separate parts, (1) the magnetic base station at Corvallis, and (2) the portable telluric field equipment. Block diagrams of the two systems are shown in Figures 2 and 3. The magnetic data aquisition system was provided by the Boeing Company, Seattle, Washington. A description of the magnetic sensors has been given by McNicol and Johnson (1964).

In brief, the magnetic sensors consist of three mumetal-cored induction coils each with $4.8 \times 10^5$ turns of wire. The diameter of the cores is 1 inch. The three coils were buried in the ground at the World Wide Standard Seismic Network Station at Corvallis, where the associated electronic equipment was housed, and were placed along three local orthogonal axes, geographic north, east and vertical. The station crystal clock provided an




Output: Voltage versus time proportional to magnitude of micropulsations

Figure 2. Magnetic data-acquisition system.




Output: Voltage versus time, each absolutely calibrated usually expressed mv/km

Figure 3. Telluric data-acquisition system.

absolute time reference. The amplified magnetic signals were recorded on Texas Instrument strip chart recorders. The magnetic system was calibrated by using an artificial oscillating magnetic field.

The telluric sensors, which consisted of three lead metal probes inserted into the ground at the individual field stations, formed an orthogonal L-shaped array where one arm pointed north and the other east. The length of the arms ranged from 200 to 500 meters, depending on local conditions. Each probe consisted of a piece of metallic lead plate 5 mm thick, 600 mm wide, and 1,000 mm long, rolled up into a tube 200 mm in diameter, and buried in the ground. Local D.C. fields were blocked out with a non-polar 20-micro farad capacitor. The output signals were amplified and recorded on a four-track strip-chart recorder. Each field station was occupied for a time sufficient to provide 1 to 2 hours of telluric field data.

## Observational Data

A comparison of the individual telluric field records with simultaneous orthogonal magnetic base station records shows that the coherency generally varies considerably over the record length. In most pairs of simultaneous records, there were, however, individual wave packets or events in the 10- to 50-second period band which showed a good coherency and which could be considered likely to furnish representative values of the electromagnetic impedance ratio. It was, therefore, decided to base the data processing on such wave packets only and to apply the simple individual event method of Berdichevsky and Brunelli (1959) to obtain the impedance ratios at the various frequencies. The method has also been described by Keller and Frischknecht (1966, p. 246).

Usually, between 5 and 10 events could be processed for each pair of orthogonal field components. The impedance ratios obtained were then applied to derive an apparent resistivity with the help of the well-known basic equation for magneto-telluric investigations (see Keller and Frischknecht, 1966, p. 217),

$$\rho_a = (\mu_o T/2\pi)\ (E/B)^2 \qquad (1)$$

where $\rho_a$ is the apparent resistivity, T is the period, $\mu_o = 4\pi \times 10^{-7}$ is the permeability of free space, E the amplitude of the horizontal electrical field, and B the amplitude of the orthogonal horizontal magnetic field, both amplitudes measured at the ground surface, all in MKSA units.

Many geological formations exhibit a substantial anisotropy, that is, the apparent resistivity depends on the direction in which the fields are measured. In the following, we therefore use the subscripts n and e for north-south and east-west, respectively, and refer to $\rho_{an}$ as the apparent resistivity value based on $E_n/B_e$ and to $\rho_{ae}$ as the value based on $E_e/B_n$.

An illustration of the results is obtained by plotting the apparent resistivities derived from the individual component pairs against the event periods. Typical plots of this kind are given in Figure 4, which shows the processed apparent resistivity data from the Corvallis base station (12) and from South Klamath Hills (6) in the Klamath Falls region.

As indicated by the examples in Figure 4, the apparent resistivity data exhibit a considerable irregular scattering, which in most cases covers a relative range from 1 to 3; that is, the highest values are about three times as large as the lowest. At most stations, the maximums are observed in the 20- to 30-second period band.

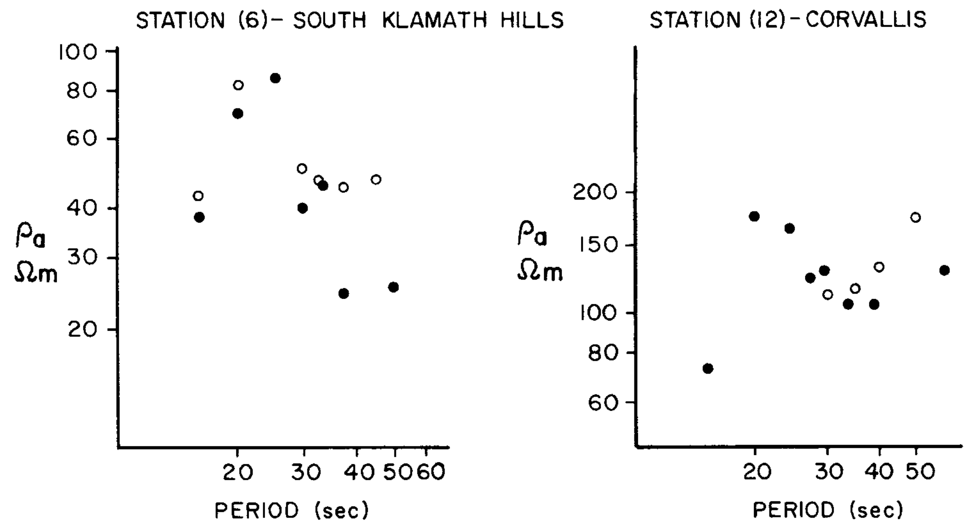



Figure 4. Apparent resistivities versus period for stations (6) and (12). Full circles represent $\rho_{an}$, the north-south resistivities, and the open circles $\rho_{ae}$, the east-west resistivities.

Scattering of this kind is frequently encountered in magneto-telluric work, and along the lines discussed above, we point out that the following causes may contribute to this situation: (I) Non-uniform source current fields; (II) enhanced non-coherency due to the distances between the magnetic base station and the individual field stations; (III) numerical errors introduced by the individual event analysis method; and (IV) instrumental errors. Obviously, all errors in the observed impedance ratios are enhanced by the squaring of the impedance ratio in equations (1).

At this juncture, it appears that the non-uniformities under (I) are a substantial cause of the scattering. Since the results obtained at the Corvallis base station exhibit a similar character as the other field stations, the distance factor mentioned under (II) does not appear to be a primary cause. We have still to evaluate the influence of the data-processing method listed under (III). The maximums observed in the 20- to 30-second band may partially be instrumental.

## Preliminary Numerical Results

In view of the character of the observational material and since we are mainly interested in a fairly large-scale average resistivity at each station, there is at this time not much incentive to attempt a more elaborate interpretation of the present data. In our present analysis, we therefore rely on the simple procedure of taking averages over the apparent resistivity values observed in the 10- to 50-second period band for each direction at the individual stations. This procedure yields two values, $\bar{\rho}_{an}$ and $\bar{\rho}_{ae}$, for each station. The first is the averaged apparent resistivity in the north-south direction, and the second is the value for the east-west direction. These data are listed in columns (1) and (2) in Table 1. Moreover, the table also lists in column (3) the averages for the two directions. Since the penetration of telluric currents depends on the skin depth, the trend of the apparent resistivities with increasing periods gives a certain indication about the downward trend of the resistivity. This information is given in the last column of Table 1. The averaged resistivity from column (3) in Table 1 is plotted on the maps in Figures 5 and 6.

## Data Evaluation and Discussion

A preliminary review of the data given in Table 1 and shown in Figures 5 and 6 can be summarized as follows. We will focus our attention on the averaged apparent resistivity data in column (3) of Table 1.

(1) Data from a total of 19 field stations are available. The average values given in column (3) of Table 1 vary from a low of 15 to a high of 360, that is, by a factor of 24. The variability is one order of magnitude greater than the scattering of the data at the individual stations.

(2) Six of the ten data obtained in the Klamath Falls area are well below 100 Ωm. With one exception, these are the lowest values observed on our project. This is of primary interest since Klamath Falls is an area of known geothermal activity (Peterson and McIntyre, 1970). Stations (6) and (7) which yield values of 60 and 40 Ωm, respectively, are close to geothermal surface manifestations. Moreover, stations (1), (3), and (9) to the northwest and north yield low values, particularly station (1). Since the Klamath Falls area is the only area with known geothermal display investigated by us, we conclude that our results exhibit an encouraging correlation with geothermal activity. Nevertheless, we have to emphasize that other non-thermal factors may also be involved, and in this respect we point out that there is an abrupt decrease in the observed resistivity from station (5) to station (6). Since the distance between these two stations is only 7 km, we surmise that local geological factors are of some importance.

Table 1. Average apparent resistivities for the 10- to 50-second period band

| Station | Name | (1) North-south resistivities, $\bar{\varrho}_{an}$ | (2) East-west resistivities, $\bar{\varrho}_{ae}$ | (3) Average (1) and (2) (rounded off) | (4) Downward trend |
|---|---|---|---|---|---|
| Klamath Falls area | | | | | |
| (1) | Lake of the Woods | 10 Ωm | 20 Ωm | 15 Ωm | D |
| (2) | Miess Lake | 210 | 260 | 240 | I |
| (3) | Indian Springs Flat | 100 | 40 | 70 | D |
| (4) | Lake Miller | 40 | 420 | 230 | U |
| (5) | Tulane | 280 | 330 | 310 | I |
| (6) | S. Klamath Hills | 50 | 70 | 60 | D |
| (7) | Noble | 40 | 30 | 40 | D |
| (8) | Nuss Lake | 30 | 240 | 140 | D |
| (9) | Swan Lake | 10 | 130 | 70 | D |
| (10) | Scranz | 30 | 120 | 80 | U |
| West-East profile | | | | | |
| (11) | Siletz | 110 | 100 | 110 | I |
| (12) | Corvallis | 130 | 130 | 130 | U |
| (13) | Sweet Home | 120 | 200 | 160 | I |
| (14) | Sisters | 330 | 360 | 350 | D |
| (15) | Hampton | 140 | 130 | 140 | U |
| (16) | Harney Basin | 360 | | 360 | D |
| (17) | Vale-Negro Rock | 40 | 10 | 25 | D |
| (18) | Vale-E. Cow Hollow | 70 | 330 | 200 | D |
| (19) | Vale-Alkali Flats | 220 | 170 | 200 | U |
| Column average | | 120 | 170 | 150 | |

D - decreases; I - increases; U - uncertain

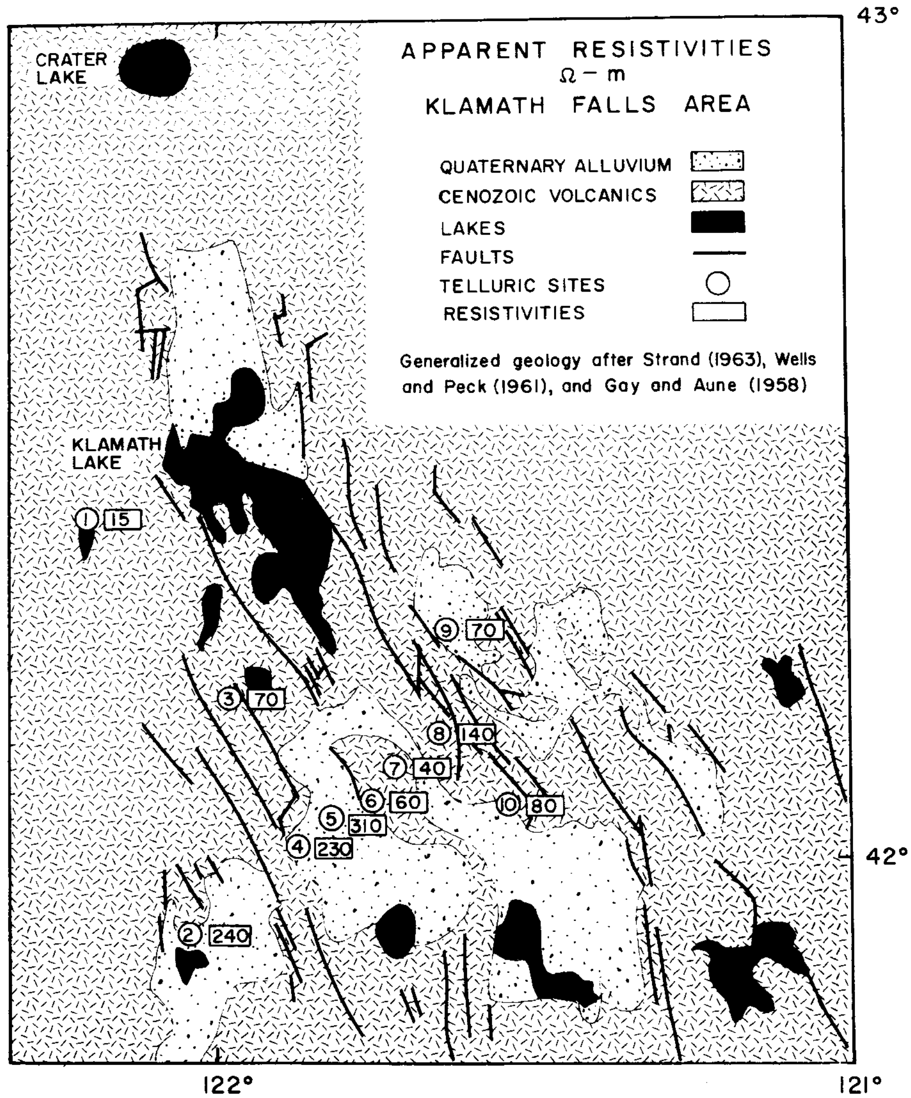



Figure 5. Average apparent resistivities in the Klamath Falls area listed in column (3) of Table 1.

(3) On the other hand, the resistivity values obtained so far in Klamath Falls are considerably above values observed by D.C. resistivity methods in known high-temperature geothermal areas (Banwell, 1970). The present data are, therefore, not indicative of typical high-temperature conditions there. The data are, however, too few to draw definite conclusions.

(4) The very low values observed at stations (1) and (17) are of particular interest although they cannot be correlated with any known

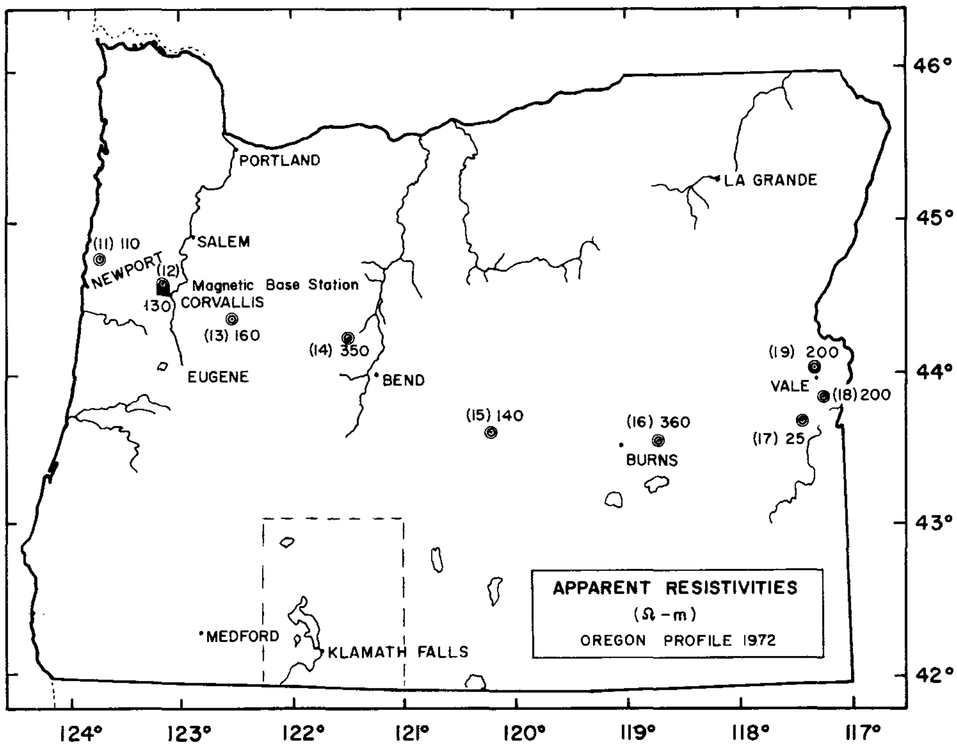



Figure 6. Average apparent resistivities on the profile from Siletz to Vale listed in column (3) of Table 1. The figure in brackets is the station number. The dashed line outlines the area of Figure 5.

local thermal surface display. A further investigation is definitely warranted.

(5) At ten of the stations the apparent resistivity decreases with increasing depth. In particular, this is true of the stations with low values and is very probably of significance with regard to geothermal anomalies.

(6) Six of the stations exhibit a very pronounced anisotropy involving ratios up to 10. There is little doubt that local effects at the station sites are important causes of some of the high ratios. On the other hand, it is noted that generally the east-west resistivities are higher than the north-south values. This appears to be a reasonable result since the general geological strike in the Klamath Falls and Vale areas is not far from being north-south.

(7) Because of the sparsity of stations along the Siletz-Vale profile, we are unable to comment on the distribution of apparent resistivities along the profile. It appears reasonable that relatively low values are observed in the coastal region and in the Willamette Valley. The values observed

east of the Cascades are typical of values observed in mafic Tertiary volcanics (Bodvarsson, 1950).

(8) We conclude that, in spite of obvious shortcomings, our preliminary results indicate that the telluric method applied has a potential of becoming a reconnaissance tool of significant interest in the exploration for geothermal resources.

## Acknowledgments

This work was supported by the National Science Foundation under Grant GA-25896. We are also indebted to the Boeing Company, Seattle, WA; Weyerhauser Company, Tacoma, WA; Pacific Power and Light Company, Portland, OR; and the Oregon Department of Geology and Mineral Industries, Portland, OR, under Bureau of Mines grant SO 122129, for partial support of our work. N. V. Peterson, Oregon Department of Geology and Mineral Industries, provided valuable guidance in selecting field stations.

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"Potential hazards from future eruptions of Mount Rainier, Washington," by Dwight R. Crandell is a map with descriptive text that shows by color and pattern the distribution of mudflows and tephra (airborne volcanic debris) and the varying degrees of risk to human life in those areas in the event of a volcanic eruption. The map, at a scale of 1:125,000, and text are on a single sheet designated as Miscellaneous Geologic Investigations Map I-836. The publication is for sale by the U.S. Geological Survey Distribution Section, Federal Center, Denver, Colorado, 80225 for 75 cents.

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## PROSPECTING WORKSHOP OFFERED

Clackamas Community College is sponsoring a Prospecting Workshop in Room B-104 on the evening of August 23 at 7:00 p.m. An all-day field trip will be held on August 24 in the Quartzville area. Both the lecture and field trip will be led by Jerry Gray of the Department staff. Tuition for the workshop is $12.00 and pre-registration is recommended. Additional information may be obtained by calling 656-2631, ext. 311.

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## FIRST VOLUME OF OREGON LAKES INVENTORY PRINTED

"Lakes of Oregon, Volume 1, Clatsop, Columbia, and Tillamook Counties" by R. B. Sanderson, M. V. Shulters, and D. A. Curtiss, has been issued as an open-file report by the U.S. Geological Survey in cooperation with the Oregon State Engineer. The 95-page, bound booklet describes 33 lakes in the three counties. Each lake is briefly described as to location, size, use, water temperature, and other pertinent characteristics, and is illustrated with an aerial photograph and a map showing shape and depth. Volume 1 is the beginning of a much-needed inventory of Oregon Lakes that will be a very useful reference. The volume is printed in limited supply. Information concerning its availability can be obtained from the U.S. Geological Survey Water Resources Division in Portland or from the Oregon State Engineer's office in Salem.

* * * * *

## JOHN ALLEN RETIRES FROM PORTLAND STATE UNIVERSITY

Dr. John Eliot Allen has retired from the faculty of Portland State University after 17 years as head of the Earth Sciences Department and a long career that had considerable influence on geological education and research.

Dr. Allen had stepped down as chairman and head of the Earth Sciences Department at PSU last year, continuing to teach during the recently ended school year. He has a long list of publications both in the scientific journals and in materials written for the layman. He received his bachelor and master's degrees from the U of O and his doctorate from the University of California, Berkeley. Between 1939 and 1944 he was a geologist with Oregon Department of Geology and Mineral Industries. He is succeeded as head of the Department by Dr. Richard E. Thoms, who joined the Earth Sciences Department staff in 1964.

* * * * *

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# SOME IMPLICATIONS OF LATE CENOZOIC VOLCANISM TO GEOTHERMAL POTENTIAL IN THE HIGH LAVA PLAINS OF SOUTH-CENTRAL OREGON

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## Introduction

Stratigraphic and volcanologic data obtained during reconnaissance mapping along the Brothers fault zone in the High Lava Plains of south-central Oregon (Walker and others, 1967; Greene and others, 1972) suggest a progressive decrease in age of eruption of silicic magmas from the Harney Basin westward to Newberry Volcano and possibly beyond into the Cascade Range. South of the Brothers fault zone, a separate less well defined, parallel zone of silicic domes and flows extends westward from Beatys Butte; this zone also appears to show a decrease in age westward, although the time span apparently is shorter and the age decrease not as well documented. The apparent age progression and the obviously very young age and character of some of the silicic volcanic rocks at the western end of the zone are important in geologic evaluations of the geothermal potential of eastern Oregon. They suggest that igneous heat sources sufficiently young to have retained significant magmatic heat are most likely to occur at the western end of the zone.

Geothermal energy associated with silicic volcanism is being explored or developed in several parts of the world (White, 1965; Muffler and White, 1972; Grose, 1972). In areas of known geothermal potential, such as New Zealand, Italy, Japan, and in North America at Yellowstone, the Jemez Mountains (New Mexico), and probably The Geysers area of California, the age of silicic volcanism is very young, mostly less than a million years and commonly only a few tens or hundreds of thousands of years old, and the volume of silicic volcanism generally is large, in many places measured in terms of many cubic kilometers of magma. Because some domal masses at the west end of the Brothers fault zone are very young and some of the silicic volcanism along the zone was volumetrically large, the potential for magmatic heat sources seems promising.

To test the concept of an age progression in and along the Brothers fault zone, as determined from field geologic evidence, and to establish the absolute ages of some of the silicic volcanic rocks in and near this zone, several potassium-argon ages have been determined on crystalline phases from rhyolitic, rhyodacitic, and dacitic domes and associated flows, on rhyolitic obsidian from chilled selvages on several domes and flows, and on crystals and glass from basal vitrophyre of small- and large-volume ash-flow tuffs erupted from centers spatially and probably genetically related to the Brothers fault zone.

## General Geology

The area from Harney Basin westward to Newberry Volcano, entirely within the High Lava Plains province of Dicken (1950), consists of a middle and upper Cenozoic volcanic upland nearly 260 km long and several tens of kilometers wide. The principal structural feature is a west-northwest-trending zone of en echelon normal faults (Figure 1), informally called the Brothers fault zone. Eruptive centers for both basaltic and rhyolitic volcanic rocks are concentrated in this zone of faults and in nearby subsidiary fault and fracture zones.

Except for small areas of older Cenozoic volcanic and tuffaceous sedimentary rocks locally exposed along the northern margin of the High Lava Plains that represent parts of the Columbia River Group and the John Day and Clarno Formations (Walker and others, 1967), the oldest rocks are small silicic domal masses of either late Miocene or early Pliocene age near the eastern margin of the province and nonporphyritic olivine basalt and andesite flows of late Miocene, or more likely early Pliocene age, exposed along the southern and southeastern margin of the province.

Both the domes and flows are partly buried by widespread sheets of ash-flow tuffs of early and middle Pliocene age; in a few places the ash-flow tuffs and olivine basalt flows appear to be interbedded. Several isotopic ages of the earliest ash-flow tuff in this sequence indicate that it was erupted about 9 m.y. ago. It spread laterally over thousands of square kilometers of the ancestral Harney Basin and adjacent parts of the High Lava Plains, the Blue Mountains, and the Basin and Range provinces. Somewhat younger (≈6-7 m.y.) large-volume ash-flow tuffs also are present in this region (Walker, 1970; Greene and others, 1972). Eruption of tremendous volumes of rhyolitic ash and ash flows apparently permitted some crustal collapse into the evacuated magma chambers. This collapse was partly responsible for the development of the large structural depression of Harney Basin, the probable source area of the ash-flow tuffs. Lower parts of the depression were subsequently filled with younger ash-flow tuffs, tuffaceous sedimentary rocks, and local basalt flows and basaltic vent complexes, all of late Cenozoic age (Piper and others, 1939; Greene and others, 1972).

In the western part of the High Lava Plains province, middle and upper Cenozoic basalt flows, ash-flow tuffs, silicic domal masses and sedimentary

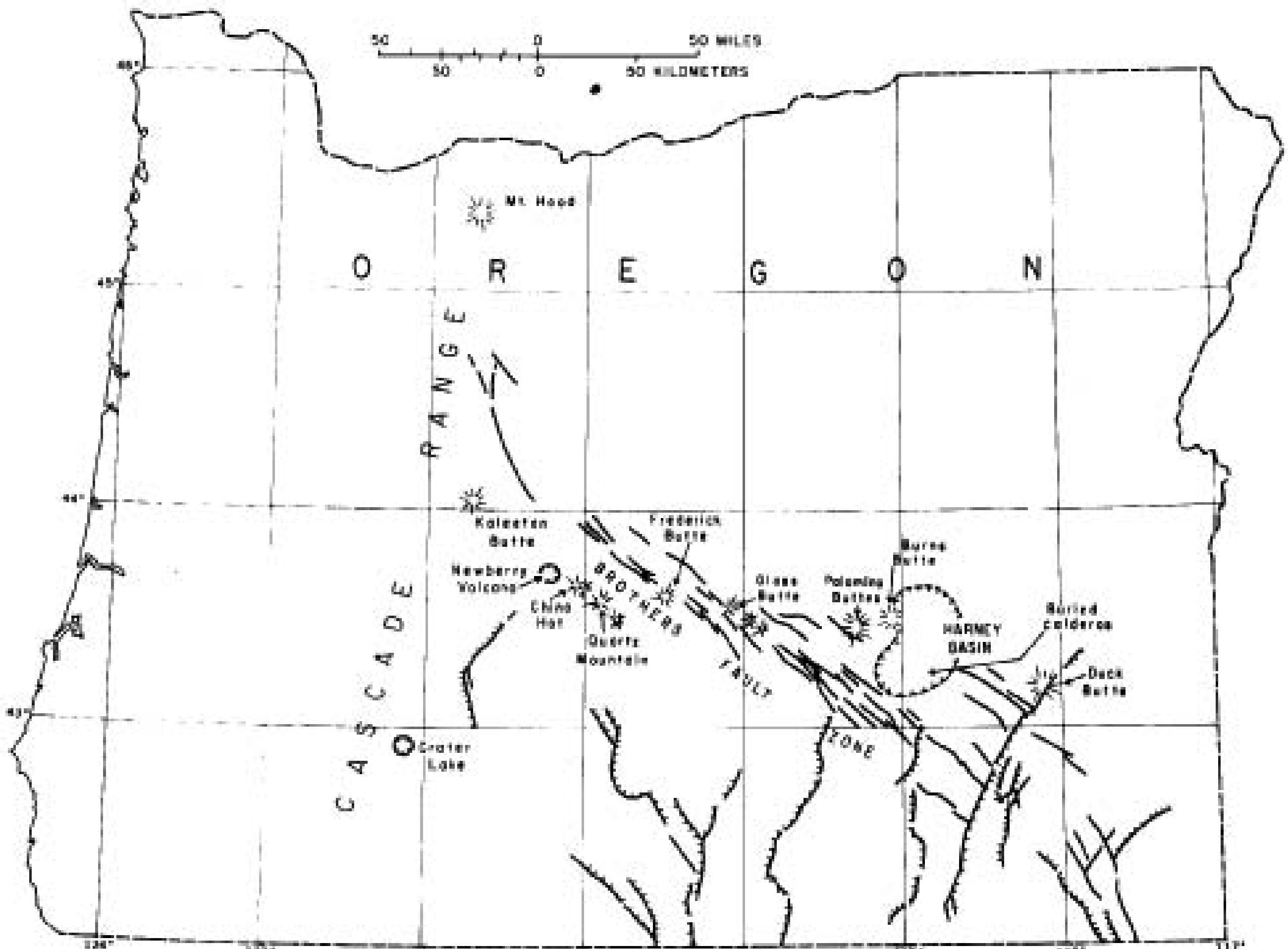


Figure 1. Index map showing some major structural elements and location of some silicic domes and vents.

