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OREGON'S MINERAL INDUSTRY IN 1966

By Ralph S. Mason*

Oregon's booming mineral and metallurgical industries, which posted a huge 21.2 percent increase in 1965 over the previous year, seem to be continuing in the more than $80,000,000 bracket. Although preliminary estimates released by the U.S. Bureau of Mines indicate a slight drop during 1966, in all probability the revised figure, usually released toward the close of the year, will show an increase over the 1965 figure of $82,967,-000. Last year the revised final figures were $14.5 million higher than the preliminary estimate.

Once again the state's mineral and metallurgical industries performed the seemingly impossible task of holding the price line on the two major mineral commodities which account for slightly more than 70 percent of the new wealth pumped into the local economy. Unit prices for sand and gravel actually dropped from $1.51 per ton in 1965 to $1.50 in 1966; stone held rock steady at $1.29. Combined value of these two vital commodities necessary for community development totaled $57,000,000 as valued in the pit.

Employment in the mining industry increased 6 percent over 1965, and primary metals saw a 7 percent gain. These figures compare with an overall state increase of 4.4 percent.

The Metals

Mercury

Despite relatively high prices during the year, mining and furnacing of Oregon quicksilver declined from 1,364 flasks in 1965 to 703 in 1966. Although activity was reported at quite a few properties, only four mines had a record of production. The largest producer was the famous Black Butte mine in southern Lane County. The property was sold by American Mercury Corp. in the spring to Allegheny Mining & Explorations Co., Ltd. Both companies are based in Canada. The Bretz mine, located near the Nevada line in southern Malheur County, exhausted all available low-grade surface ore in its pits and shut off the burners in September. The Bretz has produced

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Some of Oregon's Minerals at a Glance
Preliminary Figures for 1966
(in thousands of dollars)

	1965	1966
Clays	$ 359	$ 408
Gold	17	4
Lime	1,853	2,150
Mercury	779	298
Sand and Gravel	32,849	30,000
Stone	27,301	27,000
Misc. *	19,809	20,707
Estimated total	$82,967	$80,567

* Cement, copper, diatomite, gem stones, iron ore, lead, nickel, peat, perlite, pumice, silver, zinc.

more than 16,000 flasks since it was first operated in 1931. A new retort was constructed and considerable development done at the Doodlebug mine in southern Jackson County by five local mining men. A small amount of mercury had been produced by year's end. The Elkhead mine, situated about 5 miles west of the Black Butte mine, was intermittently operated in 1966 and furnaced a few tons of ore.

A few miles south of Canyon City in Grant County, the Canyon Creek mine owned by Lawrence Roba and Banday Sintay was leased late in the year to Standard Slag, which announced a program for exploring and developing the property. Tunneling work at the mine prior to the take-over by Standard Slag was aided by a homemade mucking machine incorporating an air-driven "tugger" hoist, a scraper, and lots of angle iron.

Jackson Mountain Mining Co. completed construction of a flotation mill and retort at Glass Buttes in the northeast corner of Lake County. The plant was scheduled to be fired up early in 1967. A unique feature of the mill is an electrically heated series of retorts which have axial screw-feed augers for transferring the charge. Minor exploration was conducted at a raw prospect located on Connor Creek in eastern Baker County.

Gold and silver

The most remarkable feature about gold mining in Oregon during 1966 was the almost complete lack of any production. A total of only 113 ounces was reported. A few small, seasonal placer mines and one or two small, hard-rock mines were active. In sharp contrast, however, was the large and growing interest by the general public in recreational gold mining. Skin diving for placer gold has been popular for a number of years and most of Oregon's streams, whether gold-bearing or not, have been prospected with underwater equipment. Many other people annually take to the hills to "do a little panning." Few of these ever recover much gold but the pleasure derived is great, particularly since no substitute for finding "color" in the pan has yet been invented.

The Buffalo mine, which has been explored and developed by Union Pacific Railroad for the past two years, became idle in September. The mine, located high in the Blue Mountains of eastern Grant County, was leased to A. W. Brandenthaler of Baker at the close of the year. The Buffalo mine has been a fairly consistent producer over the years despite the fact that it is snowbound for long periods during the winter and spring.

Nickel

During 1966 the Hanna Mining Co. and its wholly-owned subsidiary, Hanna Nickel Smelting Co., continued to operate its nickel property at Riddle on a full-production basis. The mine, located on Nickel Mountain, is the only primary nickel-ore producer in the United States and the smelter produces ferronickel by an electric furnace process.

During the year, a new and larger crushing and screening plant was put into operation at the mine. This new installation provides additional economies for the mine operation, as well as releasing a considerable tonnage of nickel ore that had previously been tied up by the original screening plant.

Uranium

Resurgence of interest in uranium as a source for atomic fuel for thermal power plants resulted in renewed activity at the White King mine northwest of Lakeview in Lake County. Western Nuclear leased the property and began a diamond-drilling and underground exploration program. Pumping of the old open pit adjacent to the underground workings was partly completed when the presence of acid waters was detected in the effluent. Pumping was stopped until corrective measures could be taken. Western Nuclear also leased the Lucky Day group of claims on Thomas Creek not far from the White King property.

Exploration Projects

More than a dozen exploration programs were conducted in Oregon during 1966. Only a few of these, however, had progressed to the point where the principals were in a position to divulge any details by year's end.

In Baker County the famous old gold camp in the Bourne area was the center of operations for Omega Mines, Ltd., of Vancouver, B.C. Omega spent the year driving tunnels under portions of the old E. and E. and North Pole mines. Further exploration of the vein, which at places is very wide, is planned by long-hole drilling. Union Pacific Railroad developed the Buffalo mine by extending the cross-cut on the 500 level until it hit the No. 3 vein, and by driving a cross-cut on the 600 level to hit the same vein.

ACTIVE MINES IN OREGON, 1966

Gold Placer

Mine	County
Big Slide	Coos
Hisow	Douglas
Hogum Creek	Douglas
Lyons Gulch	Jackson
Bobbitt	Jackson
Leopold	Josephine
Maloney	Josephine
Gold Bar	Josephine
Fowler*	Josephine
Johnson*	Josephine
Bummer Gulch	Josephine
Ideal	Josephine
Leland	Josephine
Cloverdale*	Josephine
Golden Princess	Josephine
Canyon Creek	Josephine
Bear	Josephine
Barr Mine	Josephine
Basin Creek	Malheur

Copper

Mine	County
Banfield-Rowley*	Douglas
Turner-Albright*	Josephine
Oak* (Cu-Zn)	Josephine

Gold-Silver Lode

Mine	County
Pedro Mt.	Baker
Record*	Baker
Buffalo	Grant
Fleming	Jackson
Lucky Strike	Jackson
Oregon Belle	Jackson
Double Jack	Jackson
Dark Canyon	Josephine
Snowbird	Josephine
Humdinger	Josephine
Weiss*	Josephine
Mountain Lion	Josephine
Oak Mine*	Josephine
Turner-Albright*	Josephine
Braden*	Josephine

Mercury

Mine	County
Connor Creek	Baker
Elkhead	Douglas
Canyon Creek	Grant
Doodlebug	Jackson
Glass Buttes	Lake
Black Butte	Lane
Bretz	Malheur

Nickel

Mine	County
Red Flat*	Curry
Hanna Nickel Co.	Douglas

Uranium

Mine	County
White King*	Lake

Barite

Mine	County
Almeda*	Josephine

Building Stone

Mine	County
Moon Mesa	Baker
Red Rock	Deschutes
Jones Marble	Jackson
Willowdale	Jefferson

Silica

Mine	County
Big Quartz	Douglas
Bristol	Jackson

Lightweight Aggregates

Mine	County
Boise-Cascade Pumice	Deschutes
Central Oregon Pumice	Deschutes
Permanente	Gilliam
Pacific Diatomite	Lake
Cloverleaf Mines	Washington
Empire Bldg. Materials	Washington

Limestone and Lime

Mine	County
Chemical Lime	Baker
Ideal Cement	Josephine
Oregon Portland Cement	Baker, Polk

Sand and Gravel, Crushed Stone

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

* Exploration and development only.

Standard Slag Co. of Reno, Nev., lease-optioned the Canyon Creek mercury mine a few miles south of Canyon City in Grant County, and after mapping the surface geology made a magnetometer survey of the property. Some 'dozing of the surface trace of the vein was done late in the year with additional work, including underground exploration and drilling, scheduled for early 1967.

The Department of Geology and Mineral Industries started a long-range exploration into the thermal-spring potential in the state. Considerable field work was done in the Klamath Falls area, where 500 residences are heated with hot water obtained from wells drilled at or close to the point of use. Several wells were thermally logged by staff members. Thermal activity is known to exist at several other places in the state, and the Department hopes to extend its studies to these and other areas in the future.

Materials for Lunar Research

Interest in lunar research increased during 1966 and numerous samples from Oregon's "Moon Country" in central Oregon were shipped to various research centers. A shipment of 15 tons of high-porosity basalt blocks was obtained for testing special lunar drills. At the suggestion of one of the nation's leading astro-geologists, the Department investigated the possibility of obtaining combined water from some of the volcanic tuffs of the area. An inexpensive, lightweight, electrically heated furnace was constructed by two staff members, and more than 3,000 cubic centimeters of water were recovered from 59 kilograms of pre-dried tuff. Should the lunar surface prove to be of volcanic origin, the ability to recover combined water from the easily available rocks would be of paramount importance.

Metallurgical Plants

Demand for space-age metals, particularly titanium, increased in 1966 and resulted in a plant expansion at Oregon Metallurgical Corp.'s facility at Albany. Oremet installed a titanium sponge unit with an annual capacity of 3.6 million pounds. The addition of sponge production was a further step toward complete plant integration. Wah Chang Corp. continued the manufacture of a wide range of exotic metals and powders at its north Albany site. Also in the Albany area the U.S. Bureau of Mines continued research at its Electrodevelopment Laboratory, and Northwest Industries machined reactive metals for high-temperature and corrosion-resistant applications.

Reynolds Metals Co. initiated a plant expansion at its Troutdale works. When completed, the annual capacity will be 140,000 tons of primary aluminum. Reynolds celebrated the 20th anniversary of its operation of the plant last summer. At The Dalles, Harvey Aluminum Co. produced 88,000 tons of virgin metal, slightly in excess of the previous year's record.

Industrial Minerals

Sand and gravel and stone

Despite the considerable cutbacks in other segments of the state's economy due to the slump in building construction during 1966, the production of sand and gravel and stone continued at almost exactly the same high level as that of the year before. Oregon produced an estimated 20,000,000 tons of sand and gravel, which is equal to a cone-shaped pile 2,000 feet in diameter and 250 feet high. Nearly all of this was carefully washed, screened, and then size-blended to suit the particular application at hand. The production of stone, all 21,000,000 tons of it, would make a second pile of almost the same dimensions.