Table 1. Potassium-argon dates of silicic volcanic rocks from vents in or near the Brothers fault zone*

| Map No. | Sample No. | Latitude (north) | Longitude (west) | Geologic unit | Rock type | Material dated | $K_2O$ Wt. % | $^{40}Ar$ rad ($10^{-11}$ mol/gm) | % $^{40}Ar$ rad | Calculated age ($10^6$ years) | Ref. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | RCG 281-1-67 | 43°12.2' | 118°07.5' | | Rhyodacite | Biotite<br>Plagioclase | 7.68 7.82<br>0.754 0.754 | 11.52<br>1.066 | 31<br>32 | 10.0±0.4<br>9.6±0.6 | 1 | Duck Butte |
| 2 | RCG 248-66 | 43°45.5' | 118°59.9' | Welded tuff of Devine Canyon | Ash-flow tuff | Sanidine | 7.10 7.14 | 9.710 | 15 | 9.2±0.50 | 1,2 | |
| 3 | RCG 54-5-66 | 43°30.8' | 119°08.3' | | Rhyodacite | Plagioclase | 1.147 1.163 | 1.338 | 59 | 7.82±0.26 | 1,2 | Burns Butte |
| 4 | YU-DP-119 | 43°14.3' | 119°13.5' | | Rhyolite | Rhyolite | 4.55(2) | 5.555(2) | 47-59 | 8.2±0.12 | 3 | |
| 5 | GWW-176-62 | 43°00.6' | 118°38.1' | Welded tuff of Devine Canyon | Ash-flow tuff | Alkali feldspar | 7.15 | 8.976 | 61 | 8.5±0.3 | | |
| 6 | YU-DP-243 | 43°04.9' | 119°03.8' | | Ash-flow tuff | Sanidine | 7.86(2) | 8.214(2) | 55-59 | 7.1±1.0 | 3 | |
| 7 | YU-DP-146 | 43°13.5' | 119°21.2' | | Rhyolite | Rhyolite | 5.13(2) | 6.38(2) | 4-5 | 8.4±1.3 | 3 | |
| 8 | YU-DP-316-D | 43°17.0' | 119°18.8' | | Rhyolite | Rhyolite | 4.92(2) | 5.713 | 16 | 7.8±0.5 | 3 | |
| 9 | YU-DP-311-E | 43°09.0' | 119°22.4' | Prater Creek Member of Parker and Armstrong (1972, p.7) of Danforth Fm. | Welded tuff | Tuff | 4.51(2) | 5.912(2) | 8-4 | 8.6±0.2 | 3 | |
| 10 | YU-DP-311-G | 43°09.0' | 119°22.4' | Rattlesnake Fm. | Welded tuff | Tuff | 4.93(2) | 4.852(2) | 21-26 | 6.6±0.2 | 3 | |
| 11 | YU-DP-330 | 43°09.0' | 119°22.4' | Rattlesnake Fm. | Welded tuff | Tuff | 4.87(2) | 4.797(2) | 10-11 | 6.7±0.4 | 3 | |
| 12 | RCG 257-3-66 | 43°37.7' | 119°04.2' | Welded tuff of Double O Ranch | Ash-flow tuff | Anorthoclase | 4.93 4.93 | 4.978 | 31 | 6.82±0.33 | 1,2 | |
| 13 | RCG 121-66 | 43°47.2' | 119°18.9' | Welded tuff of Double O Ranch | Ash-flow tuff | Anorthoclase | 4.64 4.66 | 3.713 | 60 | 5.40±0.20 | 1,2 | |
| 14 | YU-DP-214 | 43°30.3' | 119°18.0' | | Rhyolite | Rhyolite<br>Biotite | 4.89(2)<br>8.31(2) | 4.047<br>7.831 | 16<br>35 | 5.6±0.4<br>6.4±0.2 | 3 | About same unit as PB-2-70 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | Pb-2-70 | 43°28.8' | 119°18.0' | | Rhyolite or rhyodacite | (Biotite<br>(Plagioclase | 8.26<br>1.27 | 8.28<br>1.27 | 7.434<br>1.227 | 53<br>31 | $6.1 \pm 0.2$<br>$6.5 \pm 0.3$ | 1<br>1 | Dome, Palomino Buttes |
| 16 | GWW-16-65 | 43°41.7' | 119°54.1' | Welded tuff of Devine Canyon | Ash-flow tuff | Alkali feldspar | 6.65 | 6.65 | 9.306 | 75 | $9.45 \pm 0.21$ | 1,2 | |
| 17 | RCG 61-1-65 | 43°48.1' | 120°01.2' | | Ash-flow tuff | Alkali feldspar | 6.75 | 6.77 | 9.298 | 92 | $9.29 \pm 0.23$ | 1,2 | |
| 18 | RCG 106-1-65 | 43°48' | 120°00.6' | | Ash-flow tuff | Alkali feldspar | 6.70 | 6.91 | 9.252 | 88 | $9.05 \pm 0.28$ | 1,2 | |
| 19 | GWW-140-61 | 42°35.6' | 119°16.5' | Welded tuff of Devine Canyon | Ash-flow tuff<br>Ash-flow tuff | Alkali feldspar<br>Glass | 6.67<br>5.32 | | 9.872<br>7.160 | 56<br>36 | $10.0 \pm 0.3$<br>$9.1 \pm 0.3$ | 1,2<br>1,2 | |
| 20 | MO-73-33 | 43°32.2' | 110°01.3' | | Selvage on flow? | Obsidian | 4.15 | 4.21 | 3.038 | 17 | $4.9 \pm 0.3$ | 1 | |
| 21 | FB-1-70 | 43°37.5' | 120°27.6' | | Rhyodacite | Plagioclase | | 0.377(2) | 0.219 | 13 | $3.9 \pm 0.4$ | 1 | Dome, Frederick Butte |
| 22 | GWW-121-64 | 43°47.8' | 120°22.8' | | Ash-flow tuff | (Plagioclase<br>( | 0.62 | 0.63 | 0.335 | 59 | $3.6 \pm 0.6$)<br>) | 1,4 | |
| 23 | M3-33 | 43°31.8' | 120°46.8' | | | (Glass | 3.63 | 3.67 | 1.93 | 71 | $3.6 \pm 0.2$) | | |
| | | | | | Selvage on flow | Obsidian | 3.98 | | 2.116 | 54 | $3.6 \pm 0.1$ | 1 | Squaw Ridge |
| 24 | MO-73-31 | 43°37.2' | 120°53.1' | | Selvage on flow | Obsidian | 3.83 | 3.84 | 0.627 | 36 | $1.1 \pm 0.05$ | 1 | Quartz Mtn. |
| 25 | MO-73-29 | 43°40.1' | 120°59.5' | | | Obsidian | 3.84 | | 0.482 | 23 | $0.85 \pm 0.04$ | 1 | East Butte |
| 26 | M3-53 | 43°41.3' | 121°02.0' | | | Obsidian | 3.80 | | 0.428 | 7 | $0.76 \pm 0.1$ | 1 | China Hat |

* For additional dates on these and related units also see:
Dalrymple, G. B., Cox, Allan, Doell, R. R., and Gronmé, C. S., 1967
Evernden, J. F., Savage, D. E., Curtis, G. H., and James, G. T., 1964

References:
1. U.S. Geological Survey, unpub. data
2. Greene, R. C., and others, 1972
3. Parker, Donald and Armstrong, R. L., 1972
4. Walker, G. W., 1970

rocks are mostly buried beneath basalt flows of late Pliocene, Pleistocene, and Holocene age (Williams, 1957; Oregon Dept. Geology and Mineral Industries, 1965; Walker and others, 1967) that erupted nonexplosively from widely scattered cones, shield volcanoes, and fissures.

## Progressive Age of Volcanism

Several lines of evidence indicate a progressive, somewhat sporadic, decrease in the age of both basaltic and rhyolitic volcanism from Harney Basin westward to Newberry Volcano and beyond into the Cascade Range; although this progression is broadly defined by the geographic distribution of volcanic units of different ages, it is more precisely manifested by silicic volcanic activity and the isotopic ages of the resultant domes, flows, and ash-flow tuffs.

In the eastern part of Harney Basin, at Duck Butte, and elsewhere, large domal masses of rhyodacite are closely related structurally and stratigraphically to the Steens Basalt. In places the domes appear to be lapped by these middle(?) and late Miocene basalt flows, and in other places they penetrate the flows. Potassium argon-dates (sample 1*) on plagioclase and biotite from Duck Butte rhyodacite indicate an age of about 10 m.y., or, in the time scale of Evernden and others (1964), an earliest Pliocene (Clarendonian) age.

No rhyolitic rocks are exposed in the broad, sedimented expanse of central Harney Basin, but domal masses and flows of rhyodacite that yielded a date of $7.8 \pm 0.26$ m.y. (sample 3) form part of Burns Butte on the northwest edge of the central lower basin, and silicic domes and flows west of Harney Lake near Double O Ranch were dated at about 8 m.y. (sample 8) by Parker and Armstrong (1972). Also, very large volume ash-flow tuffs, ranging in age from about 10 m.y. (samples 2, 4, 16, 19) to less than 6 m.y. (samples 6, 10, 11, 12, 13) were erupted from vents buried beneath the sedimentary veneer of the central part of the basin.

One of the oldest of these ash-flow tuffs, informally called welded tuff of Devine Canyon (Greene and others, 1972) and equivalent to the crystal-rich basal member of the Drewsey Formation of Bowen and others (1963), covers thousands of square kilometers mostly north, south, and east of Harney Basin. It erupted from a buried caldera apparently located in the north-central to northwest part of the basin. The domal masses at Burns Butte and those west of Harney Lake are lapped by a pumiceous ash-flow tuff, informally called welded tuff of Double O Ranch by Greene and others (1972) and mapped as part of the Danforth Formation by Piper and others (1939); it also is equivalent to a welded tuff in the Rattlesnake Formation (Brown and Thayer, 1966; Enlows and others, 1973). This large-volume pumiceous tuff (Walker, 1970) is traceable over thousands of square kilometers of southeast and south-central Oregon mostly north, south, and west

*All sample numbers refer to those listed in Table 1 and shown on Figure 2.

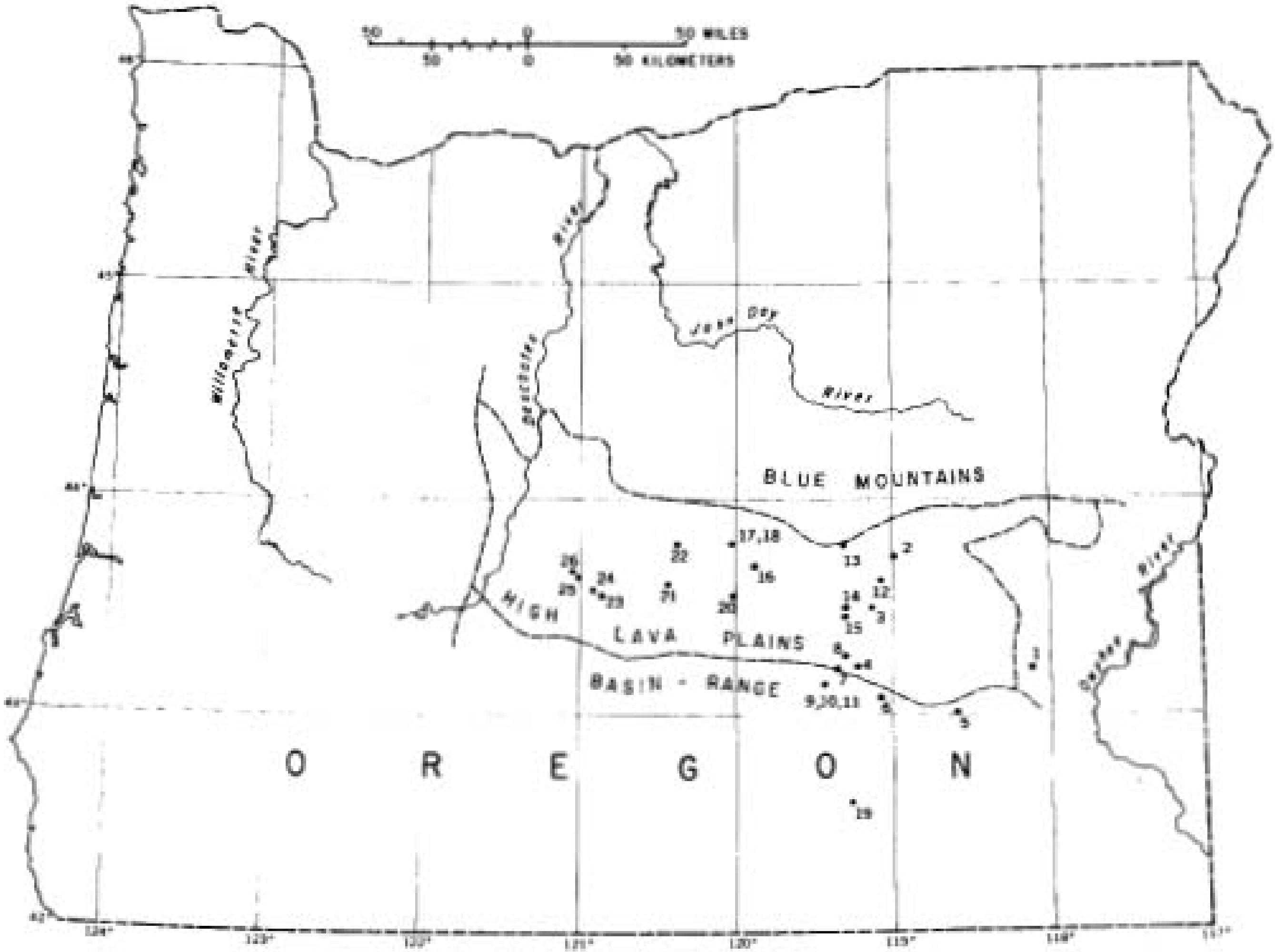


Figure 2. Index to sample localities.

of Harney Basin. It was erupted from a vent or vents apparently in the south-central part of Harney Basin, whose precise position and character is obscured by younger volcanic and volcaniclastic deposits.

Several potassium-argon dates on silicic domal masses at Palomino Buttes, near the western margin of Harney Basin, indicate an age of slightly more than 6 m.y. (samples 14 and 15). One potassium-argon age on obsidian from outcrops a few kilometers east of the summit of Glass Butte is 4.9 m.y. (sample 20), and another on plagioclase from rhyodacite at Frederick Butte, about 32 km west of Glass Butte, is 3.9 m.y. (sample 21). A thin and moderately widespread ash-flow tuff exposed in the area between Hampton Buttes and Grassy Butte that is unrelated to any known vent (but appears to have erupted from a center near Frederick Butte) is 3.6 m.y. old (sample 22), as determined both on plagioclase and glass separates from the basal vitrophyre. Obsidian from flows related to the exogenous domes at Squaw Ridge is 3.6 m.y. old (sample 23). Obsidian from chilled selvages of massive rhyolite flows exposed on Quartz Mountain, about 35 km west of Frederick Butte, has been dated at 1.1 m.y. (sample 24). The glassy domes and related flows at East Butte and China Hat appear even younger than those at Quartz Mountain on the basis of their volcanic constructional physiographic form and lack of erosion. One potassium-argon age on obsidian from East Butte is $0.85 \pm 0.04$ m.y. (sample 25), and another from obsidian on China Hat is $0.76 \pm 0.1$ (sample 26).

Newberry Volcano, which is centered about 20 to 30 km west of Quartz Mountain and only about 15 km west of China Hat, is characterized by extensive silicic and basaltic rocks of middle and late Quaternary age. Ash-flow tuffs in the walls of Newberry Volcano, the obviously very young "Big Obsidian Flow" in the floor of the volcano, and the surficial pumice and ash-fall deposits, some of which have been dated at $1720 \pm 250$ years by carbon-14 methods (see Higgins, 1969), all attest to very recent silicic volcanism in that area. Silicic flows and domes on the southeast flanks of Kaleetan Butte, just south of the South Sister in the Cascade Range, exhibit surficial features that indicate they can be no more than a few hundred or, at most, a few thousand years old. Whether they are related in any way to the silicic volcanism in and along the Brothers fault zone is unknown, but they do occur approximately in line with other young silicic masses along the Brothers fault zone; they also are, of course, generally in line with the trend of the Cascade Range.

## Volumes of Silicic Magma

Only the roughest qualitative estimates are possible on the volumes of silicic magmas involved in the Pliocene and younger ash-flow tuffs and domes erupted from vents spatially associated with the Brothers fault zone. Several of the ash-flow tuffs of early and middle Pliocene age, generally referred formally to either the Danforth or Drewsey Formations or informally to welded tuffs of Devine Canyon or Double O Ranch, represent volumes of hundreds of cubic kilometers of magma (Walker, 1970; Greene, 1972). Collectively, the early and middle Pliocene domes must represent an additional several tens of cubic kilometers of magma, mostly in exogenous bodies peripheral to the low central part of Harney Basin. The Quaternary silicic volcanic rocks near the western end of the Brothers fault zone are of much smaller volume, the ash-flow tuffs and domes combined probably totaling less than 100 $km^3$. The volume of Quaternary silicic rocks is particularly difficult to evaluate because the widespread young basalt flows inundated all but the most prominent domal or erosional masses.

## Summary

The implications of this extensive silicic volcanism and the apparent age progression from early Pliocene to very recent activity near Newberry Volcano are only now being evaluated. The age of silicic volcanism, as well as associated basaltic activity, at the western end of this zone is comparable to that found in several areas presently yielding or capable of yielding geothermal energy. However, the volume of silicic magma involved apparently is smaller at the western end of the zone than that found in favorable areas elsewhere. At the eastern end of this zone, where the volumes of silicic magma erupted to the surface were very large, the early and middle Pliocene age may be so old for the volume of magma originally involved that cooling to near ambient temperatures may have occurred; such temperatures would be lower than those that characterize commercial geothermal fields. Furthermore, although the age progression seems reasonably well established, there is presently no obvious way to predict where the next eruption of silicic magma will occur or where, along this zone, unvented silicic magma might be located relatively high in the crust. Certainly the Brothers fault zone and adjacent areas deserve further study as an area with some as yet poorly defined potential for geothermal energy.

Geologically, this apparent age progression may relate to sporadic differential movement along some deeply buried northwest-trending structural element related to movement of crustal plates that is also the underlying cause of the Brothers fault zone. Although it is tempting to relate the progressive age change to plate movement over a "hot spot" such as postulated by Dalrymple and others (1973) for Hawaiian volcanoes, the direction of age decrease appears incorrect.

## Acknowledgments

I am indebted to U.S. Geological Survey colleagues who provided several kinds of data or support in obtaining potassium-argon ages. L. B. Schlocker provided potassium analyses and R. W. Kistler, Marvin Lanphere, J. C. Von Essen, and E. H. McKee made age determinations on both whole-rock samples and mineral separates, part of which they prepared.

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## RECENT GEOTHERMAL DEVELOPMENTS

Gulf Mineral Resources Company has delayed plans to drill a 6,000-foot geothermal test well near Meadow Lake, about 5 miles northeast of Klamath Falls, in sec. 19, T. 38 S., R. 10 E. A permit to drill the well was granted Gulf last year by the Department of Geology and Mineral Industries and Gulf negotiated a contract for Hunnicutt and Camp of Rio Vista, California to drill the well. But because the Oregon State Engineer requires that all geothermal wells be drilled by Oregon-licensed water-well drilling contractors, the drilling of this test has been postponed. The drilling contractor, Hunnicutt and Camp, has long experience in the drilling of geothermal wells, having drilled many in The Geysers field.

Magma Energy Corporation has filed applications with the Department of Geology and Mineral Industries to drill four 6,000-foot geothermal test wells, two southeast of Vale in sec. 28, T. 18 S., R. 45 E., and two southeast of LaGrande in sec. 9, T. 4 S., R. 39 E. Magma hopes to drill these wells within the next 30 to 60 days.

Republic Geothermal, Inc., Whittier, California, was declared high bidder on June 27 to lease 1,347 acres of national resource lands in the Vale KGRA (known geothermal resource area). Republic's bonus bid was $10.26 per acre or a total of $13,813.00. Three other bidders were Union Oil Co., offering $5.60 per acre; Magma Energy Corp., $5.55 per acre; and LVO Corp., $3.05 per acre. This land is adjacent to the block where Magma Energy plans to drill the two 6,000-foot test wells.

American Metals Climax Corp. (AMAX) announced the establishment of a regional geothermal exploration office in Portland. AMAX, an integrated metals mining, processing, and fabricating firm has recently taken steps to enter the energy field and has purchased geothermal leases in Oregon and other western States. The office in Portland will be headed by Dean Pilkington.

* * * * *

## THE TYEE-YAMHILL RELATIONSHIPS: A DISCUSSION

It is widely accepted that in the Oregon Coast Range the middle Eocene Tyee Formation (5,000 feet of turbidite sandstone derived largely from the Klamaths) grades northward into the Yamhill Formation (a predominately siltstone unit). In November 1973 Dr. Robert McWilliams of Miami University published an alternative interpretation in The ORE BIN, maintaining that the Yamhill Formation postdates the Tyee Formation. Controversy since that time has culminated in a rebuttal by Dr. Weldon Rau in this month's issue of The ORE BIN. It is in the precise exchange of ideas such as Rau's rebuttal and the accompanying reply by McWilliams that geologic knowledge undergoes the refinement needed to resolve conflicts.

### Stratigraphic and Biostratigraphic Relationships of the Tyee and Yamhill Formations: Comments

Weldon W. Rau
Olympic, Washington

A correlation of the lower part of the Yamhill Formation and the Tyee Formation has been generally accepted by Pacific Northwest geologists. McWilliams (1973) presents a contrary conclusion - that these two formations are definitely separated in time, that no part of one correlates with any part of the other. Although it is not my intent to present evidence to prove a correlation between the lower part of the Yamhill Formation and the Tyee Formation, I believe there is considerable reason to question the conclusion of McWilliams.

First, McWilliams pointed out that the fossil mollusks from the Yamhill Formation are regarded as late Eocene in age (Vokes in Baldwin and others, 1955), but failed to mention that Vokes clearly stated that the fauna probably indicated an early late Eocene age - in other words, a position in the lower part of the upper Eocene sequence. Furthermore, the fossils were from well above the base of the formation and so do not provide evidence on the age of the lower part. Baldwin and others (1955) pointed out further that middle Eocene mollusks known to occur in the Tyee Formation and upper Eocene mollusks known to occur in the Nestucca Formation are found together in the Yamhill Formation. Thus, the molluscan fauna of the Yamhill Formation appears to contain elements of both the middle and upper Eocene. I see no reason, therefore, on the basis of mollusks, to reject the possibility of partial correlation of the Yamhill and Tyee Formations, particularly since no molluscan faunas are reported from the lowermost part of the Yamhill Formation.

Second, foraminifera of the Yamhill Formation, specifically those occurring in the Mill Creek section, do not support McWilliams' conclusions. Contrary to the views of McWilliams, I agree with Stewart (1957) that many of the foraminiferal assemblages from that section are comparable to those of the Sacchi Beach beds, a lower part of the McIntosh Formation of Washington, and that they are reasonably close to the fauna of the Llajas Formation of California, which Laiming (1940) assigned to his B-1A zone. Furthermore, I interpret assemblages from the lower part of this section as representing an uppermost part of the Ulatisian Stage or lowermost part of the Narizian Stage of Mallory (1959), a conclusion supported by a number of other workers (for example, J. E. Eke, K. A. McDougall, R. E. Thoms, and Ann Tipton, written communications, 1974). This position within our Pacific Coast biostratigraphic framework is not greatly different from that usually assigned to the faunas of at least part of the Tyee Formation. In addition, even though I do not consider the fauna of the lower part of the Mill Creek section to be diagnostic specifically of either one or the other stage, I disagree with the conclusion of McWilliams that it definitely represents the Narizian Stage. That the upper part of the Yamhill Formation is younger than the Tyee Formation is not in dispute as it has been mapped this way by virtually all workers (for example, Snavely and others, 1972). However, biochronologic evidence certainly does not point to a "black or white" middle Eocene (Ulatisian)-upper Eocene (Narizian) difference in the age of the lower part of the Yamhill Formation and the upper part of the Tyee Formation.

Third, McWilliams places undue emphasis on the chronologic significance of individual species. For example, because both *Amphimorphina californica* and *Nodosaria latejugata* are now known to extend in places up into the Narizian Stage, he rules out a Ulatisian age in favor of Narizian for the entire fauna of the Yamhill Formation. Paleontology is far from an exact science. Its application to biostratigraphy makes use of many subtleties. The interpretation of biochronologic position is not a "cut and dried" procedure based on the presence or absence of individual species. The hope that a particular species will be found to be restricted to a consistent "biochronologic niche" is sooner or later shattered when it is found somewhere above or below its expected range. Chronologically dependable species are rare indeed. Therefore, to interpret the relative age of given assemblages, the paleontologist must not only evaluate the significance of each form, but must consider the *combination of diagnostic species* contained in each assemblage. McWilliams has overemphasized the significance of individual species without giving due attention to the total congregation. His paleontological evidence is thus presented as more definitive than it actually is.

Fourth, McWilliams has arbitrarily mapped other strata together with Yamhill strata so that the stratigraphic meaning of Yamhill is lost. His mapping ignores much of what others have mapped and defined as either the Tyee Formation, Yamhill Formation, Nestucca Formation, or Siletz River Volcanics. For example, on his map the contacts of the Yamhill Formation in its type locality differ markedly from the defined limits of this unit. A large part of his Yamhill Formation was mapped as the uppermost Eocene Nestucca Formation by Baldwin and others (1955), who defined the Yamhill Formation. It is no wonder then that McWilliams lists uppermost Eocene (upper Narizian) assemblages as occurring in his Yamhill Formation.

In summary, because McWilliams has overlooked certain important concepts of biochronology, overemphasized the importance of other paleontological data, and not followed certain principles of geologic mapping, his arguments are insufficient to warrant his outright rejection of earlier interpretations. In my opinion, a truly objective evaluation of all available data does not justify his conclusions "...that correlation or interfingering of the two formations...is not possible."

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## Reply to Comments

Robert G. McWilliams
Miami University, Hamilton, Ohio

Dr. Rau's first point correctly notes that Vokes interpreted the fossil mollusks of the lower Yamhill to be "of late Eocene age, probably early late Eocene."

However, Vokes reported only two positively identified species, Acila (Truncacila) decisa Conrad and Turritella uvasana Conrad stewarti Merriam. The first species ranges through the Eocene and the second is restricted to the upper Eocene. This limited data provides no clear basis for a refined determination of age within the upper Eocene. Baldwin and others (1955) noted that Venericardia hornii subsp. calafia Stewart and Cardiomya comstockensis Turner have been recorded previously only from the middle Eocene Tyee Formation. However, these species have not been recorded from the Yamhill Formation. Schenck identified Venericardia hornii cf. var. calafia Stewart and Vokes identified Cardiomya sp. aff. C. comstockensis Turner from the Yamhill. The locality of these fossils ("two-tenths of a mile south of the Sheridan quadrangle") is clearly upper Eocene because it was so interpreted by Vokes and also because my locality 20 (three-tenths of a mile south of the Sheridan quadrangle), which is stratigraphically lower, contains a definite Narizian assemblage. Locality 20 contains Amphimorphina becki Mallory, Cibicides natlandi var. olequahensis Beck and Plectofrondicularia sacatensis Hornaday which have been previously recorded only from the Narizian. This locality also contains Bulimina sculptilis var. lacinata Cushman and Parker and Robulus chiranus Cushman and Stone, which have not been reported previously below the Narizian. It also contains Amphimorphina ignota Cushman and Siefgus, Cibicides warreni Cushman, Stewart and Stewart, and Valvulineria jacksonensis var. welcomensis Mallory, which have not been reported from above the Narizian. These eight species have a time of joint occurrence restricted to the Narizian. The fossils of this locality, together with Narizian fossils of localities 22 through 33, indicate that all of the type Yamhill Formation which I sampled is Narizian, or upper Eocene.

Dr. Rau's second point is that the fauna of the lower Yamhill Formation is not diagnostic of either the Ulatisian or the Narizian Stages. He recognizes that the upper Yamhill is younger than Tyee Formation but sees no biochronologic evidence that points to a "black or white" distinction in age between the lower Yamhill and the upper Tyee Formation. My interpretation that the Yamhill is definitely Narizian is based on the age of the uppermost Siletz River Volcanics beneath the type Yamhill Formation. Samples from localities 18 and 19 (collected below a 6-inch thick basalt bed within the Siletz River Volcanics) contain Cibicides hodgei Cushman and Schenck, and Vaginulinopsis saundersi (Hanna and Hanna) which are not known from below the Narizian. The samples also contain Vaginulinopsis mexicana var. nudicosta Cushman and Hanna which is unknown above the Ulatisian. The joint occurrence of these and other species listed on Table 2 (McWilliams, 1973) indicates to me that localities 18 and 19 are located on the Ulatisian-Narizian boundary and therefore the overlying lower Yamhill Formation can be no older than Narizian. There is no exposure between locality 19 in the uppermost Siletz River and locality 20 in the lower Yamhill Formation. The thickness of this disputed portion of the lowermost Yamhill Formation is between 80 and 100 feet. My interpretation that the Yamhill is younger than the Tyee Formation is based on the fact that Tyee is not known to be younger than Ulatisian, and the fact that my map shows that Yamhill overlies Tyee Formation and that it does not interfinger with the Tyee. I believe Dr. Rau and I are in agreement about the upper Yamhill, and our differences are centered on the age and relationship of the lower 80 to 100 feet of Yamhill Formation.

Dr. Rau's third point is that paleontology is far from an exact science and that determination of biochronologic age is not based on only the presence or absence of individual species. However, as I have pointed out (McWilliams, 1973, p. 172) Stewart's (1957) designation of the Yamhill as B-1A was based on precisely the type of data to which Dr. Rau objects. Stewart based his conclusion on the occurrence of Amphimorphina californica Cushman and McMasters and Nodosaria latejugata Gümbel. Dr. Rau agrees that these species are now known to occur in the Narizian. Therefore, I conclude there is no longer any basis for designating the lower Yamhill Formation B-1A or Ulatisian. As I pointed out above, my designation of the lower Yamhill as Narizian was based on the recognition of the Ulatisian-Narizian boundary in the uppermost Siletz River Formation. I agree that paleontology is not an exact science. I believe, however, that it can become more exact by strict use of the Oppelian method of age determination which uses the time of joint occurrence of several species as outlined above in the discussion of point one.