A long-term study of the geology and mineral resources of the Willamette Valley has been undertaken by the Department in cooperation with the State Division of Planning and Development under a prime contract with the U.S. Department of Housing and Urban Development. Identification of sand and gravel and stone resources within the area is included in the survey. The Department has long recognized the importance to community growth and industrial development of local deposits of these natural resources, and the aim of the current study is to inventory these deposits and call the attention of the various area planning groups to them.

Lightweight aggregates and pozzolan

Interest in pozzolan, the world's original cementing material, continued to grow in Oregon during the past year. Three producers, namely Empire Building Materials, Permanente Cement, and Oregon Portland Cement, were active during the year. Empire used expanded shale, Permanente beneficiated volcanic ash, and OPC ground volcanic cinders. The Permanente plant in Gilliam County was idled in mid-year and placed on a stand-by basis with its silos full. The Department cooperated with the U.S. Bureau of Mines on a sampling project of possible materials suitable for making pozzolan. The survey included clinoptilolite, volcanic tuff, pumicite, volcanic ash, tuffaceous siltstone, perlite, diatomaceous pumicite, and shale.

Production of lightweight aggregates continued at a high rate, with almost a 10-percent increase in volume over the previous year. Two producers, Cloverleaf Mines and Empire Building Materials, quarried and furnaced tuffaceous shales at their plants in northern Washington County. In the Bend area, Cascade Pumice Corp. and Central Oregon Pumice Co. quarried pumice and volcanic cinders in pits near Bend and produced crushed, screened, and blended lightweight aggregate for a wide variety of markets. Uses for these natural aggregates included athletic cinder tracks, mixes for lightweight concrete blocks and monolithic concretes, domestic walks and driveways, roofing granules, horticultural applications, and landscaping.

Plans for construction in 1967 of a perlite-popping plant at Bend were announced by A. M. Matlock of Eugene. Raw material will be trucked from a deposit 5 miles south of Paisley in central Lake County. Matlock was the only diatomite producer in the state during 1966. Raw diatomite was trucked to Eugene for processing from deposits near Christmas Valley in northern Lake County.

Lime, limestone, and cement

Limestone, mined high in the Elkhorn Mountains of Baker County, was burned by Chemical Lime at its plant on the outskirts of Baker. In the Portland area, Ashgrove Lime & Portland Cement Co. calcined limestone imported from Texada Island, British Columbia. Both plants sold their product on the open market. Pacific Carbide & Alloys Co. burned limestone for its own use in the manufacture of calcium carbide in its north Portland plant. Several other plants, principally paper mills and a sugar mill, also burned either limestone to make quicklime or reburned calcium hydrate in their kilns.

The manufacture of cement was confined to three plants in the state. Oregon Portland Cement Co. operated its plants at Lime in Baker County and Oswego in Clackamas County. The Lime plant burned limestone and shale from nearby pits; the plant at Oswego imported barge-loads of stone from Texada Island, British Columbia, and used local shales. Ideal Cement Co. quarried limestone at its Marble Mountain quarry in Josephine County and trucked it to its kilns at Gold Hill in Jackson County. At year's end Ideal announced the closure of the plant, effective April, 1967. Oregon Portland Cement began a $5.75 million plant expansion at its Oswego facility during the year. Completion is scheduled for mid-1967 and will include additional kiln capacity of 1.5 million barrels a year. This will give the plant an annual capacity of 3.5 million barrels.

Bentonite

Central Oregon Bentonite Co. quarried bentonite at its Silver Wells deposit in Crook County. The product was used in well drilling, stock feed pellets, and as a sealant for water reservoirs and irrigation canals. Anderson Mining & Development Co. custom ground bentonite at its Bend plant.

Peat

A large peat-humus deposit near Enterprise in Wallowa County was explored and developed during the year by Jewell's Mother Earth Co. Following a full year of investigation of possible markets, prices, rail rates, and beneficiation and packaging procedures, the company installed screening and sacking facilities in anticipation of marketing both bulk and packaged material in 1967.

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OIL AND GAS EXPLORATION IN 1966

By V. C. Newton*

Oil companies operated off the Oregon and Washington coasts continuously from April 1965 to October 1966, when equipment was moved to northern California to explore offshore leases in that area. During 1966, three deep holes were drilled off the Oregon and one off the Washington coast. The Standard-Union-Pan American group deepened a 5,600-foot test hole on Tract 57 to 10,010 feet. The Department issued two drilling permits, one deepening permit, and one redrilling permit. Figure 1 shows location of drillings in western Oregon. Total footage drilled onshore in 1966 was 3,090 feet, and footage on the Oregon shelf lands amounted to 29,408 feet. No favorable shows were reported in any of the Oregon tests, and interest in the continental shelf prospects appears to be waning after six years of exploration.

Offshore

At renewal deadline in December, the oil companies quitclaimed 14 federal tracts or approximately 20 percent of the Oregon shelf leases. Expenditures to date in the Pacific Northwest offshore venture are estimated to be $60 million. (A summary of the offshore exploration will be given in a later issue of The ORE BIN.) This total includes lease acquisition costs as well as operation expenses.

Thickness of marine rocks offshore is probably as great as indicated by seismic studies (20,000'+), but reportedly few sands were found in the holes drilled thus far. Apparently sands mapped on the adjacent coastal plain in rocks of Miocene, Oligocene, and late to middle Eocene age grade to finer material a few miles offshore. None of the offshore holes is believed to have penetrated the entire Tertiary marine section on the continental shelf. Possibly the test holes were stopped in middle Eocene rocks; lower Eocene rocks onshore in northwestern Oregon are predominantly volcanic, and upper lower Eocene rocks in the southern coastal region are composed of fine-grained sediments.