Dr. Rau's fourth point is that my map arbitrarily groups portions of what others have called Tyee, Siletz River, and Nestucca Formations with the Yamhill so that the stratigraphic meaning of Yamhill Formation is lost. In particular, he notes that I have grouped what Baldwin and others (1955) defined as Yamhill with what they mapped as Nestucca Formation. All of my mapping was based on purely lithic criteria. I have explained the basis for distinguishing Yamhill and Tyee Formations (McWilliams, 1973, p. 170). The primary lithic distinction I used to differentiate the underlying Siletz River from the Yamhill Formation is the presence of basalt volcanics in the former and its absence in the Yamhill Formation. The contact between the Yamhill and the overlying Nestucca Formation was drawn at the base of the basalt flows. There is no lithic change where the contact was drawn by Baldwin and others (1955). The case cited by Dr. Rau involves the uppermost Yamhill, which he agrees is younger than Tyee. In general, I believe that my map refines the stratigraphic meaning of the Yamhill since it shows what I consider to be Yamhill over a wider and more continuous area than has ever been mapped before.

In conclusion, I would like to add that my work has been an attempt to build on previous work. I regard the work of other geologists who have studied this area to be of high quality. It is primarily because more is now known than was then about the stratigraphic range of certain fossils that I have questioned the conclusions of earlier workers. Dr. Rau has done a service in examining my conclusions objectively. I will be pleased to communicate directly with others who disagree with or have questions about my conclusions.

## References

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

McWilliams, R. G., 1973, Stratigraphic and biostratigraphic relationships of the Tyee and Yamhill Formations in central-western Oregon: Ore Bin, v. 35, no. 11, p. 169-186.

Stewart, R. E., 1957, Stratigraphic implications of some Cenozoic foraminifera from western Oregon: Ore Bin, v. 19, no. 2, p. 11-15.

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## LLOYD STAPLES RETIRES FROM U. OF O.

Lloyd W. Staples, new professor emeritus, retired from the Department of Geology at the University of Oregon on June 30. In 1939 he became an instructor of geology at the University and served as head of the Department from 1958 until 1968, when he took leave to do consulting work in Europe and Iraq. Over the years, he has made news by his discoveries of new, undescribed minerals, two of which he found in Oregon. He has written extensively on rocks and minerals in Oregon and elsewhere and is widely known for his definitive study of thundereggs, Oregon's State Rock, that was published in the October 1965 The ORE BIN and reprinted many times by popular request. Staples plans to travel, look for more interesting minerals, and do research on many unsolved geological problems.

Sam Boggs, Jr., Associate Professor in the Department of Geology at U. of O., will be that Department's new Chairman beginning August 1. He will replace William T. Holser, who has served as Department Chairman for the past three years.

* * * * *

## LAND USE PLANNING BILL SIDETRACKED

The House of Representatives, by a vote of 204-211 on June 11, rejected a resolution that would have cleared for floor consideration H.R. 10294, the "Land Use Planning Act." It appears that no attempt will be made to revive this legislation during the 93rd Congress.

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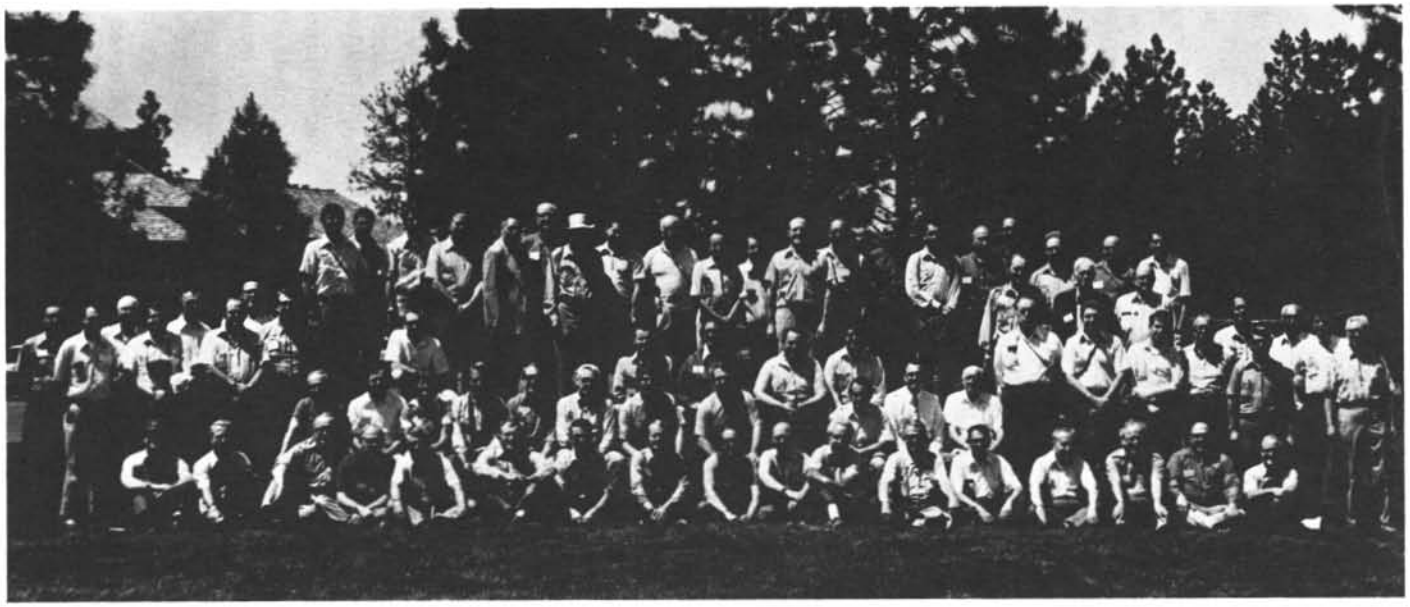

The Association of American State Geologists held its annual conference this year at Bend, Oregon, June 9 through 13, with more than 80 participating. Heads of State Geological Surveys came from nearly every state in the Union. Members of the U.S. Geological Survey, U.S. Bureau of Mines, A.E.C., and a number of other Federal agencies and professional geological organizations also attended the meetings. The 3-day conference was devoted to business and the exchange of ideas, during which time energy research, environmental problems, Federal ownership of lands, outer continental shelf exploration were some of the topics discussed. Conference sessions were broken by two field trips to see volcanic features of the area - Lava Butte and Lava River Cave. The conference ended with a banquet, at which time each visitor received a thunderegg, Oregon's State Rock, to take home.

## RECENT DEVELOPMENTS IN ENERGY FIELD

The U.S. Department of Commerce has established a panel of experts in the energy field. It is a subgroup of the Commerce Technical Advisory Board (CTAB). Although its membership is not complete, the panel held its first meeting July 10.

Briefly, the objectives and duties of this new panel will be to "...provide an independent assessment of the feasibility of the actions and policies resulting from the Project Independence Blueprint. The panel will represent a central input of private sector views concerning governmental policy decisions designed to expand the domestic supply of energy sources of the United States." Further, the panel will provide advice and information with respect to the following questions:

What is the realistic capacity for expansion of domestic energy resources within a given time frame?
What are the constraints which must be overcome to achieve this expansion?
What are the costs of expanding domestic energy resources, in terms of capital, materials, and manpower?
What are the social and environmental implications of such an expansion?

On July 10, the newly appointed head of the Federal Energy Administration, John Sawhill, following his swearing-in ceremonies at the White House, held a briefing session for high-level Administration officials on the existing and projected energy picture. Later that day Sawhill and other FEA officials held a briefing session on Project Independence for the Project Independence Advisory Committee. Mr. Sawhill declared: "The need for Project Independence at this time cannot be stressed strongly enough. Our demand has been growing rapidly while energy production for many fuels has leveled off or declined. The Middle East oil embargo alerted the nation to the risks of extensive foreign energy dependence. Although the embargo was imposed at a time when we were able to manage the shortage, a future supply disruption could have much more serious economic and social impacts. The Project Independence Blueprint will evaluate the growing dependence of the United States on foreign sources of energy, future supply and demand alternatives, and will develop positive programs to reduce our vulnerability to future oil cut-offs and price increases."

For a copy of Sawhill's briefing paper, write to the American Mining Congress, Ring Building, Washington, D.C. 20036.

(American Mining Congress News Bulletin No. 74-14)

* * * * *

## GEOTHERMAL RESEARCH ON INCREASE

Growing interest in utilization of natural geothermal resources to help meet the nation's energy needs is stimulating geothermal research and increasing the demand for this kind of information. In last month's The ORE BIN (June), the Department published "Telluric Current Exploration for Geothermal Anomalies in Oregon" by workers at Oregon State University. In this month's issue is a report on the relation of geothermal potential in south-central Oregon to progressive ages of late Cenozoic volcanism. The following recently completed theses were received by this Department's library:

Res Wai-Yuen Tang: Geothermal exploration by telluric currents in the Klamath Falls area, Oregon: OSU Dept. of Oceanography master's thesis, 86 p., 29 figs., 6 tables, June 1974.

Talal Hussein Hassoun: Optimization of single- and double-flash cycles and space heating systems in geothermal engineering: PSU Dept. of Geology master's thesis, 1974.

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## MINED LAND RECLAMATION STATISTICS RELEASED

A newly released information circular of the Bureau of Mines shows that between 1930 and 1971, the mining industry only used .16 of 1% of the surface area of the United States, and of that amount about 40% has been reclaimed.

The 61-page circular, entitled "Land Utilization and Reclamation in the Mining Industry, 1930-71," contains numerous tables and charts depicting, by State and commodity group (i.e., "metals," and "fossil fuels") the amount of land used by each and the amount of land reclaimed. The report states that growing public interest in the reclamation of surface-mined land has led to proposals for "legislation and regulation, sometimes based on seriously inadequate information" and says that the report grew out of the need for adequate data.

The report is available from the Superintendent of Documents at the Government Printing Office for $1.05 per copy.

* * * * *

## SCENIC PLACES IN CASCADE RANGE

A few copies of "Some little-known scenic pleasure places in the Cascade Range in Oregon" by Ira A. Williams, published in 1916 by Oregon Bureau of Mines and Geology, are available. The 114-page booklet contains 60 photos, several in color. For sale in Portland office only for $2.00.

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The ORE BIN
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August 1974

# OIL SHALE

Vernon C. Newton, Jr.* and Paul F. Lawson**

The United States has enormous deposits of oil shale which, if developed, could provide energy resources for centuries (Figure 1). Because of the vast size of these deposits, they are currently receiving a great deal of attention.

This issue of The ORE BIN is devoted to a discussion of oil shale -- what it is, how it formed, its distribution, methods of extracting the oil, economics of the industry, and the environmental impact of processing the shale.

## What is Oil Shale?

Oil shale is a dark, organic, thin-bedded sedimentary rock. The source of the oil is kerogen, a mineraloid of indefinite composition consisting of fossilized organic material which was trapped in fine-grained bottom sediments during deposition in ocean and lake basins. Oil shale is also called "kerogen shale." Kerogen is insoluble in petroleum solvents and does not break down into oil until heated to more than 662°F.

Any organic shale that yields 10 gallons or more of oil per ton by distillation under low pressure is considered oil shale by the industry (Duncan and Swanson, 1965). Oil shale yielding 10 to 15 gallons per ton of oil is considered low grade; that yielding 25 to 100 gallons per ton makes up the high-grade deposits.

Oil shale is neither petroleum nor coal but an intermediate material. All three have similar origins, but the processes that formed them are complex. The existence of a chemical reducing or oxidizing environment during deposition of organic matter, the type of organic material, and the minerals present in rocks determines whether petroleum, coal, or kerogen will be formed (Levorsen, 1954).

It is believed that petroleum hydrocarbons form fairly soon after the sediments are deposited, whereas kerogen and coal represent residual organic

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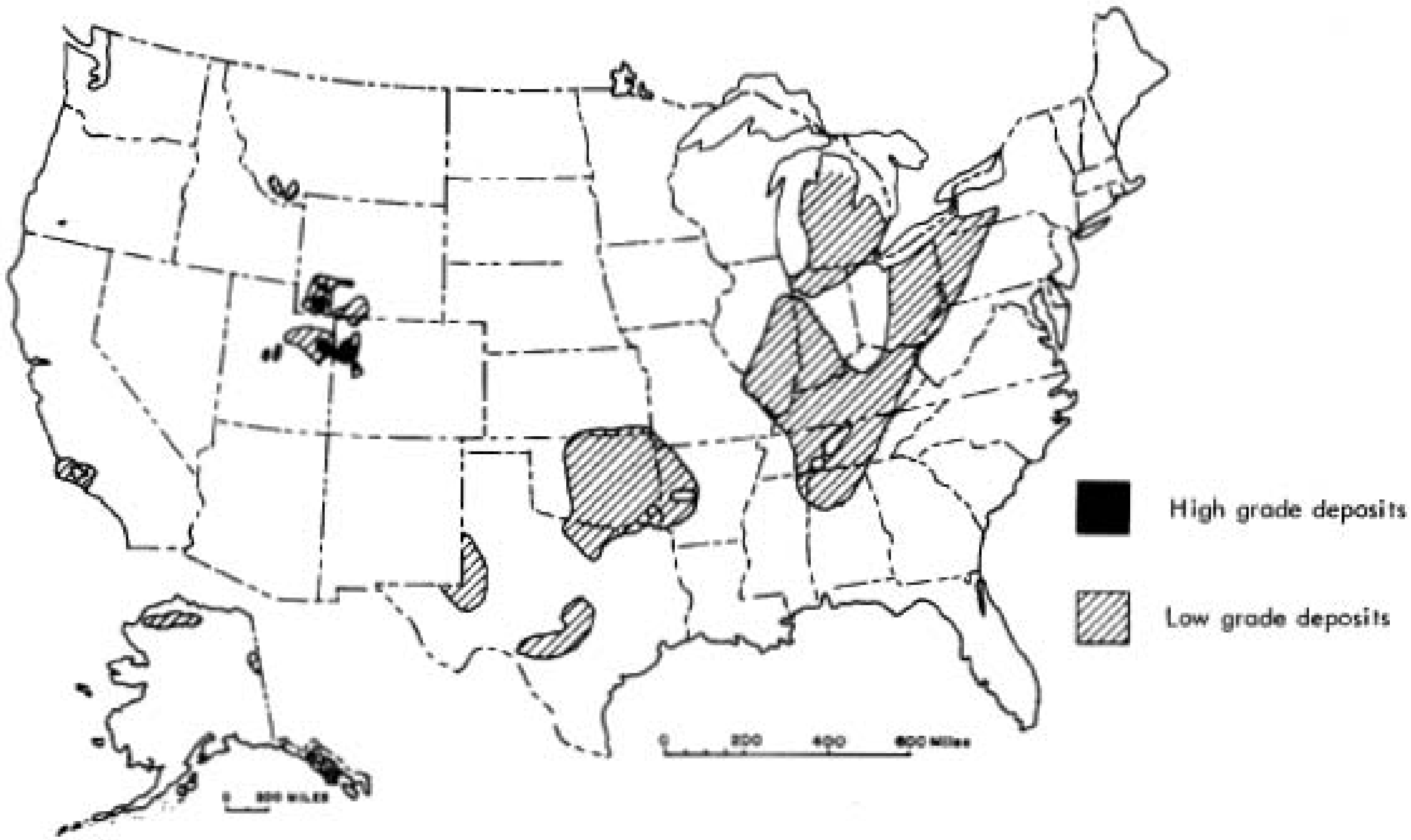


Figure 1. Principal oil-shale deposits in the United States (from Duncan and Swanson, 1965)

matter in the sediments. Kerogen and cannel coal are formed from sapropelic material (organic ooze consisting of bacterially decomposed microorganisms and plant remains); bituminous and anthracite coals are formed mainly from humic material.

These three hydrocarbon products are commonly associated. For example, oil and tar are often found in cracks and openings in oil shale; coal seams may be interbedded with oil shale. In many places, oil shale grades into cannel coal.

A comparison of the organic composition of petroleum, oil shale, and coal clearly indicates a close genetic relationship. The analyses show also the intermediated character of kerogen shale (Table 1).

Table 1. Average compositions of crude oil, oil shale, and coal

| | Crude oil | Oil shale | Bituminous coal | Anthracite coal |
|---|---|---|---|---|
| Carbon | 85 | 80.5 | 82 | 85 |
| Hydrogen | 12 | 10.3 | 5 | 4.5 |
| Nitrogen | 0.5 | 2.7 | 1.5 | 1.0 |
| Oxygen | 2 | 5.8 | 10.3 | 7.5 |
| Sulfur | 0.5 | .7 | 1.2 | 2.0 |

## Where is Oil Shale Found?

Oil shale is widely distributed throughout the world and is found in rocks of all ages from Cambrian through Tertiary. As mentioned above, it formed from organic debris deposited with bottom sediments in ocean and lake basins.

### World reserves

The world's reserves of high-grade oil shale available with present technology amount to about 1.3 trillion barrels of oil. Nearly half of this (600 billion barrèls) occurs in the United States. Southern Brazil has an estimated 800 billion barrel reserve. Africa (mainly the Congo) has 100 billion barrels, Europe has 30 billion barrels, and Asia has 20 billion barrels (Duncan and Swanson, 1965).

The world's reserves of low-grade oil shale are estimated to be equivalent to 325 trillion barrels of oil. About 8 percent of these reserves are located in the United States.

### United States reserves

Green River: The largest deposits of high-grade oil shale in the U.S. are in the adjoining parts of Colorado, Utah, and Wyoming (Table 2). They

Table 2. Green River oil-shale reserves

| | Billions of barrels of oil in place | | | |
|---|---|---|---|---|
| | Colorado | Utah | Wyoming | Total |
| Intervals 10 ft. or more thick averaging 25 gal/ton or more of oil | 480 | 90 | 30 | 600 |
| Intervals 10 ft. or more thick averaging 10 to 25 gal/ton of oil | 800 | 230 | 400 | 1,430 |
| Total: Intervals 10 ft. or more thick averaging over 10 gal/ton | 1,280 | 320 | 430 | 2,030 |

Dinneen and Cook, 1974

occur in the Green River Formation, an extensive lake deposit of early to middle Eocene age. The Formation is 1,800 to 5,000 feet thick and occupies several individual basins, mainly the Piceance, Green River, Uinta, and Washakie Basins (Figure 2).

The Green River oil shale is a "marlstone" deposited on lake bottoms as a mixture of clay, sand, and lime containing varying amounts of kerogen. The richest and thickest deposits occur near the central basin axis (Folsom, 1963) and are as much as 2,000 feet thick. In the Piceance Basin, overburden ranges from 25 feet in thickness along the edge of the basin to more than 1,000 feet near the center. The "Mahogany Ledge," which contains the richest oil shale in the Green River Formation, is 110 feet thick in the middle of the basin and yields an average of 42 gallons per ton (Oil and Gas Jour., 1964, p. 65). Other beds of high-grade oil shales in the Piceance Basin are more than 15 feet thick and yield 15 to 25 gallons of oil per ton.

Table 3 shows the inorganic content of the Green River oil shale and the high percentage of carbonate minerals. Of particular interest are dawsonite, an aluminum carbonate, and nahcolite and trona, sodium carbonates, which have significant by-product potential because of the large quantities of shale to be mined. There is an estimated 30 billion tons of nahcolite,

Table 3. Inorganic matter in Green River raw shale

| | |
|---|---|
| Carbonates | 50 |
| Feldspar | 19 |
| Illite | 15 |
| Quartz | 10 |
| Analcite, et al. | 5 |
| Pyrite | 1 |
| (Weight percent inorganic | 86.2) |
| (Weight percent organic | 13.8) |

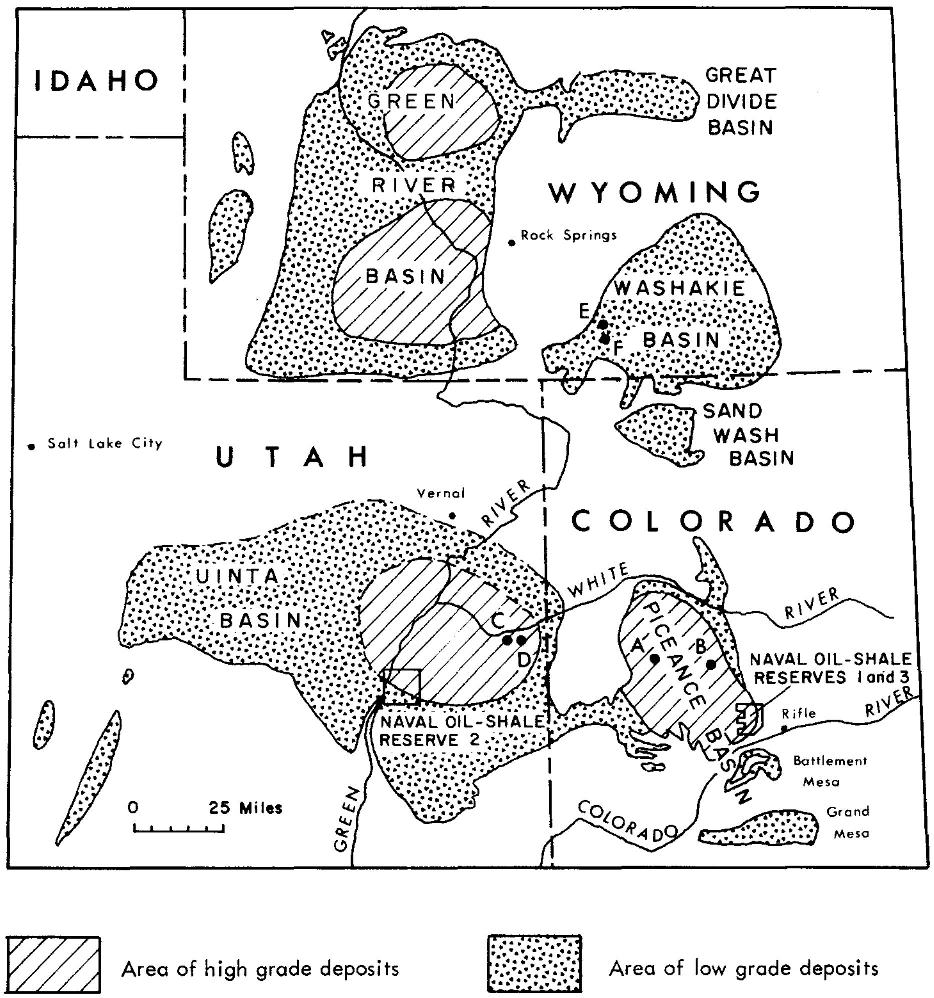


Figure 2. Green River oil shale deposits (from Duncan and Swanson, 1965). Tracts A through F shown in Table 4.

100 billion tons of trona, and 27 billion tons of dawsonite, containing 9.5 billion tons of alumina, in the Piceance Basin of Colorado and Green River Basin of Wyoming. These by-products represent major reserves of alumina and soda ash (American Mining Congress, 1968).

Other U.S. reserves: Oil shale occurs in 27 other states in the Union, and the character of the deposits varies widely. Most of the oil shale other than that in the Green River Formation was deposited in a marine environment. These deposits are mainly low grade and not minable under present economic conditions. However, yields up to 42 gallons of oil per ton of shale have been obtained on tests of the Barnett shale of Mississippian age in central Texas (Oil and Gas Jour., March 1967). Mississippian oil shales are also found in the south-central states. The Ohio shale of Devonian age underlies the eastern coal fields and extends from central Alabama through Tennessee and West Virginia. It extends west of the Appalachian coal fields, across central Ohio, through central Kentucky, across a portion of Illinois and underlies most of Michigan (see Figure 1). Diatomaceous Miocene shales in southern California contain significant oil shale reserves. Marine oil shales occur in Alaska in Jurassic and Triassic rocks.

Oil shale in Oregon: A small deposit of oil shale occurs in the Western Cascades of Oregon 10 miles northeast of Ashland. The deposit is interbedded with tuff of the Little Butte Volcanics of Oligocene age (Figure 3), and represents a local fresh-water lake environment where organic material and volcanic ash accumulated. The thickest layer of oil shale is about 4 feet, and the total thickness of the oil shale beds is about 10 or 15 feet. Assays by the U.S. Bureau of Mines yielded 35 to 37 gallons of oil per ton of shale. The extent of the deposit is not known but is probably small and is estimated to contain less than a million tons of kerogen shale.

Development of the shale deposit began in the 1930's with construction of a mill, a retort, and a small settlement of 32 cabins. The shale was first mined and processed for oil, which was noncommercial, and later

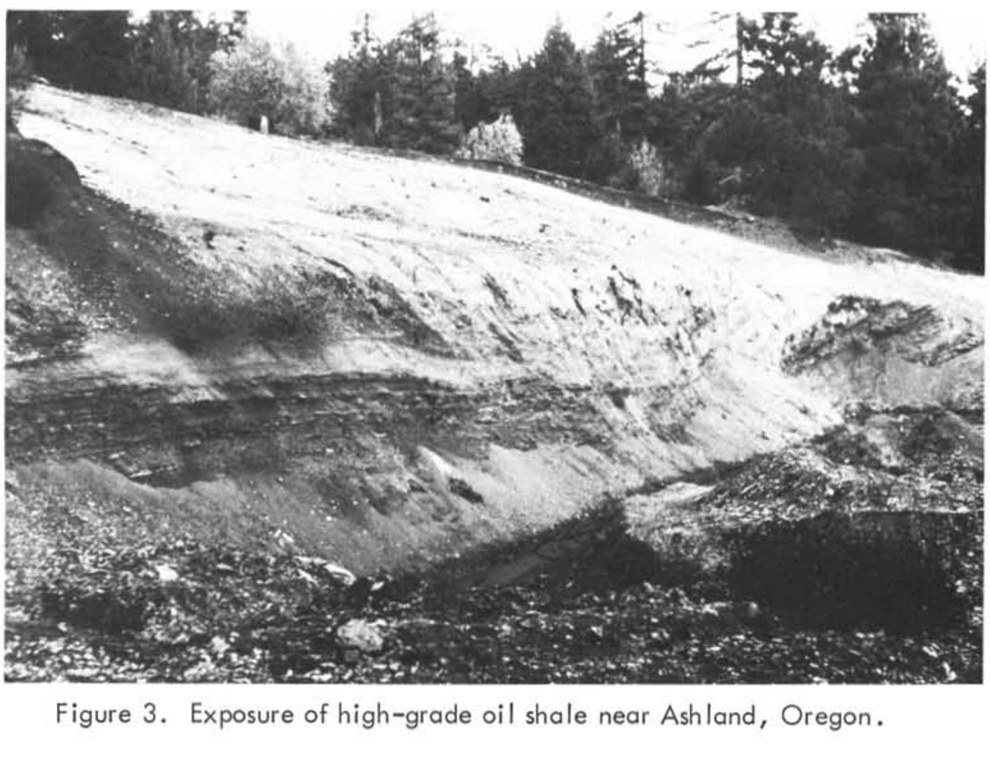

Figure 3. Exposure of high-grade oil shale near Ashland, Oregon.

was reportedly marketed as a medicinal tonic, a soil conditioner, and a cattle-feed additive.

Organic shale of possible potential value is present in beds of varying thickness in the lacustrine Payette and Succor Creek Formations of Pliocene age in southeastern Oregon. Tests made thus far, however, have yielded only half a gallon of oil per ton.

## What is the History of Commercial Development?

### Foreign Countries

The first commercial oil-shale operations began in France in 1838 and in Scotland around 1850. Oil-shale industries were later established in Russia, Sweden, Spain, Manchuria, South Africa, and Germany. By 1950, all except Russian and Manchurian operations were shut down because they could not compete with petroleum fuels (Schramm, 1970).

The Soviet oil-shale industry has been unprofitable, at least until recently. In the past, the major portion of mined shale in Estonia and north Leningrad Province was burned as raw fuel for Baltic area electric power generation. Production from Estonian and Leningrad deposits totalled 21.5 million tons in 1965. Shale gas production was approximately 100 million cubic feet per day during the same year (Oil and Gas Jour., October 1965). Although Russia now recognizes the value of extracting oil from oil shale rather than burning the raw material, future emphasis will probably be on petroleum resources.

Not much is known about the Chinese oil-shale operations, which are principally at Fushun, Manchuria. The Fushun project is producing at the present time. The Manchurian shales were an important source of oil during World War II and reportedly produced 40,000 barrels per day in 1961.

Brazil is going ahead with a major oil-shale development at Sao Paulo, where high-grade deposits are to be mined from the Iraty shale of Late Permian age.

### United States

Prior to the 1869 discovery of oil in Pennsylvania, about 60 shale and coal distillation plants functioned in northeastern United States, 25 of which were in Ohio. The plants operated on shale which yielded between 8 and 20 gallons of oil per ton (McKee, 1925). The oil-shale industry became noncompetitive when the petroleum industry was established. Since that time, no significant amount of oil shale has been mined and processed in the United States.

Table 4. Federal prototype oil-shale leases

| Company | Tract | Type operation | Reserves (tons) (20-30 gpt) | Bonus paid (millions) | Lease sale date |
|---|---|---|---|---|---|
| Gulf Oil Co. and Standard of Indiana | A.* Piceance Basin, Colorado | Underground or surface mine | $1.86 \times 10^9$ | \$210.3 | Jan. 1974 |
| Atlantic-Richfield and partners | B. Piceance Basin, Colorado | Underground mine | $1.01 \times 10^9$ | 117.8 | Feb. 1974 |
| Sun Oil Co. and Phillips Petrol. | C. Uinta Basin, Utah | Underground mine | $342 \times 10^9$ | 75.6 | March 1974 |
| White River Shale Corp. and partners | D. Uinta Basin, Utah | Underground | $372 \times 10^9$ | 45.0 | April 1974 |
| (received no bids when offered) | E. Washakie Basin, Wyoming | In situ | $354 \times 10^9$ | --- | May 1974 |
| (received no bids when offered) | F. Washakie Basin, Wyoming | In situ | $352 \times 10^9$ | --- | June 1974 |

*See Figure 2 for tract locations

## What is the Status of the U.S. Oil Shale Development?

### Economics

For the past 20 years, mineral resource experts have been giving increasing attention to United States oil-shale deposits. During this period more than 20 private firms were involved in oil-shale research. Thus far, petroleum, because of its relatively low price, has kept shale oil (kerogen) off the market. It has been estimated that under 1973 economic conditions high-grade oil shale can compete with petroleum at $8 a barrel, whereas liquefaction of coal probably becomes competitive only when petroleum reaches $10 per barrel. These potential sources of hydrocarbons should have the effect of holding prices of petroleum to around $8 a barrel.

Shale oil would be low-sulfur premium fuel oil and be in great demand in metropolitan areas. A one-million barrel per day underground operation or strip mine would require approximately $4 to $5 billion in capital investment. In-situ combustion technique would take considerably less capital. However, the latter technology is still in the research stage (West, 1974).

A depletion allowance of 15 percent on raw shale oil is allowed under Federal tax laws. The reduction of depletion on petroleum from 27 percent to 22 percent improved the competitive position of shale oil.

### Federal lands opened

The Federal government controls 80 percent of the rich oil-shale reserves in the Green River Formation; thus development of this resource depends upon government policy. Hundreds of mining claim titles, many pre-1920, had to be cleared before the Federal lands could be offered for lease. Clearing of titles and revisions to the mining law involved several years of litigation.

In June 1971, Secretary of the Interior, Rogers Morton, initiated a prototype leasing program on Federal lands in Colorado, Utah, and Wyoming. The program called for six leases of 5,100 acres each to establish commercial oil-shale facilities. The plan was to field test current technology in order to determine the actual economics and impact of the industry. The program envisaged construction of the six commercial-scale plants with an estimated production of 250,000 bbl/d to be on line in the 1980's. Each plant would require $200 million to $250 million capital investment.

After an assessment of environmental impact was completed, the first shale lease was offered for bid in January 1974. The last of the six tracts was offered for lease in June 1974 (Table 4 and Figure 2). No bids were received for the two low-grade deposits in Wyoming.

## How is Oil Removed from Oil Shale?

### Extraction techniques

There are two methods of recovering oil from kerogen shale: mining the shale and above-ground retorting, or in-situ (underground) combustion. A generalized flow sheet illustrating the entire oil-shale mining operation is shown in Figure 4.

If the deposit is to be mined, depth of the kerogen shale beds below the surface determines whether underground or strip mining will be used. Experiments in underground mining with the room-and-pillar method have been done; ideally about 75 percent of the shale is removed and 25 percent is left as supporting pillars.

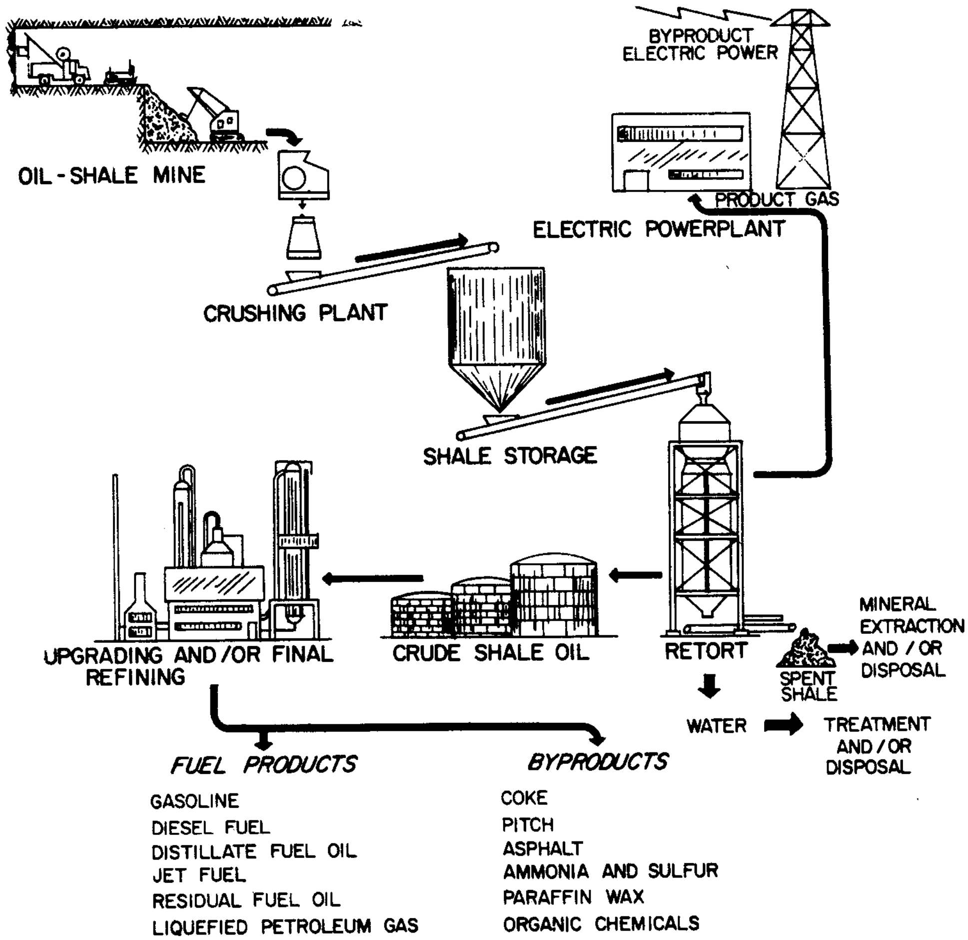


Figure 4. Surface processing system for oil shale from mine to products and byproducts (American Mining Congress, 1968).

Proponents of in-situ combustion methods (Figure 5) point out that the cost of mining, milling, and retorting can be eliminated by retorting underground. Waste is not a problem because the spent shale remains in place. This method of recovery involves drilling a pattern of wells so that the shale can be hydraulically fractured. Fuel must be pumped into the holes and burned until the temperature reaches 850°F to 900°F, at which temperature the shale will ignite and continue burning. Air must also be supplied to keep the shale burning. Thus far, none of the pilot projects using in-situ burning has been successful. Use of nuclear explosives to fracture and retort oil shale underground appears to be feasible. The type of radioactive by-products can be controlled to a certain extent by design of the explosive. The system involves detonation of many underground charges so that seismic ground motion appears to be the main problem. In this method, also, air must be introduced through wells to support underground combustion of the fractured shale (Lekas and Carpenter, 1965).

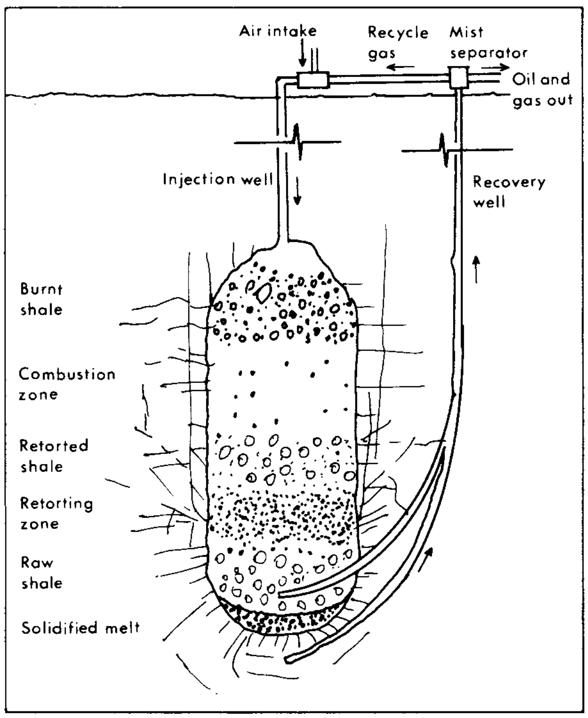


Figure 5. In-situ recovery using nuclear explosives (from Lombard and Carpenter, 1967).

Retorting technology

Experimental models of retorts have developed significantly over the past 20 years (Figure 6). The U.S. Bureau of Mines used a modified gas-combustion retort (Figure 6-a) operating on a downflow of shale and upward circulation of hot gas. Hydrocarbons leave the retort in a gaseous state. The Union Oil Company project at Grand Valley, Colorado operates on the exact opposite basis (Figure 6-b). It uses a downdraft of air with raw shale fuel being fed at the bottom and rammed upward by a piston. Oil Shale Corporation (partner with Atlantic-Richfield) introduced the Tosco Process utilizing hot ceramic balls to convey heat to the oil shale (Figure 6-c). The kerogen vaporizes and is condensed in a cooler. Advantage of the process is that the shale gas is not polluted by air. The Tosco Process has given the highest yields thus far of any of the retorting methods (Oil and Gas Jour. 1964).

Pour point of the crude shale oil ranges between 85° and 95°F, API gravity is 17° to 22°, and viscosity approximately 300 Saybolt seconds. This means that the crude shale oil has to be heated to above 90°F to pump through a pipe line. The sulphur content is below 0.75 percent.

The extractable energy in oil shale by normal destructive distillation includes 80 percent oil, 6 percent gas, and 4 percent coke and char. The character and amount of liquids and gas can be varied by introducing hydrogen under high pressure. Approximately 65 percent of the oil can be converted to shale gas by hydrogenolysis. However, the added refining in the hydrogen processes takes nearly half of the available energy in the shale. The gas obtained has a heating value of 1,000 BTU/$F+^3$. Theoretically, 1 gallon of oil will yield 100 $F+^3$ of gas by adding hydrogen under pressure (Duncan and Swanson, 1965).

## What Will be the Effect on the Environment?

The environmental effect of a shale-oil industry in the Green River, Washakie, and Unita Basins has been estimated by the U.S. Department of Interior in a statement issued in August 1973. Water requirements for the 250,000 bbl/d prototype projects will be between 8,000 and 11,500 acre feet per year. For a mature shale-oil industry producing 1 million bbl/d of shale oil, the requirement will be between 121,000 and 189,000 acre feet per year, according to an August 30, 1973 news release of the U.S. Department of the Interior.

Water resources in Utah and Wyoming are believed to be adequate to support a mature plant but a shortage could develop in Colorado as water use increases in other sectors. Construction of additional hydro-facilities or importation of new supplies into the Colorado River basin may be necessary (Schramm, 1970). Downstream pollution may occur if all the water is supplied by the Colorado system. Waste effluent containing organic substances could add to pollution if not properly processed and water salinity at Hoover Dam could increase to approximately 15 mg/liter or 1.5 percent from a mature shale-oil industry.

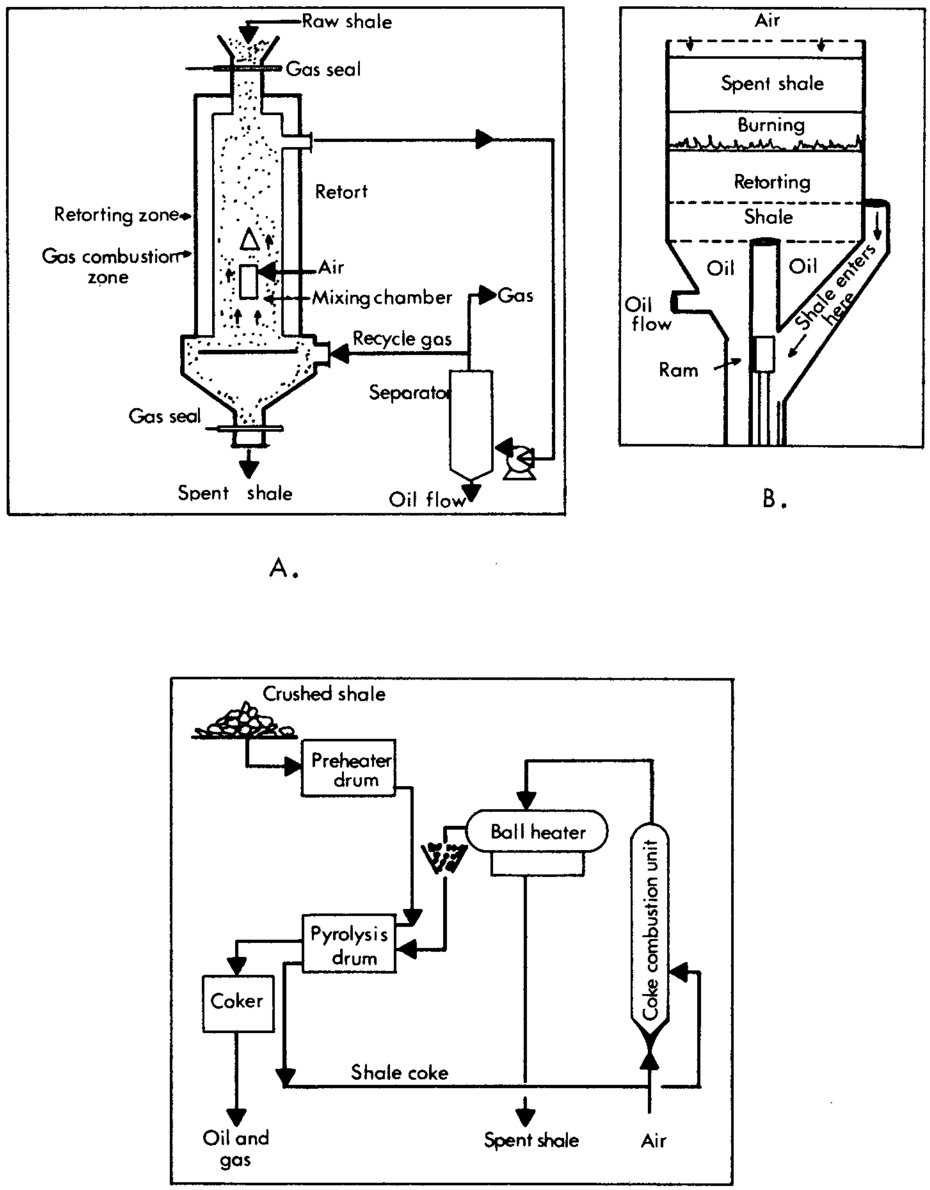


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Figure 6. Above-ground retorting methods: A. U.S. Bureau of Mines gas-combustion process; B. Union Oil Co. down-draft retort; C. Tosco Process used by Oil Shale Corp.

Air quality will be affected locally and clarity and visibility reduced. Some fine particulate matter will likely be emitted, along with small amounts of hydrogen sulfide. There is a potential for atmospheric inversions 20 days per year, according to the August 1973 U.S. Department of Interior news release. Influx of population due to the prototype operations will be approximately 34,000 persons to an area where 119,000 now live. There will be some impact on wildlife. Introduction of a mature industry into the region would reduce deer population, in some localities as much as 10 percent, according to the U.S.D.I.

Perhaps the most significant environmental problem is the handling of spent shale wastes. For the average grade shale to be mined, it will take 1.7 tons of shale to produce 1 barrel of oil. Therefore 1.7 million tons of spent shale will be accumulated every day the plant produces 1 million barrels of oil, or a total of 620 million tons per year. The problem is compounded by the fact that the shale expands approximately 25 percent by volume during retorting.

The terrain where mining will take place is rugged and relief is high; some operations may be able to take care of wastes by filling nearby arroyos. The wastes can be compacted, shaped, and terraced. Studies by the U.S. Bureau of Mines indicate that the spoils can be vegetated after three years of weathering. In other instances, the waste shale can be returned to the mined-out area. Large waste piles, though symmetrical, would not be aesthetically pleasing.

## What is the Outlook for the Industry?

The Federal program involving six prototype shale leases in Colorado, Utah, and Wyoming is projected to produce 250,000 barrels a day by 1980. Development of private properties, along with a full-scale operation on additional Federal leases, may reach 1 million barrels a day before 1990.

If the industry is able to expand its production to 2 million barrels of shale oil a day by the year 2,000, the amount will equal or possibly exceed the estimated domestic production of petroleum from wells. In light of the potential for the oil-shale industry to help offset our declining petroleum resources, it appears that we should no longer delay this development. The impact of the industry on the environment should be closely studied and the undesirable side effects reduced as much as possible.

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## LINN COUNTY ENVIRONMENTAL GEOLOGY REPORT PUBLISHED

"Environmental Geology of Western Linn County, Oregon" is the latest of the Department's bulletins dealing with environmental geology. The authors are John D. Beaulieu, Department stratigrapher and environmental geologist, and Paul W. Hughes and R. Kent Mathiot, both of Hughes and Associates, Inc., consulting geologists.

Western Linn County is characterized by the foothills of the Western Cascades, terraced valleys, and the extremely flat lowlands of the Willamette Valley. As part of the environmental geology program, the study was initiated to provide pertinent information on geologic hazards to planners and developers in the County. The bulletin discusses geologic units, engineering geology, soils, flooding, mass movement, erosion, and other hazards in addition to natural resources.

Bulletin 84 has 116 pages, 78 figures and photographs, 18 tables, and 22 full-color maps (geology, soils, hazards) on a scale of 1" to the mile. It can be obtained from the Department offices in Portland, Grants Pass, and Baker. Price is $8.00.

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## NEWPORT-WALDPORT MAP REPRINT AVAILABLE

"Geology of the Newport-Waldport area, Lincoln County, Oregon," by H. E. Vokes, Hans Norbisrath, and P. D. Snavely, Jr., published in 1949 as U.S.G.S. Oil and Gas Investigations Map OM-88, has long been out of print. Because of the demand for the map and accompanying fossil check lists and text, the Department has made blue-line ozalid prints that can be purchased at the Portland office for $2.50 each. Although geologic interpretations have been revised in more recent publications, this version contains considerable useful information.

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## FEA SETS PROJECT INDEPENDENCE HEARINGS

The Federal Energy Administration is holding 10 regional hearings on Project Independence focusing on local, regional, and national energy concerns. Project Independence is a program to evaluate the growing U.S. dependence on foreign sources of energy and to develop positive programs to reduce our vulnerability to future oil cutoffs and price increases. Hearings in west coast states are: Seattle, Sept. 5-7; San Francisco, Oct. 7-10.

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## POTASSIUM ARGON AGES OF VOLCANIC ROCKS COMPILED

All available potassium-argon age measurements on volcanic rocks in Oregon are given in a recent publication by the U.S. Geological Survey. The compilation, MF-569, is in two sheets consisting of a map of Oregon showing location of rocks sampled and a tabulation which gives alphabetically by county the location of each sample, formation, rock type, material analyzed, age, and source of information. MF-569, entitled "Compilation of potassium-argon ages of Cenozoic volcanic rocks of Oregon," is by G. W. Walker, G. B. Dalrymple, and M. A. Lanphere. The publication is for sale by the U.S. Geological Survey, U.S. Court House, Room 678, West 920 Riverside Ave., Spokane, WA 99201. The price is $1.00.

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## COASTAL AND OFFSHORE EARTHQUAKES LISTED

A recent publication issued by Oregon State University lists 2,220 earthquakes that have occurred in historic time (1853 to 1973) along and off the Pacific Northwest coast. Information given includes the date, time, location of epicenter, location of highest intensity reported, observed and computed magnitude, and focal depth. A map showing the general distribution of the earthquake epicenters is included. The compilation provides data to assess the potential effects of coastal and offshore earthquakes on coastal areas, particularly in selection of sites for nuclear installations and large construction projects.

The 67-page book, "Coastal and offshore earthquakes of the Pacific Northwest," prepared by Richard Couch, Linda Victor, and Kenneth Keeling, School of Oceanography, OSU, was done in cooperation with the Oregon Department of Geology and Mineral Industries. Copies of the publication are available from Geophysics office, School of Oceanography, Oregon State University, Corvallis, 97331.

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## MINED LAND RECLAMATION HEARINGS IN SEPTEMBER

Mined land reclamation hearings will be held late in September to consider revisions to administrative rules proposed by the Department. Information on time and place of the hearings will be available by calling or writing Oregon Department of Geology and Mineral Industries at its Portland office, 1069 State Office Building, or phone 229-5580.

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## GEOTHERMAL GROUP VISITS HOT SPOTS

A 6-day field trip June 24 to 29, 1974, showed 32 persons interested in geothermal development several areas in Oregon and Washington where geothermal fluids are known or thought to be present. The tour was led by R. G. Bowen, Department Economic Geologist, assisted in particular areas by Paul Hammond, PSU, and Department geologists R. E. Corcoran, H. C. Brooks, and N. V. Peterson. In Washington, the places visited were Government Mineral Springs and Trout Lake in the Cascades. In Oregon, the group visited Hot Lake near La Grande, Snake River Canyon, Vale-Owyhee region, Diamond Craters, and hot springs in the Alvord area and in the Oregon Cascades. The group were shown practical applications of geothermal energy for space heating in Lakeview and Klamath Falls.

Back row, left to right: H. J. Olson, D. Pilkington, AMAX; J. H. Robison, U.S.G.S.; K. H. Koenen, Geophysical consultant; M. Millis; L. Garrett, Shell; R. G. Detrick; W. H. Lee, U.S.G.S.; W. D. Michell, Reynolds; A. Alpha, Mobil; C. W. Jordan, Burlington Northern; W. S. Cox, Ore. Div. State Lands; G. W. Berry, Consulting geologist; E. Kurtz, O.I.T.; D. F. Finn, Geothermal Energy Inst.; R. J. Rossetter, Gulf; R. M. Sanford, Hunt Oil; P. E. Hammond, P.S.U.; P. M. Scott, Gulf. Front row, left to right: F. Dellechaie, AMAX; E. P. Kiver, E.W.S.C.; A. L. Strasfogel, Int'l Paper; N. J. Beskid, Argonne Nat'l Lab.; C. Isselhardt, Union Oil; E. H. Haynes, Chevron; P. Birkhahn, Woodward-Gizienski; R. M. Normark, EXXON; R. G. Bowen, Ore. Dept. of Geology and Mineral Industries.

Geothermal group visited Mickey hot springs near Alvord Desert in Harney County.

Geothermal group searched for volcanic bombs at Harney County aggregate pit in Diamond Craters area.

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The ORE BIN
Volume 36, No. 9
September 1974

# THE CATLIN GABEL LAVA TUBES

John Eliot Allen
Professor Emeritus of Geology, Portland State University

## Introduction

During detailed mapping of the Portland Hills for the Portland Environmental Geology project, the author and his students found evidence of lava tubes near Catlin Gabel School on the western slope of the Portland Hills. A lava tube is produced by surface cooling of a lava river while the hot interior continues to drain.

Existence of the tubes was first noted by R. J. Deacon (Shannon and Wilson, Inc., 1968) during a foundation study at the St. Vincent Hospital site just west of the Catlin Gabel School and was later discussed by Squier (1970). But the origin and extent of these interesting volcanic features were unknown until our field investigation in May of 1974.

The Catlin Gabel lava tubes occur among a cluster of cinder cones and associated lava flows of Pliocene to late (?) Pleistocene age (between about 5 and 1 million years old) that occupy an area of approximately 25 square miles on the west side of the Portland Hills (Figure 1). Lava tubes have not previously been described in Oregon lava flows older than Holocene (last 10,000 years).

Mount Sylvania is the largest of the Pliocene-Pleistocene volcanoes in the map area, but at least four and possibly as many as eight other volcanic vents and associated lava flows lie to the northwest as far as Germantown Road, 12 miles north of Mount Sylvania, and one other lies to the southeast. These volcanoes are probably the westernmost of this age in Oregon.

The area covered by lava flows and vents was first mapped by Trimble (1963), who assigned these rocks to the Boring Lava, a geologic unit first named by Treasher (1942) after a cluster of volcanoes around the town of Boring about 10 miles southeast of Portland.

## Discussion of the Lava Flow

The source of the lava containing the tubes is a small volcanic vent situated between two others near the southern end of the northern area of

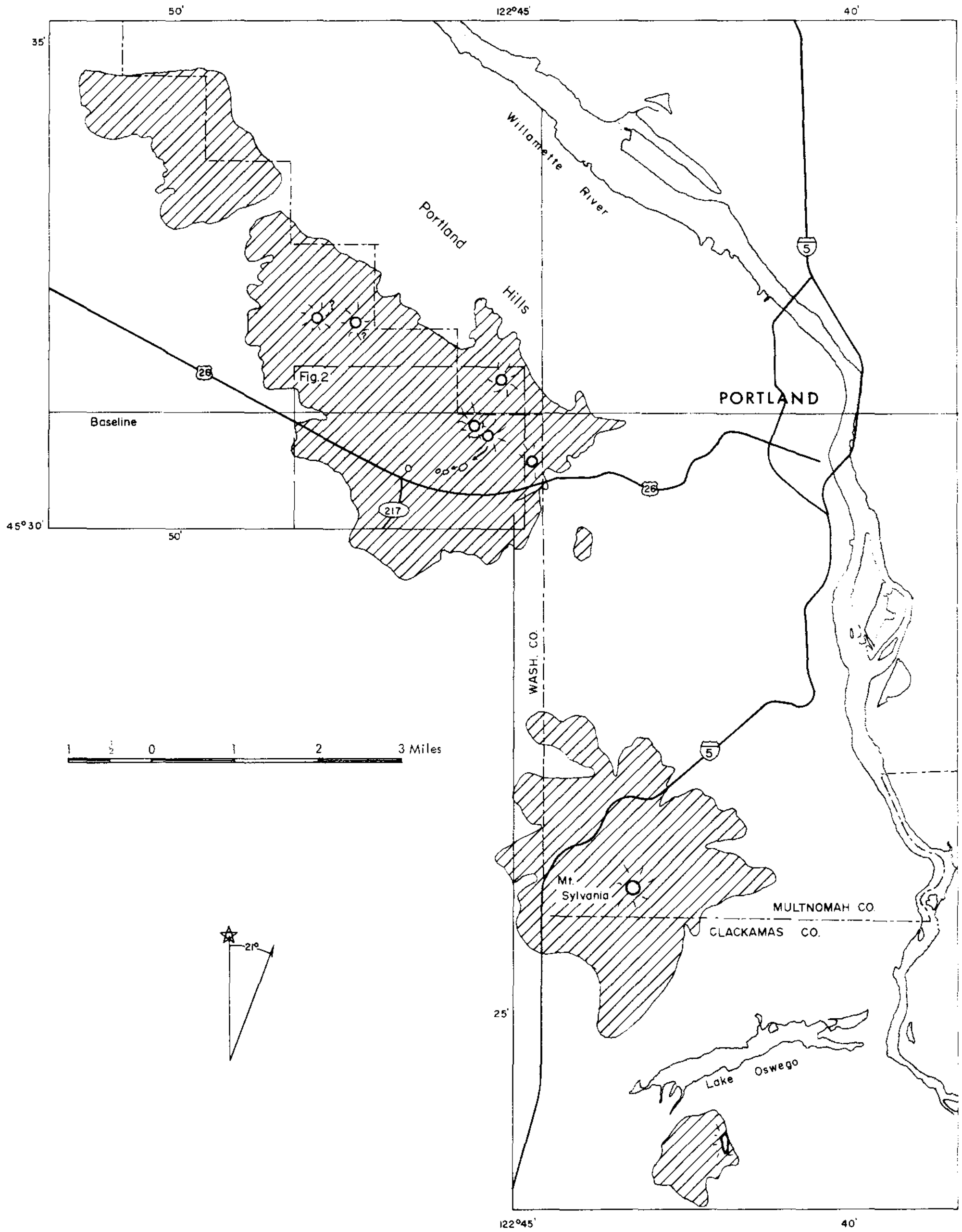



Figure 1. Index map of Boring Lava flows and vents west of the Willamette River, Oregon. Area of Figure 2 indicated by boxed area.

volcanoes (Figure 1). Its elevation is 974 feet above sea level. From the base of this vent, the lava extends south and then west for about $2\frac{1}{2}$ miles. It is about 2,500 feet wide and slopes approximately 150 feet per mile, or 3 percent (Figure 2). Near its center the total thickness of lava is 235 feet, as shown by a drill hole located 1,000 feet south of the central depression (Schlicker and Deacon, 1967, pl. 2, C-C').

The lava overlies 434 feet of silt of the Troutdale Formation, which in turn lies upon Columbia River Basalt. The surface of the Columbia River Basalt rises very steeply to the northeast and crops out only 2,000 feet east of the vent (Figure 3).

During foundation excavation for the St. Vincent Hospital, Shannon and Wilson (1968) found that the upper lava unit containing the tubes was about 90 feet thick and overlay very compact silt.

Recent erosion has modified the original surface expression of the lava, and a mantle of Portland Hills Silt as much as 30 feet thick has further masked the surface. It is perhaps surprising, in view of the age of the flow, that its outlines can still be mapped with a reasonable degree of confidence (Figure 2).

A southern lobe of lava, which extends almost a mile south of Sunset Highway (Figure 2), is interpreted to be an older flow unit, possibly from the same vent, that filled most of a pre-Boring valley.