An idea of the Tertiary section off the central Oregon coast may be inferred from the Sinclair Oil & Gas Co. "Federal-Mapleton 1" drilled onshore near the coastal town of Florence in 1954. Approximate stratigraphic

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relationships are:

Tyee sands and shales	0 - 3,100'
Umpqua shales	3,100 - 6,000'
Conglomerate	6,000 - 6,600'
Lower Eocene volcanics	6,600 - 12,880' TD

The "Federal-Mapleton 1" was abandoned at 12,880 feet after drilling 6,280 feet of basaltic flows below the Umpqua sediments; thickness of the volcanics remains unknown.

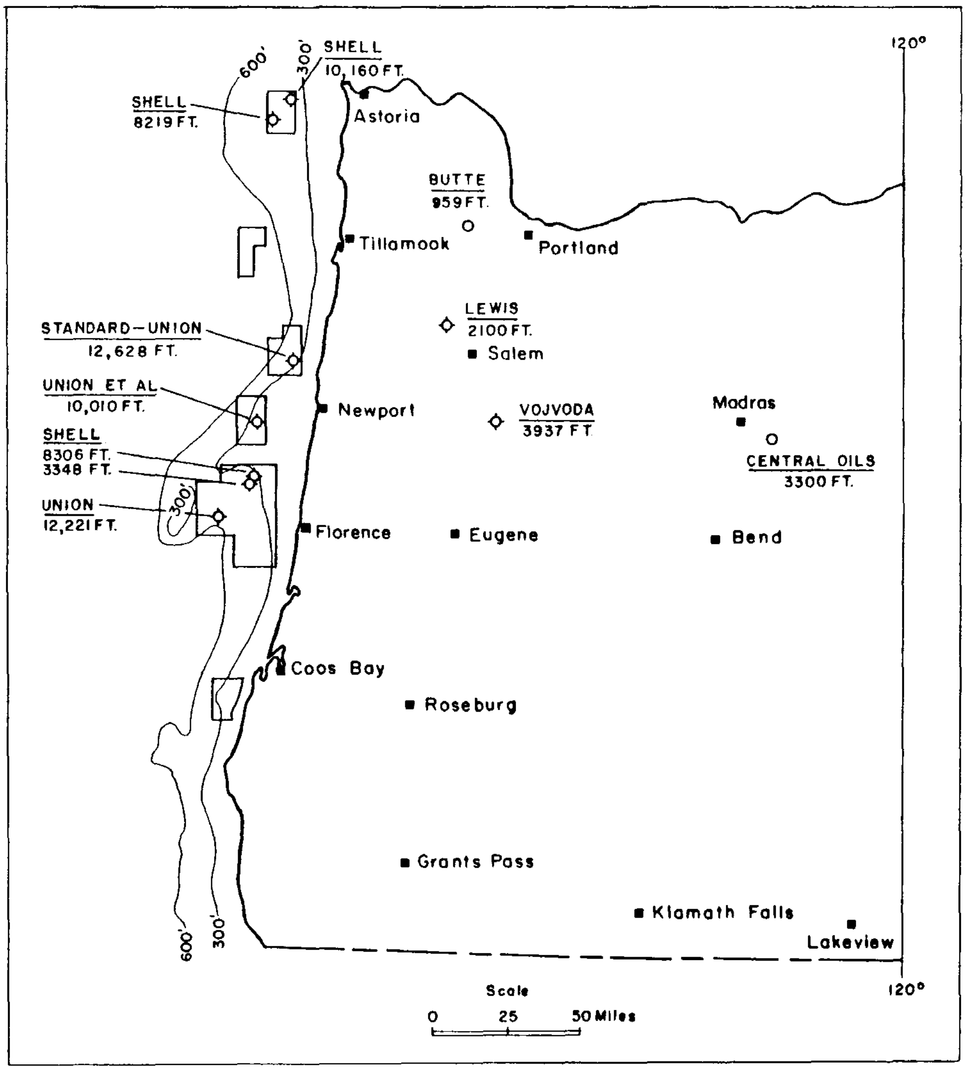

Figure 1. 1965-1966 continental shelf drillings and 1966 onshore permits in western Oregon.

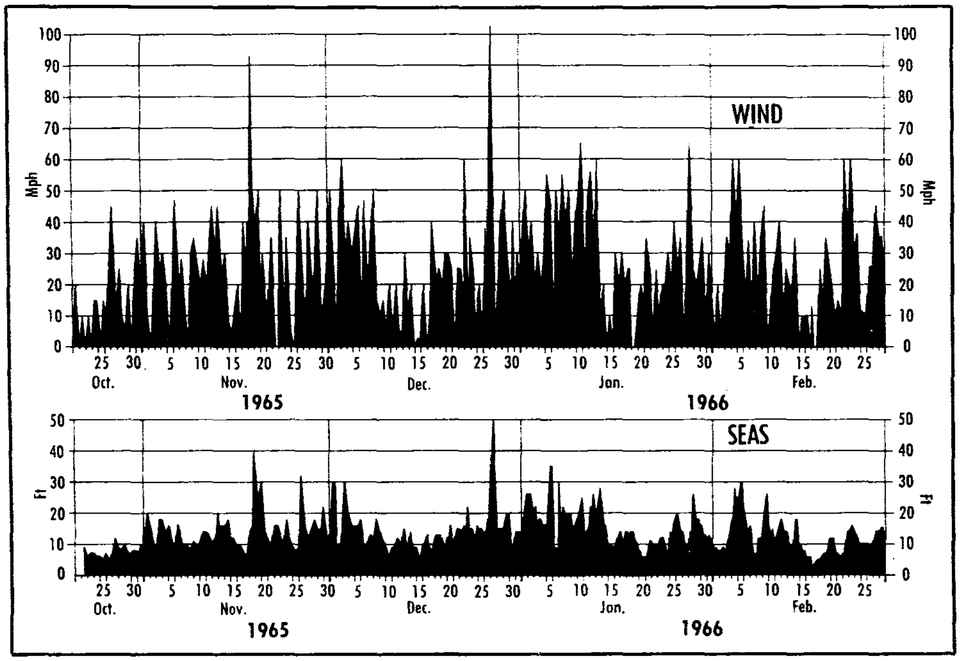

Figure 2. Wave and wind conditions off the Oregon coast (Oil and Gas Journal, August 15, 1966).