## Origin of Lava Tubes

Greeley (1971, p. 5) has carefully described the formation of lava tubes, which occur usually in flows of very fluid (pahoehoe) lava. "Tubes are so common in pahoehoe flows that they are evidently the primary means of flow advance." As molten lava flows down a valley, the bottom and sides chill and solidify; as it slows down, the top of the flow also congeals to form a solid crust, but the lava continues to flow beneath this insulating cover. When the eruption ceases, the entrapped lava continues to flow and drains the tube. More than 17,000 meters of lava tubes in the western United States have been examined and mapped in detail, according to Greeley (1971).

Notable lava tubes in the northwest occur in Oregon south and southeast of Bend, and southeast of Burns, and in Washington south of Mount St. Helens (Greeley and Hyde, 1970). Greeley (1971) described 19 tubes in the Bend area that have a total mapped length of 3.6 miles. There appear to be at least two types: minor lava tubes and major lava tubes; minor tubes are generally less than 50 feet wide and a few hundred to a few thousand feet long. "Lava flows restricted to valleys are narrow and generally have a single main tube, or multiple tubes that are vertically stacked...minor tubes are often feeder tubes from larger tubes," (Greeley, 1971, p. 5). The Catlin Gabel tubes would seem to fall into the category of minor tubes.

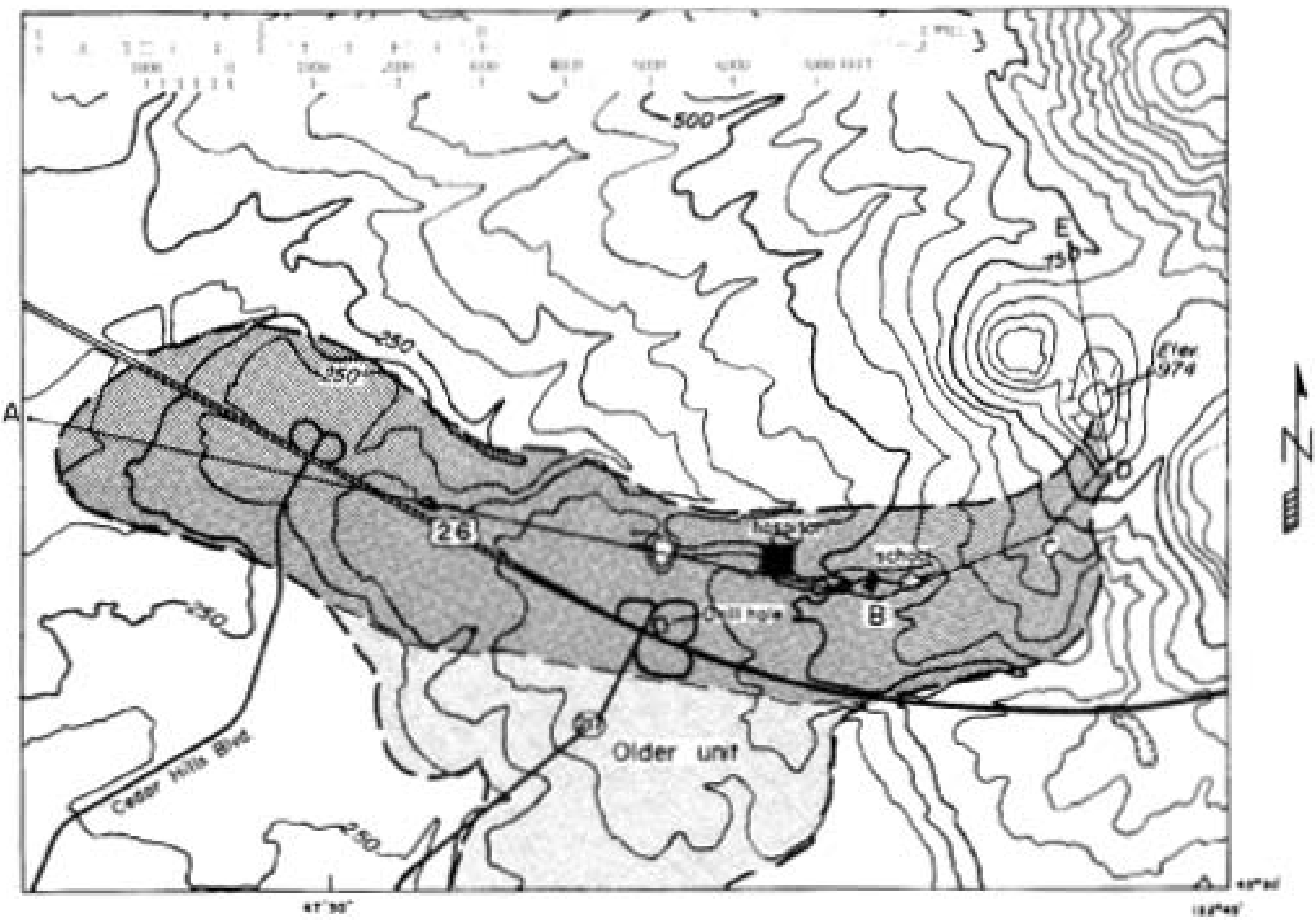



Figure 2. Catlin Gabel lava flow and lava-tube depressions.

## Discussion of the Catlin Gabel Lava Tubes

Multiple eruptions from the source vent produced several flow units which apparently followed down a pre-existing valley on the west slope of the Portland Hills. The lava tubes developed in the uppermost flow when the surface of the lava congealed and the interior continued to advance until drained.

The lava of the latest flow extends south from the vent and then west in an arc which lies just north of and nearly parallel to Barnes Road (Figure 2). Along the center of the arc, within a distance of 6,000 feet, are five closed depressions which were caused by collapse of the roofs of the lava tubes.

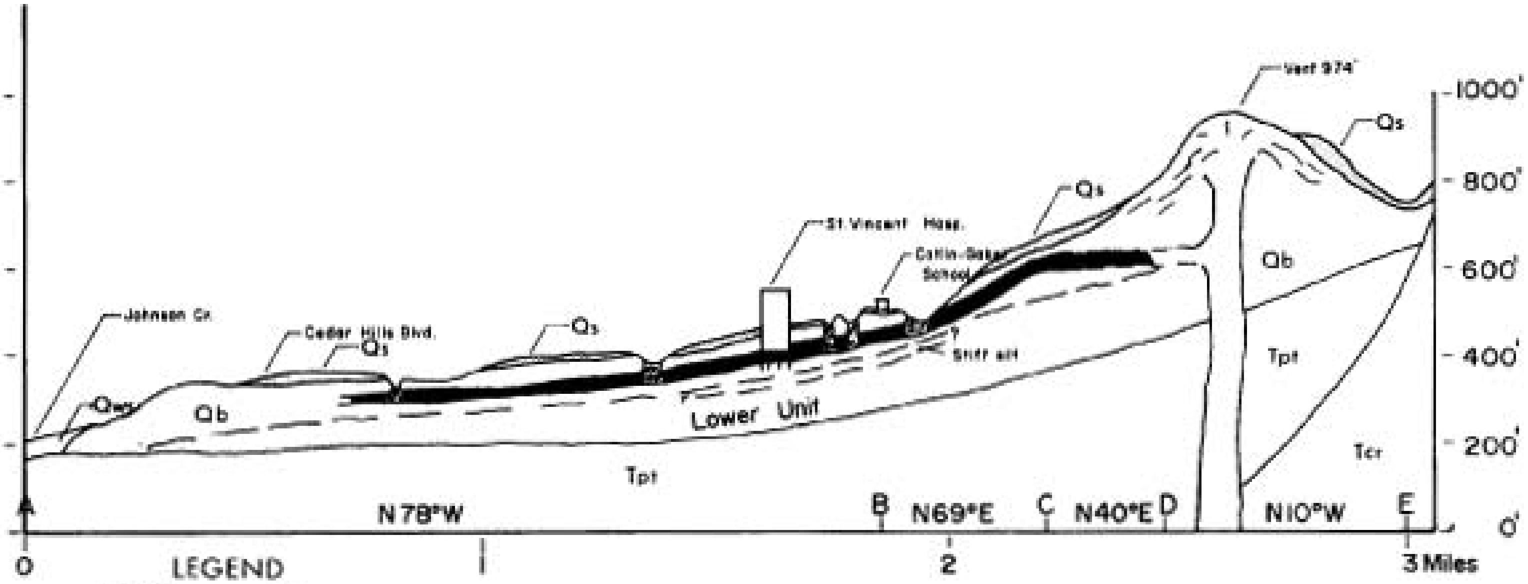
From east to west, the five depressions are as follows: The first (55 feet deep and 500 feet across) lies just east of Catlin Gabel School; the next two depressions (35 and 45 feet deep, 100 and 200 feet across) lie just west of the school; the fourth (30 feet deep and 400 feet across) is north of the interchange of Highway 217 with Sunset Highway; and the fifth depression (50 feet deep, 150 feet across) lies just north of Sunset Highway and 1,000 feet east of the Cedar Hills Boulevard interchange. (See U.S.G.S. Linnton $7\frac{1}{2}$-minute topographic quadrangle.)

Since there are no visible openings to uncollapsed segments of the tube system, little is known of its characteristics. Apparently at least part of its course was made up of branching or tributary lava tubes. At the St. Vincent Hospital site, excavation revealed two northwest trending collapsed tubes that joined to the northwest. The two rubble-filled channels were up to 40 feet wide and 60 feet deep and required special engineering design for the foundation of the 15-story building (Squier, 1970).

## Engineering Considerations

Although the cross section (Figure 3) shows segments of the tube still intact, an alternate possibility exists -- the entire tube system may have collapsed. In that event, the tubes would consist of channels filled with the debris of the collapsed roofs. According to R. J. Deacon (Shannon & Wilson, 1968), the "rubble-filled channels" beneath the hospital site were masked by undisturbed layers of ash and silt. This indicates that the roof of the two tubes at that location had fallen in <u>before</u> deposition of the overlying sediments.

The above disclosure suggests the further possibility that the five existing depressions represent the last parts of the tube roofs to break down and that their collapse occurred <u>after</u> the ash and silt were deposited. If this alternative is valid, it has important engineering implications: those structures, such as Catlin Gabel School, that directly overlie the projected course of the tubes would not be in danger of eventual collapse.




LEGEND

Qws Willamette Silt

Qs Portland Hills Silt

Qb Boring Lava

Tpt Troutdale Formation

Tcr Columbia River Basalt

Vertical exaggeration: 5X

Figure 3. Generalized longitudinal section of the Catlin Gabel lava flows showing relative position of tube and latest collapse depressions. Plan of cross section A through E shown in Figure 2.

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Planning for future heavy structures, such as St. Vincent Hospital, along the route of the Catlin Gabel lava tubes should carefully explore the subsurface for potential foundation problems arising either from channels filled with basalt rubble or from uncollapsed tubes subject to roof failure.

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Trimble, S. E., 1963, Geology of Portland, Oregon and adjacent areas: U.S. Geol. Survey Bull. 1119, 119 p.


* * * * *

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* * * * *

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1. Physical depletion of many material resources when world demand is rising.
2. High interest rates and low rates of return on investments, which discourage construction and expansion.
3. Price controls, which kept domestic prices low.
4. Two devaluations of the dollar.
5. Inflexibility of environmental protection laws and regulations.
6. Requirements of the Occupational Safety and Health Act.
7. Shortages of energy minerals.

* * * * *

## MINING CLAIMS OPINION GIVEN

The rights of the public to use the surface of unpatented mining claims filed after July 23, 1955 for recreational purposes have been determined in a recent Department of the Interior opinion, Bureau of Land Management officials reported.

Archie D. Craft, BLM Oregon State Director, noted that the opinion states that recreational use is an authorized form of resource management and therefore can be permitted on those unpatented mining claims filed after July 23, 1955, the date the Multiple Use Mining Law (Public Law 167) was passed by Congress. In certain instances, recreational use may also be appropriate on older claims where the rights to surface resource management have been obtained by the Government.

The Department opinion, Craft said, is based on recent interpretations of the 1955 law and policy changes toward outdoor recreation management. It reiterates the fact that recreational use of national resource lands is a recognized form of surface resource management authorized by law.

The opinion related that under the law the claim operator is entitled to preclude recreational uses which endanger or materially interfere with his bona fide operations.

Craft said the recreationist, such as hunters, must exercise considerable judgment in recognizing legitimate mining activities and what constitutes material interference with mining.

* * * * *

## WOULD YOU RATHER OWN A DIAMOND MINE OR A GRAVEL PIT?

Shortly after our wedding, my wife confessed that she married me because she figured that I might find her a diamond mine. I pointed out that she would be better off if I found a gravel pit! The simple fact is that although the U.S. has no commercial production of diamonds, the value of sand and gravel mined last year was $1.2 billion. The message here is that real value is not necessarily connected with glamour materials. In recent months our attention has been focused on prices and shortages of mineral fuels, and while there is also a growing concern over our increasing dependence on foreign sources of metallic minerals, there still is a surprising lack of awareness of the tremendous role which non-metallic, industrial minerals serve in our economy.

Last year the total value of all metallic minerals produced in the U.S. (including gold, silver, copper, lead, zinc, manganese, etc.) totaled $3.5 billion, but the combined value of all the non-metallic categories (stone, cement, sand and gravel) had a $4.2 billion production value, thus exceeding all metallic mineral production.

The importance of non-metallic mineral resources can further be demonstrated by per capita use data. In 1973 for every man, woman, and child, the U.S. used 9,000 pounds of sand and gravel, 8,500 pounds of stone, 800 pounds of cement, 600 pounds of clays, 450 pounds of salt, 1,200 pounds of other non-metals. This made a total of 20,550 pounds per capita of all non-metallic, as compared with 1,340 pounds of metals per person.

In Pennsylvania last year nearly 40 percent of the Commonwealth's $1.3 billion total mineral production value consisted of non-metallic industrial minerals: cement, stone, lime, sand and gravel, and clay.*

These non-metallic minerals are called industrial minerals for the very reason that they are critical raw materials necessary to maintain our industrial capability and responsible for employment of great numbers of people. Non-metallics also provide the raw materials from which we construct our homes, offices, factories, roads, bridges, railroads, and airports.

With their great dollar value and importance to our society, we are fortunate that the U.S. has great reserves of the industrial minerals. We must, however, assure their future availability by carefully mapping their distribution, planning for their accessibility, and establishing mining procedures compatible with being good neighbors to our citizens and our environment. --Arthur A. Socolow, State Geologist, Pennsylvania

(Reprinted from Pennsylvania Geology, v. 2, no. 5, 1974)

* In Oregon 66 percent of the State's $81.5 million mineral-production value is from sand and gravel and stone.

* * * * *

## JOINT ECONOMIC COMMITTEE HEARS MINING SPOKESMAN

The Subcommittee on Economic Growth of the Joint Economic Committee held a series of hearings in July on raw materials adequacy; Robert N. Pratt, president of Kennecott Sales Corp., testified on many of the problems and issues confronting the mining industry.

Covering copper pricing and the supply and demand outlook, Pratt said that with sound policies, the U.S. can continue to become more self-sufficient in copper, even though the nation currently faces short-term shortages. The one deterrent to increasing productive capacity, he said, is the huge capital investment required.

He stated that realistic and workable laws and regulations are necessary if a strong domestic mining industry is to be maintained. He acknowledged that government has a vital role to play in encouraging a strong domestic mining industry and that access to resources must not be frustrated. A copy of Pratt's statement is available upon request to the American Mining Congress. (Amer. Mining Cong. News Bull. July 26, 1974)

* * * * *

## CARLSON NOMINATED FOR INTERIOR POSITION

Jack W. Carlson has been approved by the Senate Interior Committee to be Assistant Secretary of the Interior for Energy and Minerals, succeeding Stephen Wakefield, who resigned. Carlson has served as assistant to the director, Office of Management and Budget, since 1972; previously was senior staff economist on the President's Council of Economic Advisers, 1966-67; and in 1968 became assistant director of the Bureau of the Budget.

* * * * *

## ENERGY-USE STUDY OF MINERAL INDUSTRIES UNDER WAY

Finding out how much energy is used by industries that extract and process the nation's metals and non-metallic minerals and recommending ways for those industries to conserve energy are the twin objectives of a new study launched by the U.S. Bureau of Mines.

The study, scheduled for completion in 18 months, will be conducted for the bureau by Battelle Columbus Laboratories under a $661,000 contract. The project is designed to provide comprehensive information on energy consumption by type and quantity for each phase of the metals and minerals industries, except fossil fuels, from mining to primary product, including energy required for transportation.

* * * * *

## INTERIOR SECRETARY MORTON STRESSES NEED FOR RESOURCE EXPLORATION "NOW"

In an address presented August 26, 1974 to the more than 800 earth scientists from about 30 nations attending the opening session of the Circum-Pacific Energy and Mineral Resources Conference in Honolulu, Hawaii, Interior Secretary Rogers C. B. Morton stressed both the necessity to begin now the exploration for the vital mineral resources that will be required to supply future needs and the important role that the largely unexplored Pacific basin could play in supplying those needs.

Secretary Morton's address, presented by Dr. V. E. McKelvey, Director of the U.S. Geological Survey, Department of the Interior, noted that "at some time in the future we shall indeed reach a point of equilibrium between the world's population and available resources -- if not by design, then later by necessity. But there is a world of difference between preparing for the ultimate arrival of the equilibrium between resources and population and supinely resigning ourselves to some inevitable doomsday soon to come."

"The fact is that we have the capacity to create additional resources by discovery of deposits whose existence and location are presently unknown to us, and we can increase our ability to use more efficiently the resources we have. These are the processes by which men have satisfied their increasing needs for at least 8,000 years," Secretary Morton said.

The Interior Secretary noted that "everything we can infer about the presence of minerals in the Earth's crust leads us to believe that vast resources remain to be discovered and developed." Among the recent reminders of this, he cited:

- The huge iron and bauxite deposits of Australia that were discovered within the last 25 years, although the continent has been explored for more than 200 years.
- New discoveries of tin deposits in the British Isles, where tin has been mined for 4,000 years.
- New deposits in the lead belt of the U.S. where lead has been extensively mined for two centuries.
- And in Hawaii, the center of a region that contains enormous deposits of metal-rich nodules on the sea floor, for which the recovery technology is now within our grasp.

"The Pacific region is not only a major area to explore for resources," Morton said, "it is also the world laboratory for the study of active processes of geotectonics as they relate to the origin of energy and mineral resources. By any measurement, the Pacific region is enormous. A billion people live along its shores, and the entire land area of the Earth could easily be contained in the Pacific basin. To identify and assess the mineral wealth of such a region will be a formidable task indeed."

* * * * *

## GEOTHERMAL LEASE ISSUED FOR VALE AREA

Archie D. Craft, State director of Bureau of Land Management in Oregon, has approved the lease of 1,347 acres of national resource lands in the Vale Known Geothermal Resource Area near Vale, Oregon, to Republic Geothermal, Inc., Whittier, California.

Four bids were received on June 27, 1974 to lease the acreage for geothermal exploration and development. Republic was successful with a bid price of $10.26 per acre, for a total of $13,831.

Qualifications of the bidder for the long-term lease (ten-year, renewable for 40 years) has been verified and the U.S. Geological Survey agreed that the lease rate was appropriate.

The lessee submitted a bond for $10,000 for compliance with regulations, and a bond for $5,000 for protection of personal property.

Republic's plans, filed with BLM, provide for initial work to be primarily geological mapping, followed by data collection and heat-flow studies.

Under the lease arrangements, the firm has the right to contract for a power plant on the site, subject to certain permits. It must be able to prove to the Federal Power Commission, however, that there is 30-year reserve on site before a power plant permit will be considered.

Today's action is in line with the Geothermal Steam Act of 1970, which authorizes the Secretary of the Interior to make disposition of geothermal resources under such terms and conditions as he prescribes.

The lease of geothermal lands is the first in the Oregon-Washington area and among the first in the nation.

* * * * *

## EARTHQUAKE HAZARD-REDUCTION PROGRAM SETS GOALS

The U.S. Geological Survey is now directing the single largest research and data-gathering effort on earthquake hazard reduction in the United States. The program is the result of outgrowth and merging the earthquake research programs of several agencies. Under one administrative guidance, the U.S.G.S. hopes to mold a more effective program. The specific goals and approaches are outlined in a recent publication, "Goals, strategy, and tasks of the earthquake hazard-reduction program," issued as U.S. Geological Survey Circular 701. Copies of the 27-page illustrated circular are available free from the U.S. Geological Survey, National Center, Reston, Virginia 22092.

* * * * *

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# MINING LAW STILL INTACT, BUT PROSPECTORS FACE NEW SET OF REGULATIONS BY THE U.S. FOREST SERVICE

The U.S. Forest Service has published the final version of regulations on the surface use of National Forest lands under the amended mining laws of 1872. These regulations became effective September 1, 1974.

Although the Mining Law of 1872 is still largely intact, the new regulations place some requirements in the path of prospectors and miners operating within the boundaries of the National Forests. The Mining Law of 1872 generally gives the prospector and miner the right to enter upon the public domain, and to search for, develop, and extract a wide variety of mineral resources. The Forest Service, charged with the protection and disposition of the vegetative resources and general management of wildlife and other surface resources, has become increasingly concerned with the activities of prospectors and miners. The present regulations are aimed at better control of access roads to the mine, prospect holes, open pits, mill effluent, solid waste disposal, control of erosion and landslides, and the eventual reclamation of the site following completion of the operation.

In the 49 numbered paragraphs that follow are answers to many of the questions the Forest Service anticipates will be asked by persons wanting to know about the regulations it now administers. Copies of these regulations may be obtained from the U.S. Forest Service, Portland, Oregon 97208, or from any District Ranger Station.

1. What is the purpose of the regulations?

   They are intended to protect the nonmineral surface resources of National Forest System lands against unnecessary or unreasonable damages from prospecting, exploration, development, mining and processing operations carried out under the authority of the U.S. mining laws of 1872, as amended. They are intended to provide that protection without unreasonably inhibiting or restricting the activities of prospectors and miners.

2. What is the basic authority for the regulations?

The Act of June 4, 1897. It authorizes the Secretary of Agriculture to regulate occupancy and use of the National Forests for the protection and management of their surface resources. All National Forest users, including prospectors and miners, are required to observe these regulations.

3. Do the regulations exceed the limitations imposed by law on Forest Service management and administration?

   No. By law, the regulations and their administration may not materially interfere with or endanger lawful mineral-related activities on mining claims. Further, citizens and those who have declared their intention to become citizens have the right under law, not mere privilege, to go upon National Forest lands open to operation of the mining laws for prospecting, locating, and developing their mineral resources. Miners and prospectors must recognize, however, that they are subject, also by law, to reasonable rules and regulations covering the National Forests.

4. Do the regulations affect the mining laws and mining regulations of the Department of the Interior?

   No. Those laws and regulations relate to the search for minerals, their discovery, extraction and processing. The Forest Service regulations apply to the protection of nonmineral resources affected by mineral-related activities.

5. What activities are authorized by the 1872 mining laws, as amended?

   They include prospecting, exploration, development, mining, processing, and related activities involving the locatable mineral resources on public domain lands to which those laws apply. The mining laws also authorize necessary and reasonable access and the use of certain surface resources for mineral-related activities. The regulations define these activities as "operations."

6. Does the Forest Service intend to manage the mineral resources of the National Forests?

   No. The Department of the Interior manages Federally owned, locatable and leasable minerals in National Forest lands. The Forest Service is charged with the management and protection of the surface resources. All uses and users are subject to reasonable and necessary regulation for surface resource protection.

7. Does the Forest Service recognize minerals to be natural resources of the National Forest System along with outdoor recreation, range, timber, watersheds, wildlife, streams, fisheries, esthetics, and so on?

Yes.

8. Do these regulations allow the Forest Service to tell me where and how I may prospect and mine?

No. They simply ask that you operate in a responsible way, with recognition of the need to protect nonmineral resources as much as may be possible.

9. Will these regulations be fairly, consistently, and reasonably administered by the Forest Service?

Yes. The Chief of the Forest Service committed himself to this in public speeches and congressional testimony. In addition, appeal procedures are provided for in the regulations should prospectors or miners believe they are being treated unfairly.

10. Do these regulations stop location of mining claims?

No. But certain National Forest lands have been, and others may be, withdrawn from operation of the mining laws under appropriate authority.

11. Won't these regulations substantially reduce, if not completely halt, mineral exploration and development on the National Forests?

That is neither their design nor their purpose. They will substantially reduce unreasonable or unnecessary damages to surface resources.

12. Do these regulations keep me from buying or selling a mining claim?

No. A mining claim is a possessory interest recognized as property that can be bought, sold, devised, bequeathed, and so on. However, no transaction can convey more than the interests or rights that may have been established under the requirements of the mining laws.

13. Will these regulations keep me from patenting my mining claim?

No. The requirements for patenting have not been changed. They are established by law and by regulations of the Department of the Interior, Bureau of Land Management.

14. Do these regulations apply on all lands administered by the Forest Service?

No. They apply only to National Forest System lands open to operation of the U.S. mining laws of 1872, as amended, and to operations conducted under those laws. The 1872 mining laws do not affect all National Forest System lands. They cover those lands reserved from the public domain for National Forest purposes and not otherwise withdrawn from their operation. They also apply to a very small portion of lands acquired by the Federal Government for National Forest purposes. Land status can be checked in Ranger District Offices and in National Forest Supervisors' Offices. Unpatented mining claims, tunnel sites, and millsites are subject to these regulations, along with unclaimed lands. Nearly all the National Forest lands open to the mining laws, and thus subject to these regulations, are west of the Mississippi River, and in Alaska.

15. What is the single most important feature of these regulations for the purpose of minimizing the impacts of prospecting and mining on the surface resources?

The prospector's and miner's operating plan. It provides a way for the mineral operator and the Forest Service to cooperate in developing workable procedures by which proposed operations can be done with the least impact or damage to both the surface resources and the operator.

16. What is an operating plan?

It is a document by which a mineral operator identifies himself, describes the work he intends to do, where and when he intends to do it, the nature of his proposed disturbance of surface resources, and the steps he will take to protect those resources. Operators are encouraged to contact the local District Ranger concerning any questions about operating plans or working out feasible means for protecting surface resources and reclaiming disturbed areas not needed for further operations.

17. Who has to submit an operating plan?

Anyone whose proposed operations under the 1872 mining laws could cause "significant disturbance of the surface resources." New operations should not be started until an operating plan has been approved.

The regulations provide that ongoing operations, already underway on the effective date of the regulations, may continue until an operating plan is approved as long as they are not causing unnecessary or unreasonable damages. Operators are expected to file proposed operating plans for these ongoing operations within 120 days of the effective date of these regulations if their operations are causing significant disturbance to surface resources.

18. Can I expect prompt consideration of and response to my proposed operating plan?

Yes. The Forest Service will do its best to respond within, or less than, the time prescribed by the regulations.

19. Is an approved operating plan a form of permit?

No. Prospectors and miners already have express permission, by act of Congress, to go upon those National Forest lands open to operation of the 1872 mining laws for the purposes of "prospecting, locating, and developing the mineral resources."

20. What, then, is the approved operating plan?

It is basically an agreement. The operator agrees to observe necessary and reasonable precautions, which are spelled out in the plan, to reduce damage to surface resources during his activities and to rehabilitate disturbed areas as and when feasible. The Forest Service agrees that protection of surface resources will be adequate if operations are carried out as described in the approved plan.

21. Does approval of my operating plan indicate my mining claim is valid?

No. The purpose of the regulations and the operating plan is to protect the surface resources of National Forest lands involved in and affected by mineral-related operations, whether or not the operations take place on unpatented mining claims. Claim validity is a separate matter. It is covered by the requirements of the mining laws and the pertinent regulations of the Department of the Interior, Bureau of Land Management.

22. Under what circumstances would an operating plan not be approved?

Approval would be denied if the proposed operations are by law unauthorized or specifically prohibited. Neither would approval be given if the proposed measures for surface resource protection and for reclamation were considered to be inadequate. Should this happen, it is logical that an amended or modified operating plan would be prepared for reconsideration. Nor, of course, would an operating plan even be necessary if the proposed operations will not cause "significant disturbance to surface resources."

23. What is "significant" disturbance of surface resources?

A definition cannot be given that would apply to all lands subject to these regulations. Disturbance by a particular type of operation on flat ground covered by sagebrush, for example, might not be considered significant. But that same sort of operation in a high alpine meadow or near a stream could cause highly significant surface resource disturbance. The determination of what is significant thus depends on a case-by-case evaluation of proposed operations and the kinds of lands and other surface resources involved. In general, operations using mechanized earthmoving equipment would be expected to cause significant disturbance. Pick and shovel operations normally would not. Nor would explosives used underground, unless caving to the surface could be expected. Use of explosives on the surface would generally be considered to cause significant disturbance. Almost without exception, road and trail construction and tree clearing operations would cause significant surface disturbance.

24. Where and when do I file my operating plan?

It is filed with the District Ranger in charge of the area where you operate or propose to operate. For your own benefit, it should be filed as far in advance of the proposed operations as possible.

25. How do I know which District Ranger is responsible for the area in which I plan to operate?

His office is probably the one nearest your area. Even if it is not, the nearest Forest Service office will be able to tell you which District your operations are in.

If you know which National Forest is involved, people in the Forest Supervisor's Office can tell you which District Ranger to contact. Regional Office personnel can also help. You should be able to describe the section, township, and range your operation is in, or be able to show its location on a map.