Offshore Drilling, 1966

Company	Tract No.	Well Name	Bonus Price (in millions)	Location	Water Depth (ft.)	Total Depth
Shell	18	Expl. Test 1	$1.6	26 mi. off coast from Seaside	467	8,219
Shell	22	Expl. Test 1	.5	17 mi. off mouth of Columbia River	408	10,160
Union	136	Fulmar 1	2.2	25 mi. off coast from Heceta Head	404	12,221
Union-Standard-Pan Am. group	57	Grebe (Deepening)	.35	16 mi. off coast from Waldport	195	10,010

After Shell's experience in conducting year-long operations off the Oregon coast, no one was willing to attempt drilling this winter offshore in the North Pacific. Figure 2 illustrates sea and wind conditions which hampered the 1965-66 drilling. Daily costs probably exceeded $20,000 during much of the time from November to March.

Onshore

Butte Oil of Oregon, Inc., began drilling a shallow test in Washington County south of the town of Cornelius in March. Plans were to test Oligocene marine sediments below Miocene lavas. The company was engaged in fishing operations at the close of the year. The second shallow test in 1966 was drilled by Marvin Lewis, a local wildcatter, 15 miles northwest of Salem in the Willamette Valley. Work on this hole was suspended in August. Central Oils, Inc., of Seattle, Wash., received a permit to deepen a hole southeast of Madras which was begun in 1952 by Northwestern Oils, Inc. The group plans to explore Mesozoic marine sediments which are overlain by Eocene lavas and pyroclastics. Commencement of this venture has been delayed until the spring of 1967.

Figure 3. Vojvoda "Redrill" near Lebanon (Len Owen rig, Rio Vista, Cal.)

Ivan Vojvoda, associated with Supreme Oil & Gas Corp., Mountain View, Cal., attempted to redrill Linn County Oil Development Co.'s "Barr 1", but operations were terminated after loss of tools in the hole. The "Barr 1" was drilled in 1958 a few miles north of the town of Lebanon and shows of oil were reported (Figure 3). Subsequent testing failed to produce any oil and only a small amount of gas was obtained.

Future

More drilling is expected off the coast of Oregon, probably on tracts southwest from the mouth of the Columbia River and offshore from Heceta Head. One or two additional holes will probably be drilled off the Washington coast also. Exploration beyond 1967 will depend on whether or not any significant oil or gas shows are found this year.

Onshore, one or possibly two shallow wildcats are expected to be drilled in western Oregon in 1967, and the deepening by Central Oils, Inc.,

Onshore Drilling, 1966

Company	Permit No.	Well Name	Location	Depth (Feet)	Status
Butte Oil of Oregon, Inc.	55	Cowan 1	NW¼ sec. 8, T. 1 S., R. 3 W. Washington County	959	Fishing for drill pipe.
Central Oils, Inc.	57D	Morrow 1	SW¼ sec. 18, T. 12 S., R. 15 E. Jefferson County	3,300	Suspended. Deepening has not begun.
Marvin Lewis	56	Crossley-Jennings 2	NE¼ sec. 31, T. 6 S., R. 4 W. Polk County	2,100	Suspended.
Ivan Vojvoda (Linn County Oil Developers, Inc.)	58RD	Barr 1	NW¼ sec. 32, T. 11 S., R. 1 W. Linn County	4,529 T.D. 3,937 R.D.	Abandoned. Made 31' of new hole, then twisted off.

should be underway in eastern Oregon by spring. Activity onshore by large firms is expected to be very limited, at least for the next few years.

Use of petroleum and natural gas in the Pacific Northwest is expected to increase substantially in the next two decades. Gasoline consumption is projected to increase 113 percent by 1985, as compared to the 1960 level (Conkling, 1966). The Northwest market provides an attractive reward for those who discover local sources.

Return on investments today in foreign oil is not much better than that received from domestic ventures (Oil and Gas Journal, October, 1966). Incentive to re-examine the possible producing areas in North America is growing and it is hoped that the sedimentary basins in Oregon will be explored further before the region is rejected as a prospect.

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A DECLARATION OF POLICY

By The American Mining Congress*

Within little more than a century the United States advanced from a struggling young country to the most powerful nation in the world. This remarkable achievement was attained because we were a nation of industrious people, living in a free-enterprise society, and possessing the ingenuity to develop the country's extensive natural and human resources.

The American mining industry at home and throughout the free world developed abundant sources of metals, minerals, and energy fuel for the industrial societies of the West. Recent economic and political difficulties remind us that this world-wide productive network is not a gift of nature but the work of man and of his drive and ingenuity, and that it needs to be sustained and furthered.

The discovery and exploitation of mineral deposits require enormous expenditures of capital. Profits from successful operations must make up for fruitless searches as well as furnish the starting capital for new ventures. Political and economic policies of our government must be realistic in their application to the minerals industries if these industries are to remain competitive and supply the needs of the nation's expanding economy.