26. Under what circumstances does an already approved operating plan need to be amended or modified?

When you intend to cause significant disturbance not covered in your approved plan and in the unusual case when circumstances unforeseen by either the Forest Service or the operator could result in needless damage to surface resources by operations thought to be environmentally acceptable when the operating plan was approved. In such instances, operators will be requested to revise their plans and operations to provide for better surface resource protection and for feasible adequate reclamation.

27. Can an approved operating plan be broad enough to allow for adjustments in exploration and development projects as required by information derived as the work progresses?

This is a desirable goal for all concerned. In some cases it will be possible, in others not. Case-by-case analyses will help identify those operations where it can be done.

28. Will I be required to give confidential information in my operating plan?

The Forest Service will require only the minimum data needed to make a factual evaluation of the impact of proposed operations on the surface resources. Usually, little or no information of a confidential nature will be needed. On those occasions when such information might be necessary, the operator should identify it as confidential and keep it separate from the operating plan. It may be that such information should only be analyzed by Forest Service mining engineers and geologists, rather than be submitted with the operating plan. Information identified by the operator as confidential and which is so submitted to the Forest Service will be filed separately from the rest of the operating plan. It will not be made available for public inspection.

29. What should I do if I think my proposed operations might disturb surface resources, but I'm not sure the disturbance will be significant enough to require an operating plan?

You should file a "notice of intention to operate" with the District Ranger. It should describe briefly what you intend to do, where and when it is to be done, and how you intend to get yourself and your equipment to the site. The District Ranger will analyze your proposal and will, within 15 days, notify you as to whether or not an operating plan will be necessary. In this way, you can avoid advance preparation of an operating plan until you know that it is necessary to do so and have some information as to what must be included.

30. Are there mineral-related operations that do not require the filing of operating plans or notices of intention to operate?

Yes. Operating plans or notices of intention are not required for those mineral-related activities that will cause little or no surface resource disturbance. Examples of such activities include: geologic mapping; geochemical prospecting; surveying; geophysical exploration that does not require the use of explosives; gold panning; mining operations confined underground; locating, marking, and monumenting mining claims; the use of motorized vehicles only on existing roads and trails which are open to public uses; and off-road use of motor vehicles only in areas open to such use.

31. I'm a "rockhound" or mineral collector. How are my activities covered by requirements for operating plans or notices of intention to operate?

Your activities do not generally require either an operating plan or a notice of intention to operate. However, if you have any doubt about whether or not your activities will cause significant surface resource disturbance, you should file a notice of intention.

32. Do I have to observe off-road vehicle closures?

Yes. A prospector or miner who reasonably needs to use a vehicle or earthmoving equipment in an area closed to use of off-road vehicles may do so, but he must first file a notice of intent and he may, depending upon whether the use will cause significant disturbance of surface resources, be required to file and obtain approval of an operating plan.

33. Will I be required under these regulations to post a bond or put up a cash deposit of any kind?

A bond, ordinarily a surety bond, or cash deposit will frequently be required before an operating plan is approved. Of course, no bond or deposit will be required for operations for which no operating plan is needed.

34. What is the purpose of a bond or deposit?

The intention is to assure compliance with the reclamation provisions of the regulations and operating plans (see section 252.8(g) of the regulations).

35. What will be the amount of the bond or cash deposit required?

It will be determined by the estimated cost of the work needed to reasonably reclaim surface resources disturbed by operations. If the operator failed to do the work, the bond or deposit would be used by the Forest Service to do the work or have it done.

36. Can I be required to reclaim or rehabilitate disturbed lands to improve their condition or potential over and above the condition I found them in?

Not if it will result in extra costs over what would otherwise be reasonable and ordinarily required. Of course, any voluntary improvements you might wish to make would probably be welcomed.

37. Under what circumstances can I expect my bond to be released or deposit to be returned?

The authorized officer will notify you and will return the deposit or release the bond when your reclamation work has been completed in accordance with the approved operating plan and so accepted by the Forest Service. This could be done on a piecemeal basis if you do the reclamation in definite stages.

38. Who will review notices of intention to operate and plans for proposed operations, and what are the reviewer's qualifications?

Who will do the reviewing depends on the kind and scope of proposed operations, the type of land and surface resources that may be involved, and so on. Reviewers may be foresters, mining engineers, mining geologists, civil engineers, hydrologists, biologists, soil scientists, fisheries experts, metallurgists, etc. In some cases, the U.S. Bureau of Mines and the U.S. Geological Survey will be asked to help.

39. What are the qualifications of the forest officer who will be responsible for reviewing the design and standards of roads included in the operating plans?

His experience and training will have made him familiar with the type of road proposed. In many cases, he will be a graduate experienced civil engineer, especially when high standard roads are proposed for heavy haulage.

40. What action would the Forest Service take if I were to operate without an approved operating plan?

If you were causing significant surface resource disturbance, you could expect to be contacted to work up an operating plan. The Forest Service seeks your cooperation. In those rare cases where operators refuse to cooperate, the Forest Service will, as a last resort, take whatever legal action may be required.

41. What kinds of proposed operations are most likely to require the preparation of environmental statements by the Forest Service?

We expect environmental statements will not often be necessary; mostly they will be for new roads that may be needed across National Forest lands for access. Note that the Forest Service will prepare them.

42. Will appeals to Regional Foresters be reviewed by knowledgeable people, including mining engineers and geologists?

Yes. Regional Foresters are expected to base their decisions on the advice of people who know the activities involved in appeals.

43. Do the regulations apply to building houses or cabins on mining claims?

No. The right to build and occupy residences on mining claims is governed by law. Residences ordinarily can be justified only on valid mining claims and under circumstances where they are necessary and directly related to mining purposes. However, the regulations do call for the removal of structures under certain circumstances.

44. Will these regulations be used to identify mining claims for validity determinations?

No. However, the Forest Service will, as always, seek to end unauthorized uses of mining claims and may resort to validity determinations.

## Operations in National Forest Wilderness

45. Do these regulations apply to National Forest Wildernesses?

    Yes. However, Congress has given special status to Wildernesses, and the standards will be somewhat stiffer than on other lands.

46. How do I identify National Forest Wilderness areas?

    Maps are available at Forest Supervisors' Offices, Ranger Stations, and Regional Offices of the Forest Service. Also, Wilderness boundaries are marked on trails crossing them.

47. May I prospect in a wilderness under the 1872 mining laws and under these regulations?

    Yes, as long as such activities are carried out as prescribed by the Wilderness Act and in conformance with the applicable regulations.

48. What prospecting methods may I use in a wilderness?

    Most ordinary prospecting methods; however, special limitations and restrictions have been placed on the use of mechanized equipment.

49. May I locate mining claims in a wilderness?

    Yes, until midnight, December 31, 1983.

* * * * *

## GEOTHERMAL ENERGY BILL APPROVED

H.R. 14920 - Geothermal Energy Research, Development and Demonstration Act has been approved. The bill will further research, development, and demonstrations in geothermal energy technologies, establish a geothermal energy coordination and management project, amend the National Science Foundation Act of 1950 to provide for the funding of activities relating to geothermal energy, amend the National Aeronautics and Space Act of 1958 to provide for the carrying out of research and development in geothermal energy technology, and carry out a program of demonstrations in technologies for the utilization of geothermal resources.

* * * * *

## NORTHWEST MINING ASSOCIATION TO MEET

The 80th annual convention of the Northwest Mining Association will be held this year at the Davenport Hotel in Spokane, Washington, Friday and Saturday, December 6 and 7. It is expected that attendance may reach 1,500 persons. Non-members are welcome. The program will include sessions on: Gold and Silver; Geology and Exploration; New Developments in the Region; Mineral Processing; Mining Technology; and Industrial Minerals. Related activities include dedication of the U.S. Bureau of Mines' new center and tours of the facility, symposium on geology in land planning, and a student-oriented panel discussion on careers in mineral sciences and technology.

For further information address the Northwest Mining Association, West 522 First Avenue, Spokane, Wash. 99204. Phone 509-624-4822.

* * * * *

## COASTAL LANE COUNTY GEOLOGY PUBLISHED

"Environmental Geology of Coastal Lane County, Oregon," designated as Bulletin 85, is the Department's latest in a series of reports on the environmental geology of areas in the State where development is on the increase and where geologic hazards pose problems in construction and possible threats to human safety. Authors are H. G. Schlicker and R. J. Deacon, and a section on ground water is by R. C. Newcomb and R. L. Jackson. A soil interpretive guide and soils map by Ted Dietz are in the Appendix.

Bulletin 85 describes the geography, geologic units, and structure of the area and relates these inherent characteristics to the potential hazards, such as landslides, excessive erosion, flooding, and unstable soils. Economic mineral resources and ground-water conditions are also reviewed. The report is designed for planners, developers, engineers, geologists, and others concerned with the nature and use of the land.

The coastal Lane County report has 116 pages, many photographs, charts, a multicolor geologic map, and a hazards map. It is for sale at the Department's offices in Portland, Baker, and Grants Pass for $7.50.

* * * * *

## WORLD'S DEEPEST HOLE

Lone Star Producing Co. bottomed its "Bertha Rogers 1" well in Washita County, Oklahoma at a depth of 31,441 feet this past summer. Molten sulfur was encountered at the bottom of the hole. The hole was plugged back to 13,000 feet and was completed as a gas well. Reported cost was $5 million.

* * * * *

## 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

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| 8. Feasibility of steel plant in lower Columbia River area, rev. 1940: Miller | $0.40 |
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| 35. Geology of Dallas and Valsetz quadrangles, Oregon, rev. 1963: Baldwin | 3.00 |
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| 81. Environmental geology of Lincoln County, 1973: Schlicker and others | 7.50 |
| 82. Geol. hazards of Bull Run Watershed, Mult. Clackamas Cos., 1974: Beaulieu | 5.00 |
| 83. Eocene stratigraphy of southwestern Oregon, 1974: Baldwin | in press |
| 84. Environmental geology of western Linn Co., 1974: Beaulieu and others | 8.00 |
| 85. Environmental geology of coastal Lane Co., 1974: Schlicker and others | in press |

### GEOLOGIC MAPS

| | |
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| Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck | 2.15 |
| Geologic map of Oregon (12" x 9"), 1969: Walker and King | 0.25 |
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| GMS-4: Gravity maps of Oregon, onshore & offshore, 1967: Berg and others [sold only in set] flat $2.00; folded in envelope | 2.25 |
| GMS-5: Geology of the Powers quadrangle, 1971: Baldwin and Hess | 1.50 |
| GMS-6: Prelim. report, geology of part of Snake River Canyon, 1974: Vallier | in prep. |

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# COASTAL LANDFORMS BETWEEN ROADS END AND TILLAMOOK BAY, OREGON

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Bold, rocky headlands alternating with long curved beaches, sandspits, and bays -- these are the dominant landforms that make up the more than 40 miles of scenic coastline between Roads End and Tillamook Bay. With the exception of Cape Kiwanda, which is composed of sandstone, the headlands are made of basalt, a rock that erodes slowly. The lowlands and bays between the headlands are in more easily eroded sedimentary rock. Thus the coastline is scalloped by a sequence of large protrusions and indentations. Viewed in detail, however, there are numerous small shoreline features such as points, knobs, coves, and sea stacks that are due to local variations in bedrock characteristics.

## Geologic Background

Most of the bedrock of this part of the coastal region was laid down on the sea floor during the Tertiary Period when the Pacific Ocean extended inland over part of western Oregon. Some of the bedrock units (geologic formations) were erupted from local volcanoes, while others were carried into the sea by rivers. Their total thickness is now measured in miles. Their ages range from late Eocene (about 40 million years old) to late Miocene (about 12 million years old). See Figure 1.

In Miocene time, the land that is now the Coast and Coast Range began rising from the sea. According to McKee (1972, p. 157), "By the middle of the Miocene Epoch, about 15 million years ago, most of the Coast Range region had emerged from the Pacific." The major uplift and folding of the rock layers occurred during late Tertiary, within the past 10 million years, and culminated during the Pliocene Epoch. Volcanism continued along the edge of the sea until late Miocene or early Pliocene.

Resting on the eroded Tertiary bedrock are younger semi-consolidated sedimentary rocks and loose sedimentary material that has been deposited within the past 2 million years, the Quaternary Period. The oldest of these were deposited during the Pleistocene Epoch, which ended about 10 to 15

| Period | Epoch | Beginning |
|---|---|---|
| Quaternary | Holocene<br>Pleistocene | 10-15 thousand years<br>2 million years |
| Tertiary | Pliocene<br>Miocene<br>Oligocene<br>Eocene<br>Paleocene | 6 million years<br>22 million years<br>36 million years<br>58 million years<br>63 million years |

Figure 1. Geologic calendar for the Cenozoic Era. (From Flint and Skinner, 1974)

thousand years ago with the culmination of the ice age, and the youngest are of the Holocene (Recent) Epoch, the epoch in which we are living.

Since the characteristics of each rock unit (geologic formation) have important roles in landform development, a brief description of each is given below. The descriptions are in order of oldest to youngest. The accompanying map, pages 184-185, shows their distribution.

## Tertiary bedrock

Nestucca Formation: The Nestucca Formation, of late Eocene age, "...consists primarily of interbedded, tuffaceous, and somewhat shaly siltstone and claystone, and feldspathic and basaltic sandstone," (Snavely and Vokes, 1949). Because of its high clay content, this formation is weak and very subject to landsliding. Weathering of the volcanic ash which makes up the tuffaceous component of the rock and also forms discrete ash layers produces a clay of soapy consistency and very little strength when wet.

The Nestucca Formation crops out along the beach at Roads End and in the cliffs of the small headland north of Roads End. It is exposed at numerous places along U.S. Highway 101 behind Cascade Head, along the road to Three Rocks, and along the seaward face of Cascade Head just north of Salmon River.

Basalt of Cascade Head: The basalt of Cascade Head is of late Eocene age and rests on the Nestucca Formation. It consists of a variety of volcanic rocks that includes dense flow lava, flow breccia, and tuffs. Some of the rock is vesicular, and in places the vesicles are filled with quartz. Interspaces between breccia fragments are filled mainly with quartz and zeolites. Numerous basalt dikes cutting the Nestucca Formation in roadcuts along the highway on the back side of Cascade Head probably solidified in fissures that channeled lava to the surface eruptions.

From the main occurrence of this basalt at Cascade Head, the unit extends to the northeast and forms hilly terrain south of the Little Nestucca

Figure 2. Roads End, north of Lincoln City, is built mostly on a Pleistocene marine terrace. Cascade Head is in the distance. (State Highway Division photo by Kinney)

Figure 3. Coves in the small headland south of Salmon River. Points of dark rock are basalt; lighter rock is Nestucca Formation. (State Highway Division photo by Kinney)

River. It forms a resistant facing along the sea cliffs in the small headland north of Roads End.

Oligocene to Miocene sedimentary rocks: Rocks of this age are widespread but are not assigned to specific formations by Schlicker and others (1972, p. 14) for this part of the Oregon Coast. The unit is composed of tuffaceous siltstone with lesser amounts of sandstone and claystone of considerable thickness. Erosion tends to produce a low, subdued topography. Exceptions are where more resistant beds occur, as at Porter Point south of Nestucca Bay. Here, a dense, hard, basaltic sandstone forms sea cliffs and rock knobs along the beach.

Astoria Formation: The Astoria Formation is a thick-bedded, medium-grained gray sandstone; it is generally weathered to a buff color. The main body of the formation on this part of the Coast begins south of Cape Lookout, where it is exposed in roadcuts along the highway and extends northward around Cape Meares to Tillamook Bay. It is the bedrock beneath the the terrace along the east side of Netarts Bay. The headland of Cape Kiwanda is composed of this rock.

Tertiary intrusive rocks: These are dikes, sills, and other intrusive bodies of middle to late Miocene age and are mostly of basaltic composition. The only outstanding example along this part of the shore is Haystack Rock off Cape Kiwanda. A large dike is exposed in a roadcut about a mile south of Tierra Del Mar, and a small one cuts the sandstone on the south side of Cape Kiwanda at its landward end.

Miocene volcanic rocks: These are late Miocene basalt flows and associated intrusions that were feeders to the flows. The flows are partly pillow lavas and breccias, which either erupted under the ocean or flowed into it, and partly dense, columnar-jointed basalt that erupted onto land. Both pillow basalt and thin flows with columnar structure are exposed in roadcuts and in a quarry at the summit of the road over the Cape. In some places, lavas and sandstone are intermixed.

This basalt is a time equivalent of the Columbia River Basalt in the Columbia River Gorge and of the basalt at Depoe Bay, Cape Foulweather, and Yaquina Head on the Oregon Coast to the south. From Cape Lookout, it extends northeastward along the southern end of Netarts Bay. It is the bedrock at Oceanside and extends north to form Cape Meares headland.

## Quaternary deposits

Marine terrace sediments: Terrace deposits were laid down over wave-cut benches during interglacial stages of the Pleistocene Epoch when there was little ice on the land at northern latitudes and sea level stood higher than it does now. The most recent interglacial stage, the Sangamon, preceded the Wisconsin glacial stage; remnants of a terrace formed during that stage are present at several places along this stretch of the Coast.

Marine terrace deposits are composed mostly of loosely cemented sandstone, but locally there may be conglomerate at the base, or siltstone or conglomerate interbedded with the sandstone. In some places wood is abundant. Where the terrace deposits are adjacent to basaltic headlands, layers of angular basalt fragments (talus) are interbedded with the terrace sediments.

Roads End (Figure 2) is at the north end of the long terrace segment that begins at Siletz Bay and upon which nearly all of Lincoln City is built. Part of Tierra Del Mar is on a terrace that extends northward for about 2 miles along the southeastern side of Sand Lake. A small segment extends south from Cape Lookout to about Camp Meriwether, where it is mostly covered with dune sand. The camping and picnic areas at Cape Lookout State Park are on a terrace that extends northward along the east edge of Netarts Bay about a mile beyond Netarts community, where it disappears beneath a sand dune.

River alluvium: The rivers all have alluvial plains, most of which extend many miles upstream. At the lower ends of the valleys, the alluvial sand, silt, and clay merge with the silt and clay of the tidal flats along the estuaries to form meadows that support the dairy industry. The most extensive alluvial plain is in the Tillamook embayment, where bay filling and the alluvial sedimentation by the five rivers that empty into the bay have created an extensive lowland that forms the heart of the Tillamook dairyland.

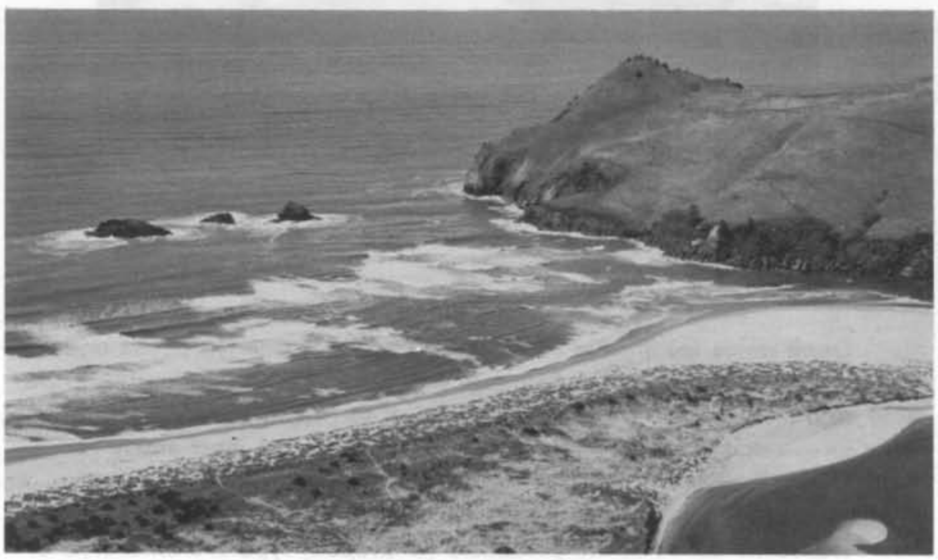


Figure 4. Three Rocks at the mouth of Salmon River are composed of Cascade Head basalt and are remnants of the basalt promontory at the southern part of Cascade Head. (State Highway Division photo by Kinney)

Figure 5. Irregular shore along the face of Cascade Head.
(State Highway Division photo by Kinney)

Dune sand: Dune sand is of both Pleistocene and Holocene age. In places, stratified terrace sandstones are overlain by ancient rusty-yellow dune sand that in turn is mantled by a thick soil layer beneath a forest of large spruce and fir trees. Pleistocene dune sands are most easily recognized where they are penetrated by roadcuts that reveal their complex cross bedding.

Holocene dunes of the parabolic (U-shaped) type are extensive at Cape Kiwanda and Sand Lake, and remnants of three large parabolic dunes lie north of Netarts Bay. Smaller dunes occupy the crests of beach ridges and sandspits. Most of the dune surface is stabilized with grass or pine forest, but in the Cape Kiwanda and Sand Lake localities there is still considerable dune-forming activity (see Figure 13).

North of Roads End is a small headland consisting mainly of sedimentary rock of the Nestucca Formation partly protected from erosion by basalt along its seaward side (Figures 2, 3). The basalt was once continuous along the shore in the form of a wall in front of the sedimentary rock, but wave erosion has breached the wall in several places. Where the basalt wall has been removed, erosion is cutting rapidly into the soft sedimentary rock, and small coves have formed (Figure 3). Landsliding in the Nestucca Formation combined with wave erosion continues to enlarge the coves. In time the sedimentary rock will be removed from behind the basalt, and the basalt masses will become separated from the mainland, forming offshore sea stacks. Three Rocks, just to the north off the mouth of Salmon River (Figure 4), are of similar origin.

Cascade Head (Figures 4,5), with sea cliffs rising more than 500 feet above the sea and a shore front of more than 5 miles, is one of Oregon's largest headlands, rivaling Tillamook Head in size. The basalt mass that makes up the headland lies between Salmon River and Neskowin Creek and covers an area of about 7 square miles. The highest point has an altitude of 760 feet.

The shore front of the southern half of Cascade Head is undergoing the same kind of erosion as the small headland to the south. With breaching of the basalt wall, extensive landsliding has been activated along six embayments (North and Byrne, 1965, p. 228). The largest landslide, a tenth of a mile north of Salmon River, is reported to have occurred in 1934 and destroyed 20 acres of pastureland.

Proposal Rock (Figure 6), a small tree-covered island or sea stack at Neskowin, is a basalt remnant of a once larger Cascade Head. Tree stumps (Figure 7) on the beach just north of the sea cliffs have a radiocarbon date of nearly 2,000 years. Their presence at sea level indicates that either the land has subsided since the trees were growing or the sea has risen (or both).

North of Cascade Head to Nestucca Bay is a continuous beach along a shore that, from the headland almost to Porter Point north of Camp Winema, has been built outward from the edge of the upland. Such a built-up shore is referred to as prograded. A beach ridge with sand dunes along the crest has impounded Daley Lake (Figure 8). The lake was once more than twice its present size, but the southern part is now a bog.

Nestucca Bay is the main body of an estuary at the confluence of Nestucca and Little Nestucca Rivers. A south-projecting sandspit (Figure 9) has deflected the mouth of the Nestucca River southward about $3\frac{1}{2}$ miles. Both rivers have wide alluvial plains, and the main Nestucca plain extends far inland.

Cape Kiwanda (Figures 10,11), at the north edge of the Nestucca embayment, is an unusual promontory in that it is composed almost entirely

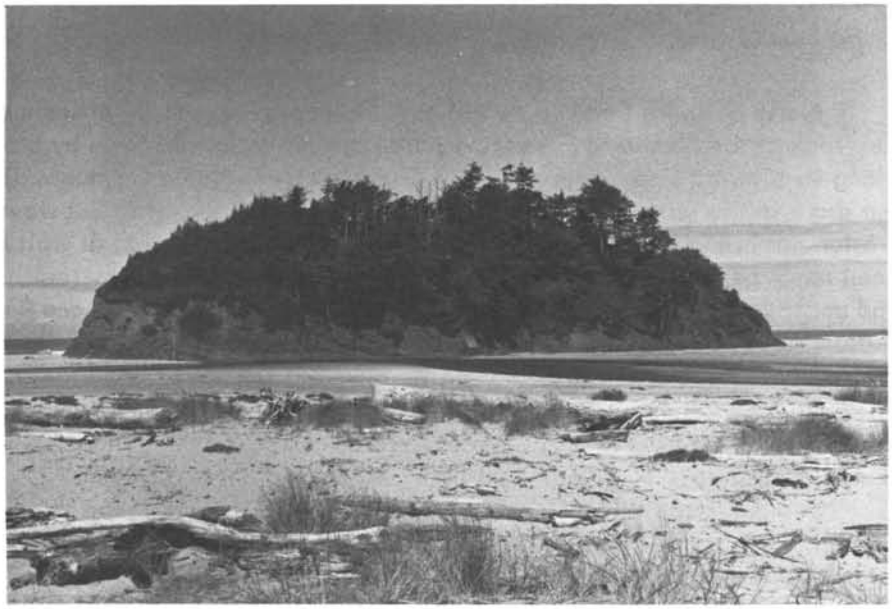


Figure 6. Proposal Rock, on the beach at Neskowin, is a remnant of Cascade Head basalt.

Figure 7. Tree stumps in surf south of Neskowin indicate rising sea level or sinking land. (Photo by Bill Holser)

Figure 8. Daley Lake is impounded by a beach ridge on a prograded shore north of Neskowin. Rocky shore north (left) of the lake is Porter Point. (State Highway Division photo by Kinney)

of sandstone of the Astoria Formation. This point of sandstone owes its survival in small part to the basalt dike on its south side but more importantly to Haystack Rock (Figure 10), a basalt sea stack four-tenths of a mile to the southwest. At one time, the promontory extended to Haystack Rock, which defended the sandstone from severe winter wave attacks from the southwest. Erosion on the flanks of the promontory finally separated the the basalt from the sandstone, isolating it as a sea stack. With the loss of the protection provided by the basalt, the tip of the Cape receded to its present position. Haystack Rock still gives some protection to the Cape by receiving part of the assault of the storms from the southwest, but the Cape is being visibly eroded, principally by undercutting along the sea cliffs and by rock fall. Cape Kiwanda, with its caves and arches and deep chasms, is a marvelous example of natural sandstone sculpture on a large scale (Figures 11, 12) and has been referred to as one of the most photogenic landforms in America. Remnants of huge parabolic dunes that mantle the highest parts of Cape Kiwanda add to the scenic interest of the locality. East of the Cape, dunes, now partly forested, have blocked drainage to the ocean and have formed small lakes behind tongues of sand (Figure 13).

North of Cape Kiwanda, Sears Lake (Figure 14) occupies a shallow indentation in the Tertiary bedrock and is dammed by beach sand that forms a barrier similar to that at Daley Lake.

Figure 9. Nestucca Spit, projecting from Cape Kiwanda, deflects the Nestucca River southward to Nestucca Bay, where it joins the Little Nestucca River. (State Highway Division photo by Kinney)

Sand Lake (Figure 15) is in a small embayment occupied by a shallow body of water and about an equal amount of tidal marshland. Only small streams flow into the embayment, but an opening between north- and south-projecting sandspits allows the tidal movement of water in and out; consequently Sand Lake is actually a small estuary. From Sand Lake, the beach continues to Cape Lookout; along the northern part it is in front of a sea cliff of terrace sediment.

Cape Lookout (Figure 16) is a narrow promontory of Miocene basalt about 1 3/4 miles long. The layers of basalt in the Cape are tilted toward the north and the ground surface slopes in the same general direction; hence, the cliffs along the nearly straight south side are considerably higher --

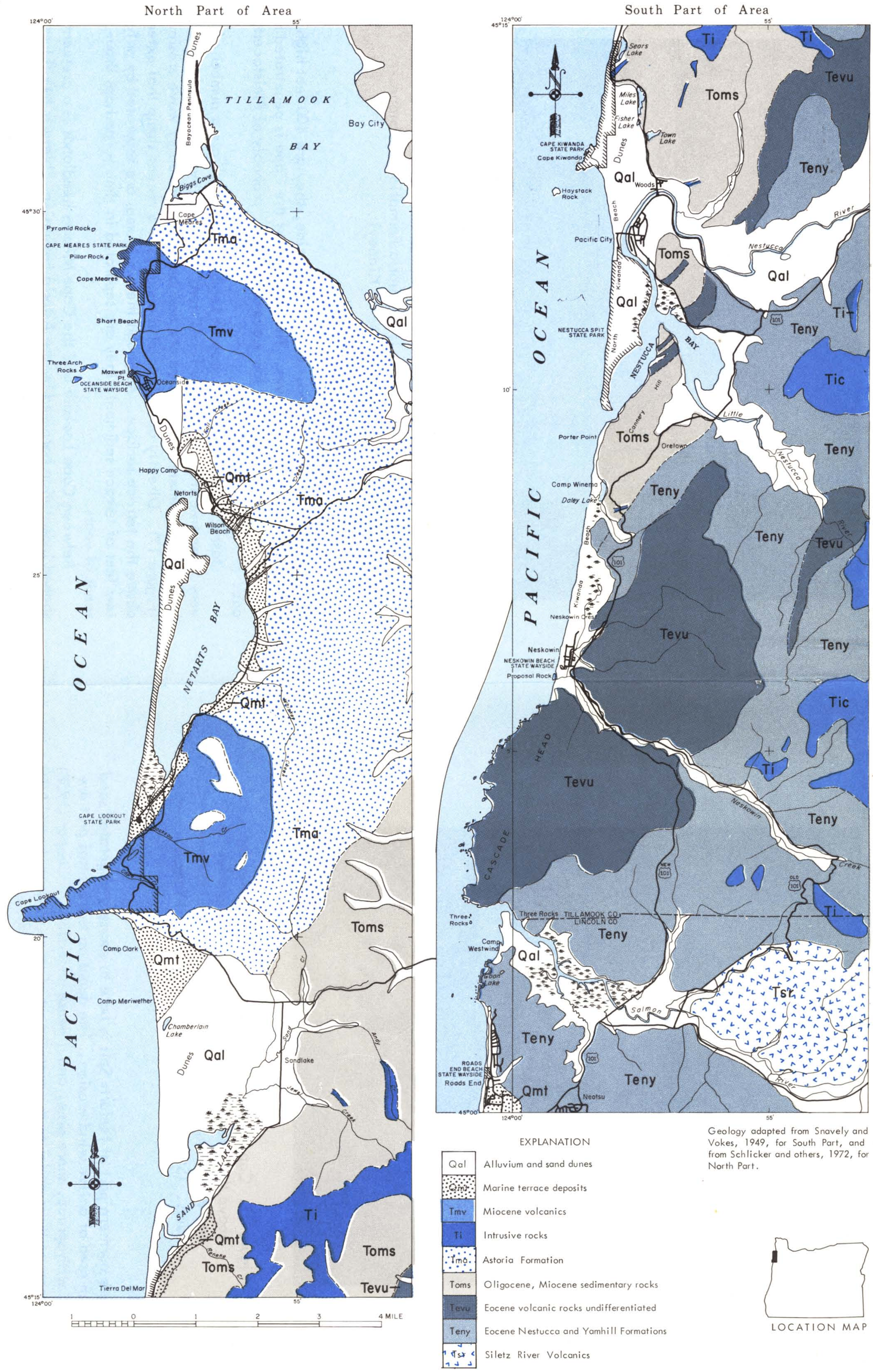
Figure 10. Haystack Rock off Cape Kiwanda is a remnant of a basalt intrusion. Cape Kiwanda is of Astoria Formation sandstone. (State Highway Division photo by Kinney)

800 feet on the landward end. On the north side, they are 400 feet high and indented with scenic coves. The blunt tip of the Cape is penetrated by a sea cave and notched by a low wave-cut bench, probably of Pleistocene age.

Just south of the picnic area at Lookout State Park are a number of very large tree stumps, in growth position, at beach level. Once buried by terrace sediments, the stumps are now being uncovered by wave erosion (Figure 17). Directly above one of the stumps is a recent stump that extends above the terrace surface. Although the two stumps are separated by only a few feet of terrace sediment, they are separated in time by perhaps thousands of years.

Between Cape Lookout and the Cape Meares headlands is a crescent-shaped indentation bordered by the Astoria Formation. Netarts Bay (Figure 18) occupies the indentation behind the long, narrow Netarts Spit projecting 6 miles northward from Cape Lookout. Netarts Bay is a very shallow body receiving water from a few small streams. The bay empties and fills through a well-established channel at the north end, and at low tide it becomes a broad mudflat with small drainage channels.

# GEOLOGIC MAP OF THE OREGON COAST FROM ROADS END TO TILLAMOOK BAY




Geology adapted from Snavely and Vokes, 1949, for South Part, and from Schlicker and others, 1972, for North Part.

Figure 11. Cape Kiwanda. The roundish wooded area above the center of the photograph and a smaller one at the southern edge of the Cape are dune remnants. (State Highway Division photo by Kinney)

The northern part of Netarts Spit is bare to sparsely vegetated sand and is an area of active wind erosion. The dunes on the central part are forested with spruce, shore pine, and a dense understory. Cooper (1958) relates part of these dunes to the easternmost of three truncated parabolic dunes north of the bay.

North of Netarts Bay is a large area of Miocene basalt with two seaward-projecting lobes. From the southern lobe a small headland, Maxwell Point, shelters the beach at Oceanside (Figure 19). Between the two basalt lobes is Short Beach (Figure 20). The northern basalt lobe, Cape Meares (Figure 21), consists of elongate rock points separated by deep coves. There

Figure 12. Waves beating against the cliff at Cape Kiwanda. A tunnel penetrates a wall of sandstone to form an arch. (State Highway Div. photo)

Figure 13. Parabolic (U-shaped) sand dunes east of Cape Kiwanda. Town Lake, Fisher Lake, and Miles Lake are impounded by the dunes. (State Highway Division photo by Kinney)

Figure 14. Sears Lake is impounded by a beach ridge on a prograded shore. Sand Lake and a large parabolic dune are in the distance. (State Highway Division photo by Kinney)

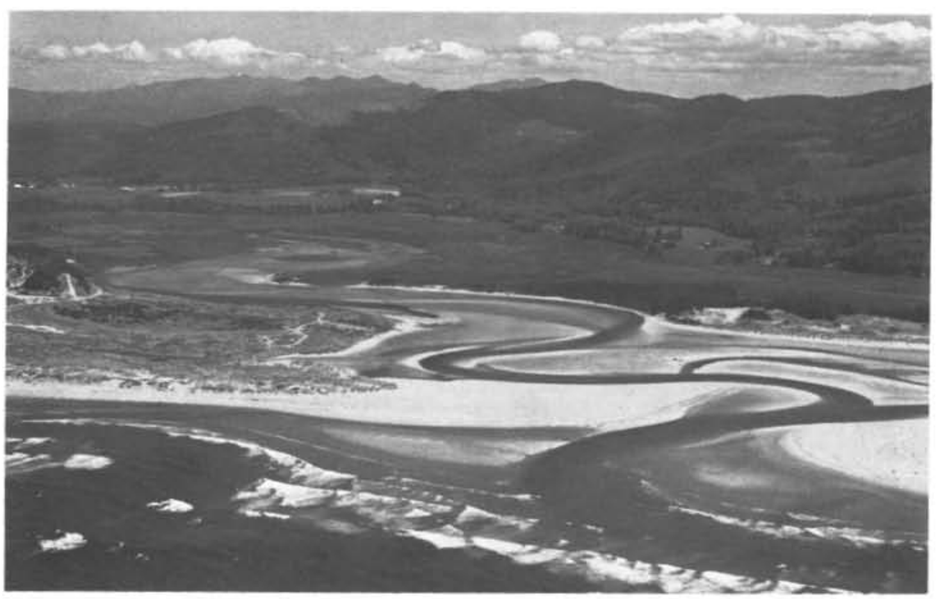


Figure 15. Stream channels wind through the tidal flats at Sand Lake. The wooded island east of the bare flats is a dune remnant. (State Highway Division photo by Kinney)

Figure 16. Cape Lookout is a narrow basalt headland 1 3/4 miles long with a sea cave and a wave-cut bench at its tip. (State Highway Division photo by Kinney)

Figure 17. Tree roots of two ages in terrace sediments at Cape Lookout State Park. Upper stump is of modern age; lower may be as old as Pleistocene.

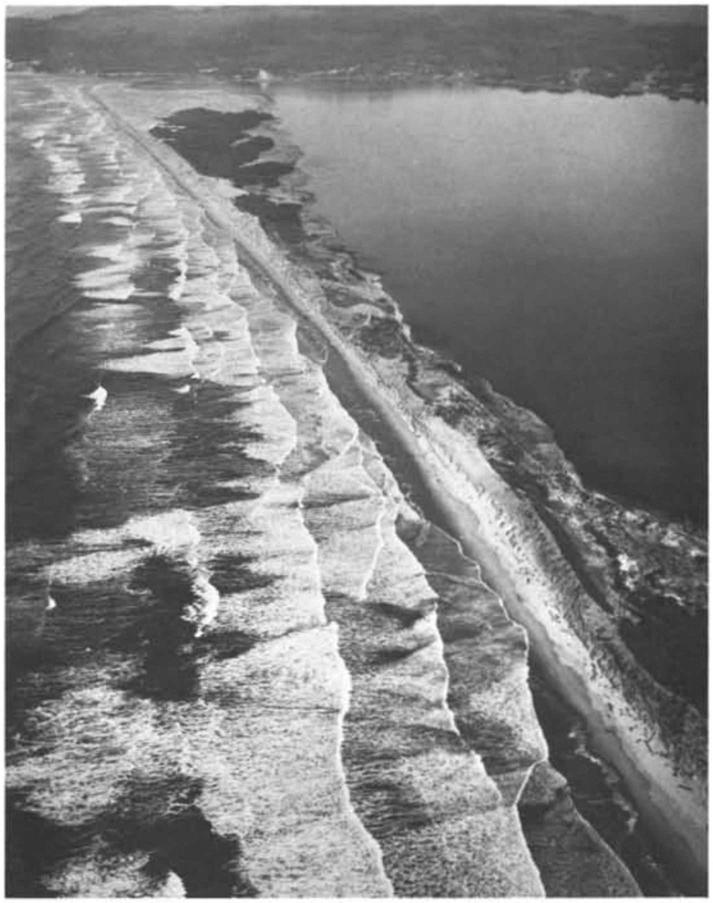


Figure 18. Netarts Bay and sandspit. The forested area near the middle of the sandspit is on dune remnants. (State Highway Division photo by Kinney)

sea cliffs rise in vertical or nearly vertical walls to elevations of 400 feet. A lighthouse is situated at the tip of the longest projection.

Extending offshore from Maxwell Point for nearly a mile are rock knobs, stacks, and arches, all remnants of a former promontory. The largest are Three Arch Rocks (Figure 22) whose arches were most likely sea caves or tunnels when these rocks were connected to the mainland. The middle arch is visible from the southern end of Netarts Bay, and the inner and outer ones can be seen from the tip of Cape Meares. Ofshore from Cape Meares are Pillar Rock and Pyramid Rock (Figure 23). Both of these sea stacks are nesting places for sea birds and, like a number of other offshore rocks, have been declared wildlife sanctuaries.

Figure 19. Maxwell Point at Oceanside is a small basalt promontory on the southern lobe of the basalt mass. (State Highway Div. photo by Kinney)

Figure 20. Short Beach, south of Cape Meares, lies along an indentation in the basalt mass. (State Highway Division photo by Kinney)

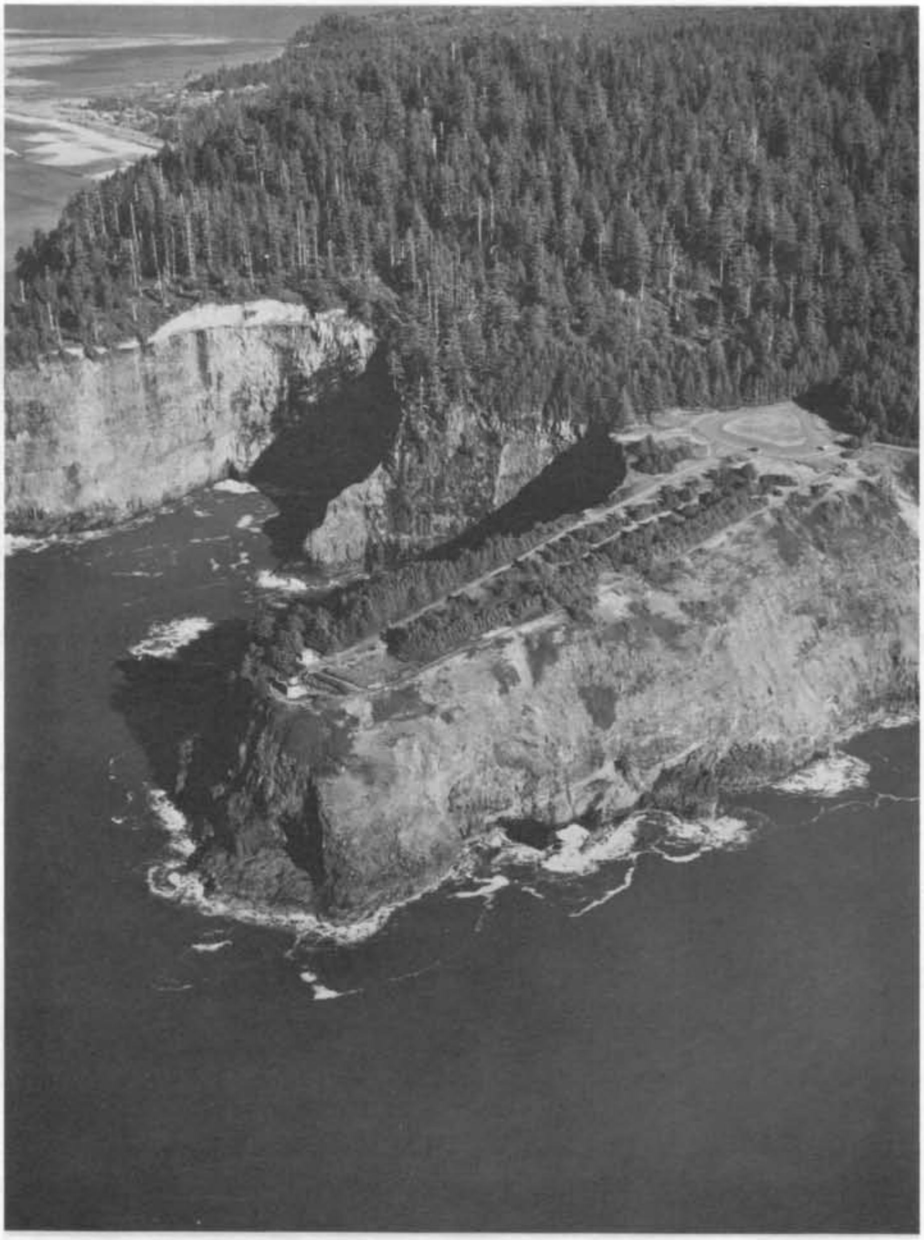


Figure 21. Cape Meares consists of basalt flows that are overlain in places by Miocene sedimentary rock, some of which is exposed at the top of the sea cliff in the upper left part of the photograph. (State Highway Division photo by Kinney)

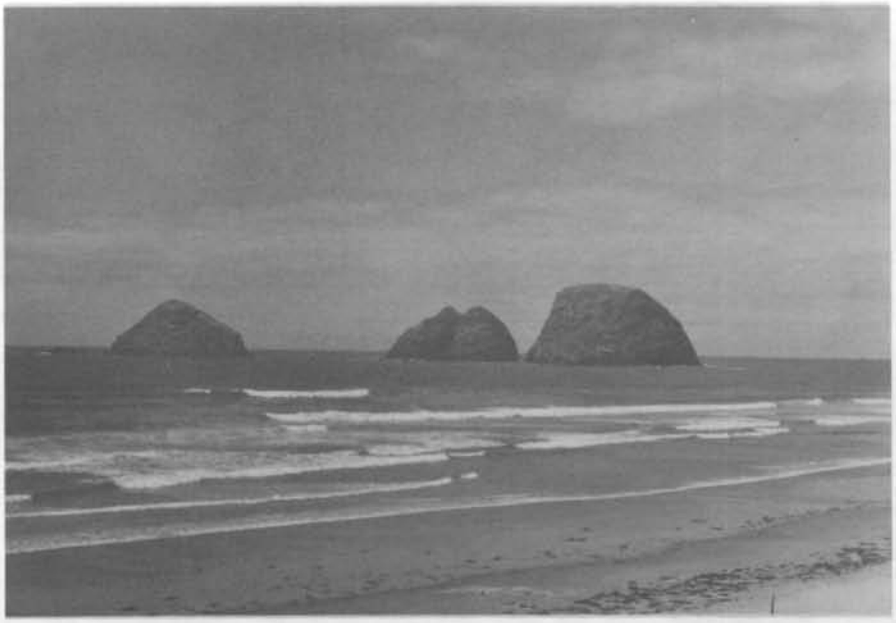


Figure 22. Three Arch Rocks off Oceanside are basalt remnants, each with a tunnel through it.

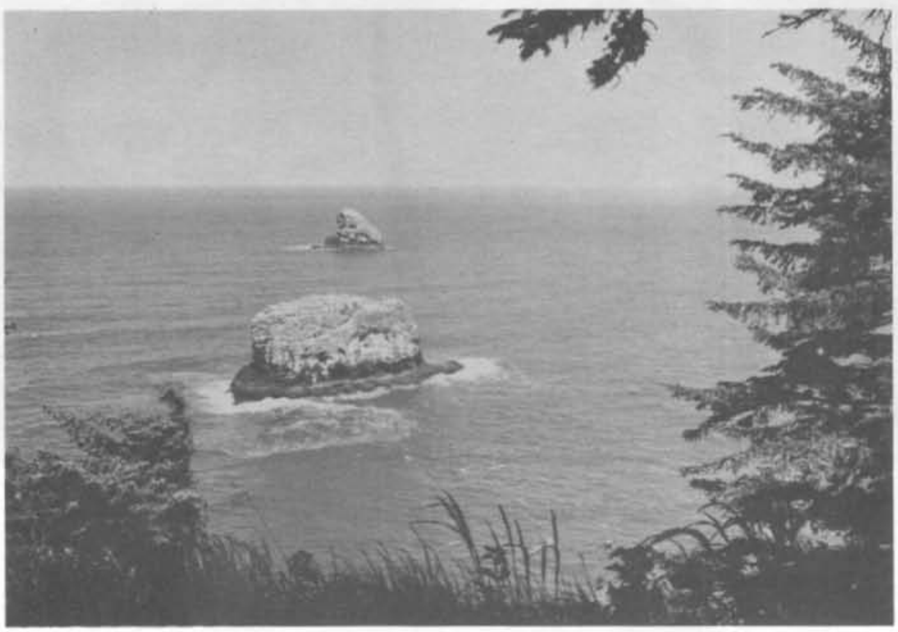


Figure 23. Pillar Rock, shaped like a brimmed hat, and Pyramid Rock in the distance are basalt sea stacks off Cape Meares.

Figure 24. Bayocean Peninsula, the sandspit at Tillamook Bay, projects 4 miles northward from Cape Meares. A dike along the Bay was built to close a mile-long gap eroded during a storm in 1952. A beach ridge makes a natural connection along the ocean shore. (State Highway Division photo by Kinney)

Projecting 4 miles northward from Cape Meares is Tillamook Spit, known also as Bayocean Peninsula (Figure 24). Toward its northern end, the spit has dune remnants that reach heights of 140 feet. Most of the dunes are forested, but some are still active. According to Cooper (1958, p. 84), a reconstruction of the dune system indicates that the outlet for Tillamook Bay was formerly at the south end of the spit.

Tillamook Spit has had a history of damaging erosion that began during the construction of the jetty on the north side of the Tillamook Bay outlet. Jetty construction began in 1914, and the structure was completed in 1933. According to Dicken (1961), erosion probably began between 1920 and 1925. The rate of erosion was slow at first but became noticable in the early 1930's. From 1926 to 1932 erosion was about 1 foot per year at Bayocean, a resort developed on the spit in 1906. Waves broke through the spit in 1932, and property at Bayocean was severely damaged. In 1939, winter storms caused heavy damage to the peninsula. The road at the south end of the spit was cut in two, and a hotel and natatorium at Bayocean were destroyed. Dicken estimates that erosion between 1939 and 1960 was about 50 feet per year.

By 1952, there was a mile-long break in the sandspit. In 1955-56 a dike was constructed to seal it. A beach ridge has subsequently formed a natural connection between the mainland and the detached part of the spit, and a shallow lake lies between the dike and the beach.

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* * * * *

## HULL NEW GEOLOGIST AT BAKER OFFICE

Donald A. Hull has joined the Department staff as Economic Geologist at the Baker field office. During the coming months he will be working with Dick Bowen in the Department's on-going geothermal exploration program funded by the U.S. Bureau of Mines.

Don has had considerable experience in geologic and mineral exploration and management and has been working in these capacities for Homestake Mining Co. for most of the years since 1964. Prior to joining the Department staff, he was manager of Homestake's regional exploration programs in northwestern United States and Canada.

Don graduated from Wallace High School, Wallace, Idaho in 1955; he obtained his B.S. degree from the University of Idaho, Moscow, Idaho in 1960, his M.S. degree from McGill University, Quebec in 1963, and his Ph.D. degree from the University of Nevada, Reno, Nevada in 1970. He is married and has three children.

* * * * *

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# THE COLUMBIA RIVER GORGE
## THE STORY OF THE RIVER AND THE ROCKS

Ron Suchanek*

## Introduction

The Columbia River Gorge is a most spectacular and beautiful sight. Although it is not the deepest canyon in North America, its primitive beauty makes us wonder what tremendous forces of nature interacted to bring about its creation. The most obvious force of nature is the erosive power of the Columbia River itself as it cuts its way through the Cascade Mountains.

But, what about those steep cliffs, how did they form? Why are there more waterfalls on the south side of the river than on the north? Were the Cascade Mountains always there, or were they formed by some particular force? As we wonder about it, more and more questions arise.

In order to seek answers to our many questions, let us travel the 65-mile length of the Columbia River Gorge for a closer look at the rock formations and geology of the area. We will supplement our observations with information from the literature on the geology of the Gorge (see references at end of report) and try to put together a picture of how the Gorge came to be as we see it today. Particularly helpful in this regard is the article by A. C. Waters, "The Columbia River Gorge: Basalt stratigraphy, ancient lava dams, and landslide dams," published in Bulletin 77 of the Oregon Department of Geology and Mineral Industries.

## Our Field Trip

Our route east will take us up the Columbia Gorge on Interstate Highway 80N to the Bridge of the Gods at Cascade Locks, where we will cross the Columbia River and continue on the Washington side as far as the bridge to Hood River. Here we will cross back to the Oregon side, going east nearly

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* Ron Suchanek, a graduate student in Secondary Education at Portland State University, designed this non-technical account of the Columbia River Gorge for use by his students. The report was a term paper submitted in May 1974 for a course in Geology of Oregon taught at PSU by R. E. Corcoran.

to The Dalles. Our return trip to Portland will be on the Oregon side of the Columbia River via Interstate 80N and the old Scenic Highway (see accompanying map).

Starting from Portland State University, we will drive south on Broadway, enter the Freeway, and follow the signs for I-80N east toward The Dalles. Once on I-80N, continue east. Near Troutdale we will cross over the Sandy River. From this point on, start observing the rock formations on both sides of the river.

Take the Rooster Rock State Park exit, cross over I-80N, turn left, and follow the road to the west end of the parking lot.

STOP 1: Crown Point and Rooster Rock

Looking up, we see a great vertical bluff of resistant rock, named Crown Point, rising about 700 feet above the river. It is composed of columnar basalt. (Basalt is a dark-colored rock that has formed from molten lava flows.) It is believed that the bluff is a remnant of a great lava flow that filled an ancestral canyon of the Columbia River (Waters, 1973). Because this type of basalt is so common in this area, it was named Columbia River Basalt (nicknamed "Coriba" by E. T. Hodge, 1931). Some geologists have found that this same type of basalt extends farther north in eastern Washington and have called it Yakima Basalt (Waters, 1961). In this paper, we shall call it "Coriba" (Columbia River Basalt).

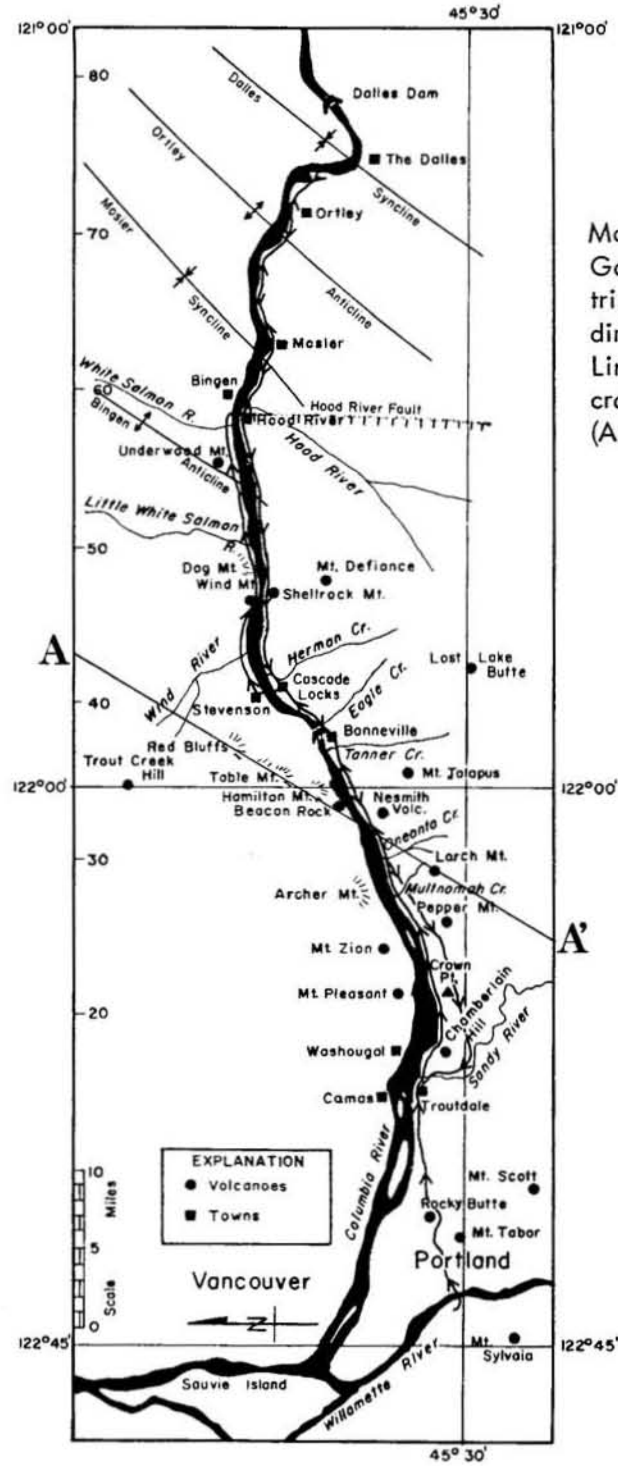
One characteristic of Coriba is its vertical or columnar jointing. (A joint is a fracture or break in the rock.) Because of the vertical jointing, weathered pieces of Coriba break away parallel to the face of the bluff and fall to the base of the bluff, forming a slope of fragments and scattered blocks known as talus.

Looking toward the river, we see a pinnacle of rock known as Rooster Rock, which is a huge piece of columnar-jointed basalt. What is this rock doing at the edge of the river? How did it get there? If we look just west of Crown Point, we see a recessed area in the cliff. It is thought that this is the scar of a landslide which, among other debris, deposited the huge piece of basalt upright at the river's edge (Williams, 1916; Waters, 1973). Because the rock is very hard and resistant to weathering and erosion, it still stands today.

Let us return to I-80N and continue east. Note the high bluffs of basalt on the right. Also note that there is another formation on top of the basalt, which we will examine later on our return trip to Portland.

About $6\frac{1}{2}$ miles farther, we pass Multnomah Falls and Larch Mountain on the right. We will also visit this area on our return trip.

As we proceed east, we get occasional glimpses of a huge rock at the river's edge on the Washington side. This rock, named Beacon Rock, rises about 800 feet above river level. As we drive, we can see that its sides are perpendicular for hundreds of feet. Is this another basalt pinnacle like




Map of Columbia River Gorge showing route of trip (arrows indicate direction of tour). Line A-A' is position of cross section on p. 207. (Adapted from Allen, 1957)

Rooster Rock? No, geologists believe that it is part of a volcanic plug. At one time it was an active volcano, which later plugged its own vent. The river eroded away the sides of the volcano and left the more resistant rock that formed the plug; hence Beacon Rock as we see it today (Williams, 1916; Waters, 1973).

On the Oregon side, we can see the basalt (Coriba) cliffs rising higher and higher above the river, in some places over 2,000 feet (Williams, 1916). Notice the many layers. Obviously they are the result of many huge lava flows and much volcanic activity in the geologic past.

About 14 miles beyond Crown Point we reach McCord Creek. Stop at the roadside outcrop of rock just before crossing the bridge.

STOP 2: McCord Creek - Eagle Creek Formation

Here a very different type of rock is exposed beneath the Coriba, rising to a height of about 250 feet above the river. Instead of solid dark rock like the basalt, we see a mixture of different sized light-grey rocks (from pebbles to boulders) held together by finer material. This rock formation is known as the Eagle Creek Formation, so named because of its discovery along Eagle Creek, a tributary of the Columbia River on the Oregon side (Williams, 1916). Since this formation is found beneath the Coriba, it must have been formed before the basalt flows. The obvious question, "How did it form?" comes to mind.

A study of the rocks in the Eagle Creek Formation show they are mostly volcanic fragments. The finer material appears to be composed of ashy silt and sand. All of this seems to indicate that the material was deposited as mudflows and slurry floods from nearby active volcanoes (Waters, 1973).