With strains of war, with new dimensions of space and atomic energy has come a larger role of government in national and international economic life. While public responsibilities are inherent in our complex society and the need for cooperation between public and private sectors of the economy is recognized, great care must be exercised by government to avoid infringement of the rights, responsibilities, and incentives of the private sector which are essential to our free-enterprise system and a cornerstone of our national security and welfare. * * *

Public Lands

Our growing population, expanding economy, and modern armament require a constant increase in the supply of metals and minerals. This is the responsibility of the American mining industry. For the mining industry to meet these demands under a free-enterprise system, the public lands of

* Excerpts from a policy declaration adopted at Salt Lake City, Utah, on September 11, 1966.

the United States must be freely open to location so that the prospector and engineer may make new discoveries and open new mines.

We welcome and urge a thorough study by the Public Land Law Review Commission of the mining laws and government regulations and procedures relating to the administration of the mining laws.

We are confident that such a study will recognize the importance of preserving the fundamental principles of the mining laws, which are based upon the right of individuals to search for, discover, develop, and acquire title to the metals and minerals lying within the public domain. We firmly believe that such a study will reveal erroneous interpretations of the mining laws and that regulations and administration inconsistent with the basic principles of these laws have not been in the public interest and have frequently prevented the operation of the mining laws in accordance with the intent of the Congress.

We recognize that the public lands should be used in as many ways as their resources permit, and we again express our agreement with the principle of multiple use. The public domain should be open to compatible uses even where one use predominates. No area should be closed to exploration for minerals or to mining in the absence of a compelling national interest demonstrated in a public hearing.

All withdrawals should be reviewed periodically, and areas found to be in excess of need should be reopened to mining locations.

As the nation's mineral resources cannot be developed and their value to the country determined until after they are discovered, public lands should be kept open wherever possible to mineral exploration and the location of new discoveries.

Exploration must, for the most part, be directed to the discovery of nonoutcropping and often deeply buried mineral deposits. Hence, appropriate supplementary legislation, in keeping with the basic concepts and intent of our present mining law, is required to afford reasonable prediscovery protection to one who is in good faith engaged in seeking a discovery of minerals. Such protection is needed to encourage expenditure of the large sums necessary to carry forward mineral exploration.

The Congress should explicitly and with care spell out the limits within which the administrative agencies are permitted or required to act in administering public lands. The administration of public lands is a proper subject of concern to the states in which such lands are located. Therefore, we believe that the views of such states relating to policy for the utilization of resources within their respective boundaries should be considered.

The law of discovery, as intended by the Congress in enacting the mining laws and as interpreted by the contemporaneous decisions of the courts, encouraged the search for and development of new ore bodies. The law of discovery has been distorted by the Office of the Solicitor of the Department of the Interior as to discourage rather than encourage this search. The original concept of discovery should be maintained.

We urge the Department of Agriculture and its Forest Service, the Department of the Interior and its Bureau of Land Management, and all other government agencies dealing with the public lands to administer their regulations fairly and uniformly and to formulate and carry out their regulations in a manner which will encourage and not discourage the development of our mineral resources. * * *

Gold, silver, and monetary policies

Current estimates indicate that the nation is still faced with a substantial deficit in its balance of payments. Monetary gold stocks of the United States continue to decline as foreign central banks and other official agencies exercise their right to convert dollars into gold at $35 per ounce. No discernible progress has been made in efforts to achieve a more stable monetary order by international agreements. None to date has done more than meet an immediate crisis.

Gold remains the final basis of settlement in international financial transactions and is not likely to be displaced by any monetary units based on credit alone. Maintenance of a monetary stock of gold more than ever is a vital need, and additions to it from whatever source are surely in the nation's interest. One obvious move to accomplish this end and improve our country's financial strength would be to increase the output of gold from domestic mines. To gain this objective, we again recommend:

> Enactment of legislation by the Congress of the United States to provide tax incentives or financial assitance payments, or both, to present and potential domestic gold producers to stabilize and insure greater life of existing properties, to reopen closed mines, and to stimulate aggressive search for new gold ore reserves.

As ever larger quantities of the new base-metal 10-cent and 25-cent coins authorized by the Congress in June 1965 are released for circulation, it is apparent that silver dimes and quarters are disappearing, following in the footsteps of the silver dollar and the silver half-dollar. We believe that the complete substitution of base-metal coins for our silver coinage was a mistake and has proved unnecessary. We believe that a subsidiary coinage of intrinsic value is of great benefit to the nation and to the prestige of the dollar. We urge that the Congress, at an early date, authorize the mint to strike 10-cent and 25-cent coins of 40 percent silver content as it is now authorized to do in the case of 50-cent pieces. Furthermore, as soon as minting capacity permits, silver dollars of 40 percent silver content should be minted.

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METALS AND MINERALS CONFERENCE TAKING SHAPE

The nineteenth Pacific Northwest Metals and Minerals Conference, scheduled for April 19, 20, and 21, 1967, will attract miners, geologists, metallurgists, and economists from all of the West. The conference is jointly sponsored by the American Institute of Mining, Metallurgical, and Petroleum Engineers, the American Society for Metals, and the American Welding Society. The three days of technical sessions and various social functions will be held at the Sheraton Motor Inn in Portland. Field trips to local metallurgical plants and tunneling and dredging projects are scheduled.

One of the highlights of the conference will be the Third Gold and Money Session. The two previous sessions, both held in Portland, have attracted mining men and economists from a wide area. Speakers from as far away as South Africa are expected to be present. A full day of papers and a noon luncheon have been set aside for this popular feature. Dr. Ian Campbell, Director of the California Department of Conservation and until recently Chief of the California Division of Mines and Geology, will speak on the growing problems of "Social Geology" at the Friday night banquet.

Eight major technical sessions at which 81 papers will be presented include the following: material science, welding, electric furnace, gold and money, mining and geology, minerals beneficiation, petroleum and marine mining. A complete program for the ladies will include tours, fashion shows, and luncheons. Additional information may be obtained from Ralph S. Mason, 1069 State Office Building, Portland, Ore., 97201.

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BRONOWSKI TO DELIVER CONDON LECTURES

The Condon Lectures this year will be delivered by Dr. Jacob Bronowski, Senior Fellow at the Salk Institute for Biological Studies at San Diego, Cal. Dr. Bronowski received his degree at Cambridge in England and was senior lecturer at the University of Hull. He is an internationally known mathematician, anthropologist, and philosopher of science. His lecture dates are: February 20-21, University of Oregon; February 22-23, Oregon State University; and February 27-28, Portland State College.

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OAS TO MEET AT WILLAMETTE U.

The Oregon Academy of Science will hold its annual meeting February 25 at Willamette University, Salem. Presentation of papers will begin in 9:30 a.m. in Collins Hall. At 1:30 p.m. there will be a short business meeting followed by a speaker. Afternoon papers will be given from 3 to 5 o'clock. Dr. G. T. Benson of the Department of Geology, University of Oregon, is chairman of the Geology-Geography section.

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Vol. 29, No. 2
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SUMMARY OF OIL AND GAS EXPLORATION OFF THE COAST OF OREGON AND WASHINGTON 1961 - 1966

By V. C. Newton, Jr.*

Oil companies will be hard pressed to evaluate all their holdings on the continental shelf bordering Oregon and Washington before the leases expire. Federal OCS (outer continental shelf) leases will terminate in December 1969 for those 5760-acre tracts not definitely established as productive. The five-year period 1961 through 1965 was a time of vigorous activity involving geophysical studies and test drilling. By the end of 1966, the oil industry had expended an estimated $73 million in the Pacific Northwest venture to test promising offshore locations. To date no commercial discoveries have been announced. The two summer seasons left for drilling operations must yield a discovery well, or interest will decrease until another exploration cycle is generated.

Originally, 101 lease tracts were taken in the October 1964 sale (600,000 acres), but 20 tracts were dropped in December 1966. This leaves 470,000 acres to evaluate before the close of 1969.

Results Examined

Assessment of geophysical data and borehole-survey records lies solely with the oil-company scientists, since such information is available only to them and will not be released to outside organizations for some time. However, many deductions can be made concerning the offshore prospects by observing the activity of exploration companies. Increases or decreases in operations are easily noted, and lease cancellations are open to public perusal.

Cancellations occurred following the drilling of deep holes in the Alsea, Siletz, and Heceta offshore lease blocks in Oregon and in the lease block off Willapa, Wash. (see table 1). Undoubtedly, the drilling showed these areas to be unproductive. Just as significant as the cancellations are the leases retained near deep test holes (see accompanying maps). Standard and Union retained leases near the hole in the Siletz lease block on the west flank of Stonewall Bank. Therefore, these leases must still hold promise.

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* Petroleum Engineer, State Department of Geology and Mineral Industries.

Table 1. Lease Cancellations*

OCS No.	Lease Block	Tract No. **	Lessee
PO90 PO93 PO94 PO95 PO96 PO99	Alsea Bay, Ore.	54 57 58 60 61 64	Pan Am. 50%; Atlantic 25%; Sinclair 9.375%; Superior 7.375%; Canadian Superior 6.25%; J. Ray McDermott 2%.
PO103 PO106 PO107 PO108	Siletz Bay, Ore.	74 79 82 87	Standard Oil; Union Oil.
PO130	Heceta Head, Ore.	136	Union Oil.
PO135 PO136	Heceta Head, Ore.	142 143	Pan Am. 50%; Atlantic 25%; Sinclair 9.375%; Superior 7.735%; Canadian Superior 6.25%; J. Ray McDermott 2%.
PO137	Heceta Head, Ore.	144	Texaco; Atlantic; Mobil.
PO148	Willapa, Wash.	14	Pan Am. 50%; Atlantic 25%; Sinclair 9.375%; Superior 7.375%; Canadian Superior 6.25%; J. Ray McDermott 2%.
PO149	Willapa, Wash.	16	Shell 50%; Pan Am. 25%; Sinclair 10.9375%; Superior 9.9375%; Canadian Superior 3.125%; J. Ray McDermott 1.0%.
PO151 PO152 PO153 PO160	Willapa, Wash.	20 21 24 36	Pan Am. 50%; Superior 19.875%; Sinclair 21.875%; Canadian Superior 6.25%; J. Ray McDermott 2%.

* Cancellation data obtained from: Branch of Oil and Gas Operations Office, West Coast Region, U.S. Geological Survey, Los Angeles, Cal.
** Maps showing lease tracts can be found in the November 1964 ORE BIN.

Most leases in the Heceta Bank area have been maintained even after the abandonment of two deep holes. Union Oil Co. dropped its $2 million tract following drilling of a 12,285-foot hole in 1966, while Texaco, Atlantic, Pan American, and others relinquished three tracts nearby but no others.