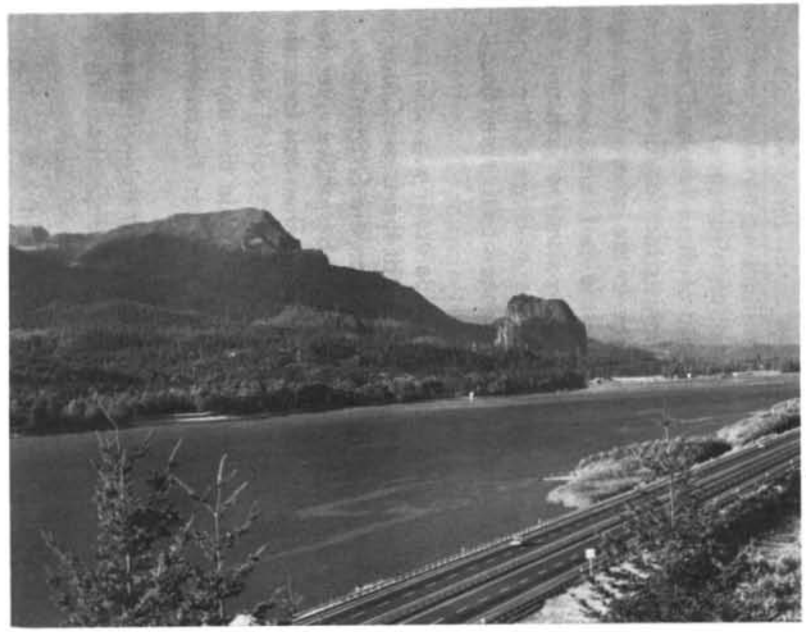
Closer study of the rock formation will reveal dark bands containing plant fragments. Chaney (1918) found wood and leaves of many plant species that are now extinct and determined that they grew here in early Miocene time, 14 to 16 million years ago (Chaney, 1959).

Two and a half miles farther east on I-80N, we will pass Eagle Creek, the type locality of the formation. Continue east.

Take the Cascade Locks exit and cross the Columbia River on the toll bridge. On the Washington side, turn right onto Washington Highway 14 (US 830). We are now skirting the lower portion (or toe) of the Bonneville Landslide. Note the hummocky ground and the jumble of rocks in the slide. As we pass Ash Lake, we have a good view of the cliffs forming the scarp, or break, at the head of the landslide.

STOP 3: Eagle Creek Formation

About 1.8 miles beyond the toll bridge we come upon a large block of Eagle Creek Formation perched on edge near the railroad track. Similar rock occurs in the roadcut (Waters, 1973). Stop here. Examine the Formation and compare it with what we saw on the Oregon side.



Above: Beacon Rock, the plug of an old volcano, rises from the Washington side of the Columbia River. (Hwy. Div. photo)

Left: Rooster Rock is a piece of an ancient landslide that slid from the recessed cliff to the south. (Hwy. Div. photo)

STOP 4: Overview of Bonneville Landslide Area

About 0.3 miles farther, stop again. From here we have an overview of the Bonneville Landslide area. Rockfalls and landslides peel off the cliffs of Eagle Creek and Coriba Formations at the head of the slide and move slowly toward the river. The forward motion of this slide has forced the river to the southern bank, causing a big rounded bulge in the otherwise straight course of the river. In the recent past, it is possible that there was a great downslope movement of material so as to temporarily dam the Columbia River and give rise to the local Indian legend of the ancient Bridge of the Gods. The rapids at Cascade Locks may be all that remained of this river dam (Waters, 1973).

Look again at the cliffs at the head of the slide area (e.g., Greenleaf Peak, Red Bluffs) and compare the relative positions of the Eagle Creek and Coriba Formations with the corresponding formations on the Oregon side. The formations on this side of the river seem to rise higher above river level than the corresponding formations on the Oregon side. The rock formations are lower on the Oregon side because they slope gently (2° to 8°) downward from north to south across the Gorge (Waters, 1973). Could this dip slope from north to south explain why more landslides are found on the north side of the gorge?

Before we answer this question, let us continue east through the town of Stevenson. At the east edge of town, notice the outcrops of a different kind of rock. It looks bluish green.

STOP 5: Ohanapecosh Formation Equivalent

Continue on for approximately 2.7 miles until you come to a good outcrop of the bluish-green rock. Stop and examine it closely. Note that in some places there appears a purplish-brown to red-brown clay material. This material, called "saprolite" by geologists, results from long weathering and alteration of rock. Saprolite layers 10 to 100 feet thick have been found within this bluish-green rock formation (Waters, 1973).

Recent studies of this rock formation along the Columbia River Gorge showed that it contains altered volcanic rocks which are considered to be equivalent in age and origin to the upper Eocene (45 to 37 million years ago) Ohanapecosh Formation (Fiske and others, 1963) of Mount Rainier National Park. Since the evidence for this classification is inconclusive, the formation along this portion of the Columbia River Gorge is called the Ohanapecosh Formation equivalent. The base of the Ohanapecosh Formation equivalent has not been found in the Columbia River Gorge area. It is believed that its total thickness may exceed 10,000 feet. The formation itself appears to be composed of volcanic rock fragments from underwater eruptions and mudflow and slurry flood deposits from eruptions on land (Waters, 1973).

The top layer of the Ohanapecosh Formation equivalent is also deeply weathered and converted to a purplish-brown to red-brown clay saprolite. On top of the Ohanapecosh we find rocks of the Eagle Creek and Coriba Formations.

Cause of the Landslides:

Rainwater penetrates the permeable Coriba along its numerous vertical joints and is transmitted deeper by other vertical joints in the rocks of the Eagle Creek Formation. The water cannot enter the Ohanapecosh Formation equivalent at most places because all joints and other openings have been sealed by the alteration of the rocks, so water collects at the saprolite boundary and converts the saprolite to slippery clay. Then the vertically jointed formations above begin to break away, tilt, and slide downslope on this unstable and well-greased skidboard (Waters, 1973).

This situation exists all along the north side of the Columbia River Gorge from Cape Horn (which is nearly opposite Crown Point) to about two miles east of Wind Mountain. The largest and most typical of these landslides is the Bonneville Landslide, which we have already observed.

The Ohanapecosh Formation equivalent underlies extensive areas between Rock Creek and Little White Salmon River on the north side of the river and can be seen in outcrops along the highway. On the south side of the river it is covered by overlying formations, except in a few small patches near the river bank. A few outcrops occur in the area immediately around Cascade Locks (Waters, 1973).

Let us continue along Highway 14, past Carson and Wind River, and about a mile farther on, stop to see a different kind of rock.

STOP 6: Wind and Shellrock Mountains

Wind Mountain on the Washington side and Shellrock Mountain across the Columbia on the Oregon side are two volcanic stocks. These rock masses are part of a north-south chain of quartz diorite intrusions which pushed up through older rocks in late Miocene to Pliocene times (Waters, 1973). The rocks are lighter in color than basalt and have a platy jointing. Note the ring of platy talus around the base of Wind Mountain. We will pass Shellrock Mountain on our return trip.

Continue about one mile farther and turn left onto Bergen Road, which crosses the active Wind Mountain Landslide. (The landslide material is not from Wind Mountain itself but from the formations overlying the slippery Ohanapecosh Formation equivalent.) Note the bumps and displacements on the road, and the "drunken forest" on either side.

STOP 7: Wind Mountain Active Landslide

Stop at junction of Bergen and Girl Scouts Road. Note the effects of the landslide on the former pavement, on the forest, and on the house. Note the large piece of red saprolitized Ohanapecosh among the jumble of different rock types in the roadcut.

Return to Highway 14, turn east. Notice the Coriba on both sides of the river. We will pass through two tunnels in thick Coriba.

In the area of Underwood Mountain, we find lava beds of more recent origin over the Coriba. The lower portions of the Underwood lavas, as they are called, are marked by pillow lavas. (Pillow lavas are rounded structures produced by molten lava flowing into water.) This would seem to indicate that the Underwood lavas poured into an ancestral Columbia River (Waters, 1973).

Just after we pass the Underwood lavas we see an upfold in the rock formations. This upfold or anticline is known as the Bingen anticline, named after the nearby town of Bingen, Washington. The Bingen anticline can also be seen in the rock formations on the Oregon side of the river.

Cross over the bridge to the town of Hood River on the Oregon side of the Columbia River Gorge. Hood River Valley was formed by a downdrop along a fault which runs from north to south through the valley. Over 1,000 feet of fall on the east side of the valley is marked by a fault scarp. Several small cinder cones and shield volcanoes are on the line of the fault.

Continue upriver along the Oregon side of the Columbia River on I-80N. Soon, on the north side of the river, we can see the Coriba dipping toward the river. This downfold, which continues across the river and onto the Oregon side, is known as the Mosier syncline, named after the town of Mosier, through which the syncline passes.

Farther on, we see the Coriba folding upward again in the vicinity of Ortley, Oregon. Appropriately, it is called the Ortley anticline. Each of these anticlines and synclines follows a northeast-southwest orientation across the Gorge (see map).

Continue on and take the Rowena exit to the right. Follow the Rowena Loop Road to the top of the Coriba flows and turn left to the viewpoint.

STOP 8: Rowena view - East end of Columbia River Gorge

From here we can see the Columbia River Gorge giving way to a flat flood-swept area of basalt of the Columbia Plateau. Around the bend of the river to the right is The Dalles, Oregon. This town is located on a downfold called Dalles syncline. In The Dalles area, sedimentary beds of rock known as Dalles Formation lie on top of the basalt.

This stop marks the farthest point east we will travel through the Gorge. Return to I-80N and head west through the town of Hood River.

Twelve miles west of Hood River, we pass round the huge talus piles crowding the highway at the base of Shellrock Mountain. At times, some rocks actually land on the highway itself. On the opposite side of the river is Wind Mountain.

About a mile beyond, between Shellrock Mountain and the town of Dodson, the highway is heaving upward. The Highway Department has encountered much difficulty in this area and has unsuccessfully tried to

Oneonta Gorge, a narrow slit in Coriba has a waterfall at its end. (Hwy. Div. photo)

Multnomah Falls drops in two falls, each held up by harder layers of basalt. (Hwy. Div. photo) relieve the problem by removing many thousands of cubic feet of material from the slopes above the highway. Just east of the town of Wyeth, red mud boils up and spreads over the ground near the highway each spring (Waters, 1973). What is the cause of all this?

The culprit, as explained by Waters (1973), is the thick clay saprolite of the Ohanapecosh Formation equivalent discussed earlier. Although the Ohanapecosh can be seen on the Oregon side in only a few places near the river level, it is nevertheless underlying the Eagle Creek Formation and the Coriba. We must also remember that the rock formations slope downward from north to south across the Gorge. Because of this southerly dip away from the river, the slick saprolite cannot cause landslides as it does on the north side of the Gorge. However, the great weight of the overlying rock formations can squeeze the saprolite mud upward toward the north, thus forcing it up through the ground just south of the river. This is probably what is causing the highway to heave upward and red mud to ooze out each spring.

Continue west on I-80N. After passing the town of Cascade Locks, look again across the river at the Bonneville Landslide area.

About 3 miles farther, we pass Bonneville Dam on the right. On the left, there are good exposures of the Eagle Creek Formation in the roadcuts. Across the river, we can again see Beacon Rock.

About $5\frac{1}{2}$ miles farther, take the exit to the Scenic Highway. High up on the left rises Saint Peters Dome, a 2,000-foot cliff composed of basalt.

The first waterfall we pass is Horsetail Falls. Continue on to Oneonta Gorge.

STOP 9: Oneonta Gorge

Here a waterfall has eroded through a possible structural weakness in the lava flow to form a narrow box canyon with a waterfall at its end. Molds of trees that were buried in the base of a lava flow are visible in the walls (Allen, 1957, p. 14; Waters, 1973).

Continue on to Multnomah Falls.

STOP 10: Multnomah Falls

Multnomah Falls is the most beautiful falls along the Columbia River Gorge. It is also the second highest falls in the United States. The upper main falls drops 541 feet. It should be obvious by now that the exposed cliff of the falls is composed of basalt. At least four layers representing four lava flows can be identified.

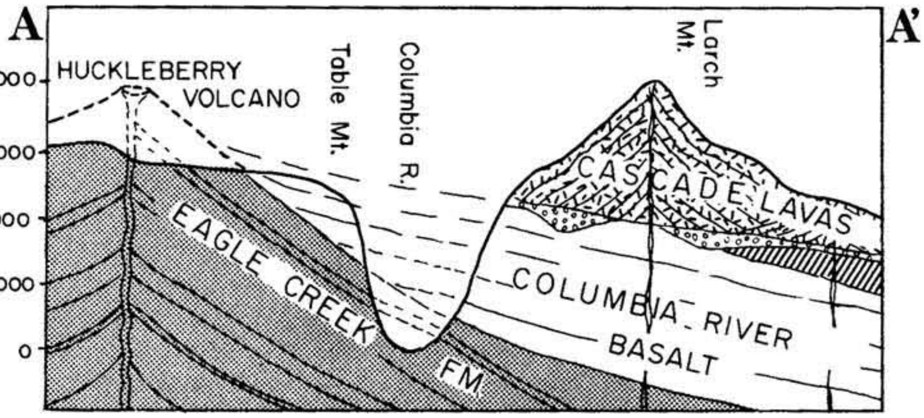
Why is the cliff of the falls so steep? Think back to the type of jointing found in this basalt for the answer. Such basalt breaks in vertical fragments. As the water of the falls wears away the basalt of the cliff, the basalt weakens at the jointing and eventually falls to the base, where it is eroded further by the falling water.

Why is there a lower falls as well as an upper falls? Why does not the upper falls drop directly to the lowest stream level? It is believed that the rock at the base of the upper falls is much harder and therefore more resistant to water erosion, hence the two falls.

Continue west on the Scenic Highway. About half a mile farther, we pass Wahkeena Falls on the left, then Latourell Falls. At this point we might ask: "Why are there so many waterfalls on the Oregon side of the Gorge?" For the answer, think back to the previous discussion about the numerous landslides along the north side of the river and the fact that all the rock formations dip from north to south across the Gorge (see cross section). Since Coriba forms the steep walls on the south side, it is not as prone to landsliding; hence high basalt cliffs and waterfalls.

West of Latourell Falls, the Scenic Highway begins to ascend to Crowr Point in a series of loops. Look at the rock outcrops as we ascend. They are composed of Coriba. Continue on past Vista House. Again, look closely at the rock outcrops. Soon we will see a change. The basalt is overlain by gravels similar to what we saw in the Eagle Creek Formation. Can Eagle Creek Formation be on top of, as well as under, the Coriba? It is unfortunate there is no stopping place along the road because we have come upon a new rock formation, the Troutdale Formation, but we will see more of it later.

As we continue to ascend, we soon see a red band in the outcrops and a different material on top of the red band. This is yet another new formatio




Diagrammatic cross section of Columbia River Gorge from ancient Huckleberry Volcano (source of Eagle Creek Formation) to Larch Mountain. Tilt of rock layers toward southwest produces high cliffs of Columbia River Basalt on Oregon side (adapted from Allen, 1957).

known as Boring Lava. The red line was caused by the red-hot flowing lava baking the top layer of rock, the way bricks are burnt in a kiln (Williams, 1916).

Continue on around the top of the crescent-shaped cliff; stop at the Viewpoint on Chanticleer Point.

STOP 11: View of Gorge From Chanticleer Point

If the day is clear, we can get an exceptional view of the Columbia River Gorge. Across the river, to the northeast, is Cape Horn, composed of thick flows of Coriba. On top is Troutdale Formation similar to that seen in the roadside outcrops west of Vista House. Farther up the Gorge on the Washington side are the Bonneville and other slide areas and Beacon Rock.

On the Oregon side we can see Crown Point, itself composed of hundreds of feet of Coriba flows. Beyond is Larch Mountain sloping down toward the steep cliffs of the Gorge where we passed so many waterfalls. At the river's edge below Crown Point is Rooster Rock. To our right is the recessed cliff from which Rooster Rock presumably broke during a gigantic landslide. Heavy growth of trees on the debris slope indicates that this is mainly an old slide; however, slumped pavement on the Scenic Highway we just passed over tells us that slight movement is still going on.

Return to the Scenic Highway and continue west. At Corbett Junction, keep left. At Bell Road Junction, take Bell Road to the right (this is a short-cut). About 1 mile farther, rejoin the Scenic Highway. Along the road, we can see numerous roadcuts of the same gravel formation we found above the Coriba and beneath the Boring Lava just west of Crown Point.

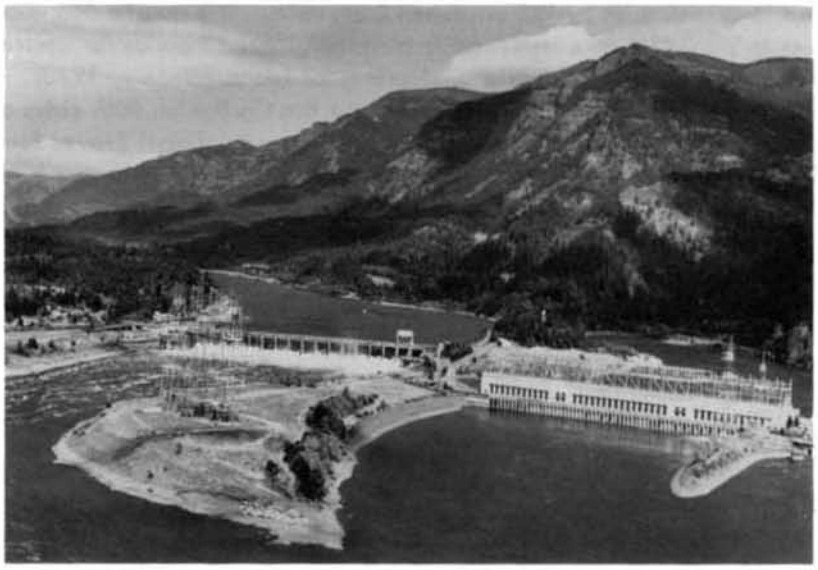
Continue on to the vicinity of the bridge across the Sandy River leading to the town of Troutdale. Stop somewhere near the bridge.

STOP 12: Troutdale Formation

Superficial examination of the outcrop on the right would lead us to believe that we are observing more of the Eagle Creek Formation. However, closer scrutiny will show marked differences. There are no large boulders as in the Eagle Creek, the rocks show less size variation and appear to be better sorted, and the particles are more rounded.

A study of the type of rocks found in the Troutdale Formation show that they are mostly Coriba fragments, with the finer material being volcanic debris. The formation also contains some reddish quartzite and quartz pebbles not found in the Eagle Creek Formation. The upper layers of the Troutdale Formation also contain beds of sandstone.

All geologists who have studied this formation agree that it is a huge gravel deposition made by the ancestral Columbia River as it flowed into the Willamette basin (Waters, 1973). Because the pebbles are more rounded and better sorted, we are lead to believe that these rock fragments have been



View of Bonneville Dam. On upper right Gorge walls are composed of flow upon flow of Coriba overlying Eagle Creek Formation. On left is toe of Bonneville landslide. (Hwy. Div. photo)

View looking up Columbia River Gorge from Chanticleer Point. Crown Point and Vista House on right, Cape Horn on left, and Beacon Rock in distance. (Hwy. Div. photo) carried long distances by the ancestral Columbia. The quartz and quartzite pebbles in particular are believed to have originated from as far upstream as northeastern Washington, British Columbia, or Idaho (Waters, 1973).

Since these Troutdale deposits overlie the Coriba on both sides of the Gorge, they formed after the period of basalt flows. Fossil leaves found in the Troutdale Formation have been dated as being Pliocene in age (Chaney, 1944).

This ends our journey through the Columbia River Gorge. To return to Portland, follow the highway along the Sandy River, through the State Park, to Interstate 80N.

## Putting it all Together

Now that we have traveled through the Columbia River Gorge, let us put all that we have seen and learned into a complete picture, starting with the sequence of rock formations. Assuming that the younger formations are laid on top of the older formations, we find the following pattern appearing in the Columbia River Gorge:

| Relative age | Name of formation | Geologic time (m.y.=million years ago) |
|---|---|---|
| Youngest formation | Recent alluvial deposits (at river level) | Holocene (Recent) (<0.01 m.y.) |
| ↑ | Cascade Andesite and Boring Lava | Plio-Pleistocene (5 - 0.01 m.y.) |
| | Troutdale Formation and Dalles Formation | Pliocene (12 - 3 m.y.) |
| | Columbia River Basalt (Coriba) | Miocene (26 - 12 m.y.) |
| ↓ | Eagle Creek Formation | Early Miocene (26 - 20 m.y.) Oligocene (37 - 26 m.y.) |
| Oldest formation | Ohanapecosh Formation equivalent | Upper Eocene (45 - 37 m.y.) |

## The Geologic Story

During Eocene time, the present position of the Cascade Range was probably a rolling land surface dotted with volcanoes, while a shallow arm of the ocean lay to the west. Over a span of millions of years, lavas and explosive volcanic fragments, together with mudflows and flood debris, formed the thick Ohanapecosh Formation. Between eruptions, weathering of the rock produced layers of red, clayey saprolite. After volcanism ceased, a thick layer of saprolite formed on the surface of the Ohanapecosh. Later, in Oligocene to Miocene time, a new episode of volcanic eruptions spread debris of the Eagle Creek Formation over the Ohanapecosh. Between eruptions, the Eagle Creek Formation weathered enough to form a soil on which plants grew, as evidenced by the fossil leaves and wood found in this formation.

A new period of great volcanic activity occurred during the Miocene. From fissures in the earth came many successive flows of Columbia River Basalt. Total thickness ranges from several hundred to several thousand feet along the present Gorge. Before the time of these lava flows, the Columbia River had already come into existence, as evidenced by the pillow lavas found in the Coriba. The Coriba buried the mudflows and flood deposits of the Eagle Creek Formation and compressed and solidified them into a more or less firm rock (Williams, 1916).

The active volcano, which later became Beacon Rock, is believed to have erupted through the sediments of the Eagle Creek Formation before the forming of the Gorge. Much later, the river eroded away the less resistant sides of the volcano and left the more resistant plug.

After the great lava flows of Coriba had ceased, pressures within the earth's crust began causing the rock layers to fold into anticlines and synclines and to break along faults.

During this same geologic time period (Pliocene), the Columbia River continued to flow and wear away at the rock formations as they were uplifted. This erosion resulted in the deepening of what was to become a gorge, and the depositing of sediments to the west to form the Troutdale Formation. Continued uplift raised some of the early Troutdale sediments above the river level to heights such as Crown Point (about 700 feet above the present river level), forcing the Columbia to cut deeper to reach ocean level.

During later Pliocene time, new volcanic eruptions occurred in a north-south band along the crest of the Cascade Range. These volcanoes (e.g., Larch Mountain, Mount Defiance) produced what is known as the Cascade Andesite and Boring Lava, which covered the Coriba and the Troutdale Formation (Lowry and Baldwin, 1952). Also during this period, stocks (large masses of molten rock) intruded older rocks and cooled to form Wind and Shellrock Mountains, which, like Beacon Rock, were exhumed by the Columbia River at a later time.

In Pleistocene time, large volcanoes erupted along the crest of the Cascades, forming the snow-capped peaks we know today. Two of these, Mount Hood and Mount Adams, sit on either side of the Columbia River Gorge.

During the millions of years of its history, neither erupting volcanoes nor folding rock layers could stop the mighty Columbia in its journey to the sea. Its erosive power kept pace with these obstacles. There is evidence that in fairly recent times large landslides and tongues of lava dammed the river at various places in the Gorge, but the river carved its way through.

The growth of the Cascade Range and the corresponding deepening of the Gorge appear to have lessened in recent times. Although man-made dams now control the waters of the Columbia, the river still erodes where the current is swift and deposits alluvium elsewhere, as evidenced by the numerous sandbars.

Now we know the probable origin of the Columbia River Gorge as it exists today. The rock formations have told us their story. Man can only stand in awe of the tremendous forces of nature which made the Gorge a most spectacular and beautiful sight.

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## SELF-RESCUE MINE EMERGENCY COURSE MANDATORY

Anyone going underground in a mine must have completed a mine emergency safety training course on the use of self-rescue units. This is now a Federal law under the Department of Interior's MESA (Mines Emergency Safety Administration). A card certificate will be issued at the end of the course. This card and a self-rescue unit must be carried by each person at all times while underground. The mandatory 2-hour course will be given by John English, MESA, Health and Safety Training Center, Bldg. 2, Albany Metallurgy Research Center, Albany, Oregon on January 29, 1975, between 8:00 a.m. and 3:00 p.m. To arrange for attendance write or call the Oregon Dept. of Geology and Mineral Industries in Portland (phone 229-5580) or the Bureau of Mines Liaison Office in Salem (phone 399-5755).

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## NEW ENERGY ADMINISTRATION AGENCY CREATED

Bill H.R. 11510, "Energy Research and Development Administration," signed by the President October 11, establishes a new executive agency to consolidate the Federal energy research and development efforts of four existing agencies: The Atomic Energy Commission, the Interior Department, the National Science Foundation, and the Environmental Protection Agency. The new agency will have a broad charter to develop new and improved energy source and utilization technologies covering a broad range of energy sources including fossil, nuclear, solar, and geothermal. Responsibilities, transfer of functions, funding, and administrative programs are summarized in the American Mining Congress Legislative Bulletin, November 13, 1974.

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## EOCENE STRATIGRAPHY OF SOUTHWESTERN OREGON PUBLISHED

"Eocene Stratigraphy of Southwestern Oregon," by Ewart M. Baldwin, Department of Geology, University of Oregon, has been published as Bulletin 83 by the State Department of Geology and Mineral Industries. The bulletin represents the culmination of many years of detailed mapping by Dr. Baldwin and his graduate students in a region that extends from the Oregon Coast to the Western Cascades and includes most of Coos County and parts of Curry and Douglas Counties. In coordinating the results of these investigations and those of other workers in southwestern Oregon, Dr. Baldwin has worked out the Eocene history of this large region and has recognized and defined many new stratigraphic units.

(continued next page)

The 40-page bulletin is illustrated by paleogeographic maps, photographs, a multicolored geologic map at a scale of 1:250,000. The bulletin is for sale by the Oregon Department of Geology and Mineral Industries at its Portland, Baker, and Grants Pass offices. The price is $3.50.

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## INTERNATIONAL GEOTHERMAL CONFERENCE AT KLAMATH FALLS

More than 200 persons participated in the International Conference on Geothermal Energy (the first such conference in the United States) held in Klamath Falls October 7-9, 1974. Sponsors were the Oregon Institute of Technology, Oregon Department of Economic Development, Oregon Department of Geology and Mineral Industries, the city of Klamath Falls, and Klamath County Chamber of Commerce. The conference focused on industrial, agricultural, and commercial-residential uses of geothermal energy and included field trips to see a number of installations in the Klamath Falls area. Governor Tom McCall, luncheon speaker on the first day of the seminar, urged development of geothermal energy and cited examples of cost advantages already experienced by users of geothermal energy in Oregon. Featured speakers on the conference program represented four widely divergent regions: Budapest, Hungary; Reykjavik, Iceland; Rotorua, New Zealand; and Klamath Falls, Oregon.

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## GEOTHERMAL LEASE SALES SCHEDULE ANNOUNCED

The following tentative schedule for competitive leasing of geothermal steam resources in KGRA areas has been announced by Archie Craft, State director, Bureau of Land Management:

Fiscal year 1975

April 23 -- Vale Hot Spring addition
May 22 -- Mickey Hot Springs (Alvord Desert KGRA)
May 29 -- Alvord Hot Springs (Alvord Desert KGRA)
June 5 -- Borax Lake Hot Springs (Alvord Desert KGRA)

Fiscal year 1976

July 1975 -- Warner Valley
February 1976 -- Klamath County

Craft states that the announced schedule is subject to stipulations of the Environmental Protection Act and other possible considerations. Leases are granted to qualified persons or corporations offering the highest bid at a public sale.

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INDEX TO THE ORE BIN
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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

| | | |
|---|---|---|
| 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 |
| 58. | Geology of the Suplee-Izee area, Oregon, 1965: Dickinson and Vigrass | 5.00 |
| 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 |
| 66. | Geology, mineral resources of Klamath & Lake counties, 1970: Peterson & McIntyre | 3.75 |
| 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 |
| 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 |
| 74. | Geology of coastal region, Tillamook Clatsop Counties, 1972: Schlicker & others | 7.50 |
| 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 |
| 81. | Environmental geology of Lincoln County, 1973: Schlicker and others | 7.50 |
| 82. | Geol. hazards of Bull Run Watershed, Mult. Clackamas Cos., 1974: Beaulieu | 5.00 |
| 83. | Eocene stratigraphy of southwestern Oregon, 1974: Baldwin | in press |
| 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 |

### GEOLOGIC MAPS

| | |
|---|---|
| Geologic map of Oregon west of 121st meridian, 1961: Wells and Peck | 2.15 |
| 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 |
| GMS-5: Geology of the Powers quadrangle, 1971: Baldwin and Hess | 1.50 |
| GMS-6: Prelim. report, geology of part of Snake River Canyon, 1974: Vallier | in prep. |

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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 | 2.00 |

MISCELLANEOUS PAPERS

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| 1. | Description of some Oregon rocks and minerals, 1950: Dole | 0.40 |
| 2. | Oregon mineral deposits map (22 x 34 inches) and key (reprinted 1973): Mason | 0.75 |
| 4. | Rules and regulations for conservation of oil and natural gas (rev. 1962) | 1.00 |
| 5. | Oregon's gold placers (reprints), 1954 | 0.25 |
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| 7. | (Supplement) Bibliography of theses, 1959 to Dec. 31, 1965: Roberts | 0.50 |
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| 12. | Index to published geologic mapping in Oregon, 1968: Corcoran | 0.25 |
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| 4. | Prelim. identifications of foraminifera, E. M. Warren Coos Co. 1-7 well: Rau | 1.00 |

MISCELLANEOUS PUBLICATIONS

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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 |
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