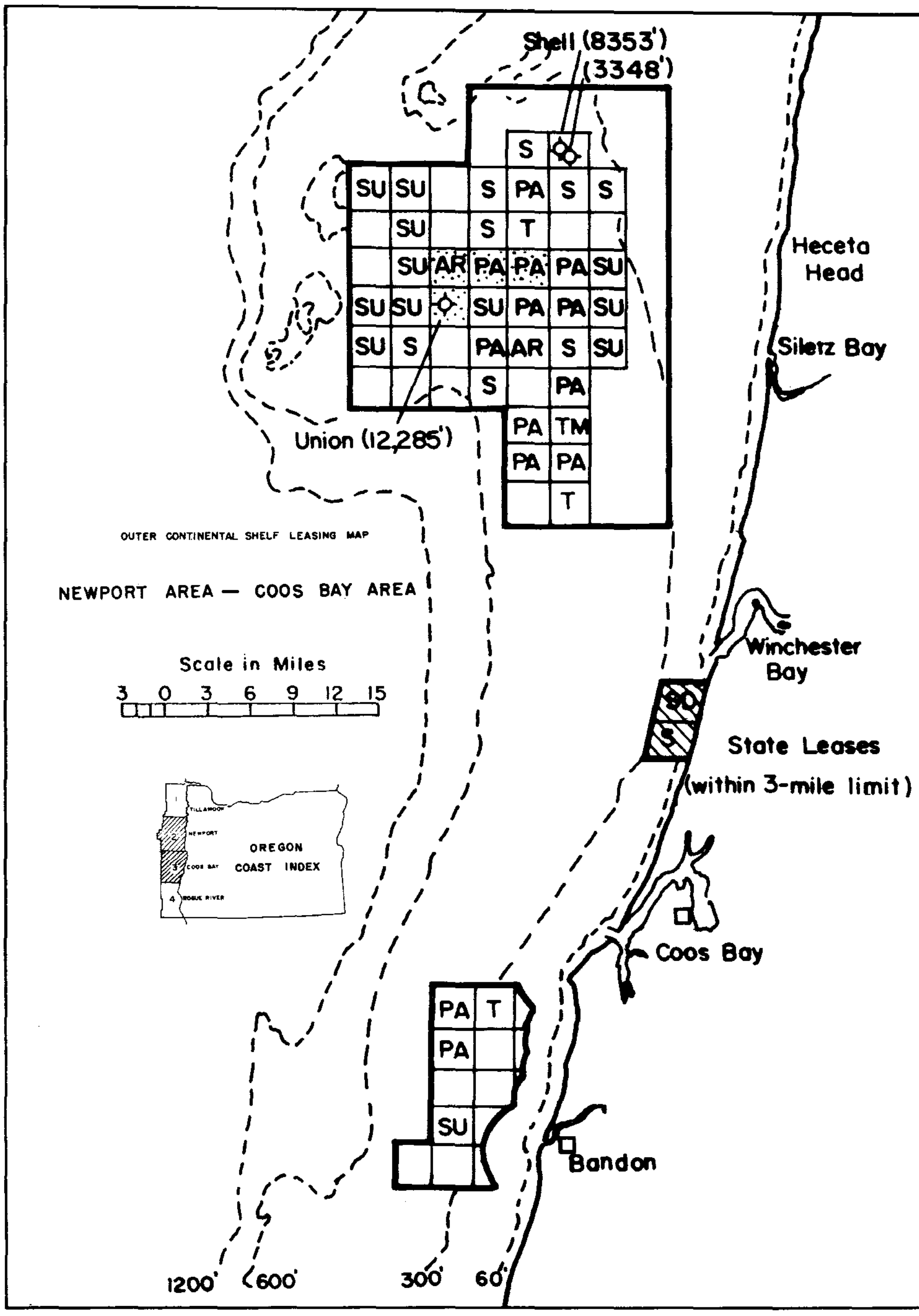
Shell Oil Co. has kept all of its offshore leases in Oregon and Washington, which is quite surprising since the firm has either drilled or been a part of the drilling of five of the eight holes thus far put down in the shelf region. It is also apparent that Shell has more information about the shelf geology than any of the other oil companies (see table 3). Attention should be drawn to the fact that Shell retained its lease off Willapa Bay with the deep hole drilled by Shell-Pan American Group, even though all the nearby leases were dropped. Several postulations could be made for this, but perhaps future deepening or redrilling is the most reasonable explanation. Sands containing hydrocarbons were tested and reported to be non-commercial. Re-entering the hole and drilling the lower portion in a new direction would allow testing of the sands at a nearby location, while utilizing the casing and the upper several thousand feet of the old hole. This would save the cost of drilling a second test on Shell's Willapa lease.

The decision by Pan American Petroleum not to bring Southeastern Drilling, Inc.'s large floating platform to the West Coast from Japan in 1966 was the first suggestion that at least some firms were becoming disenchanted with the Northwest shelf prospects. The conclusion to leave SEDCO "135A" in the South Pacific apparently came after an agreement was reached with Shell in the summer of 1966. Shell had an exclusive contract to operate the Blue Water II, but decided to let its competitors use the equipment. Most of Shell's leases are near enough to test holes to have been evaluated geologically, except three tracts in 1500 feet of water 30 miles off the coast from Tillamook and one tract 15 miles off the coast from Hoh Head. Since Pan American and others hold most of the leases in the Hoh Head area, Shell may agree to share costs of a test drilling with them.

Depth of holes drilled thus far off the Oregon and Washington coasts demonstrates that sediments are at least 15,000 feet thick. Some reports suggest thicknesses in excess of 20,000 feet. However, siltstones and mudstones are found to be the dominant rock types, with occasional sands. Clay and volcanic ash no doubt limit the permeability of the sands, a situation which is prevalent onshore along the coast. Apparently geologic conditions found to date in the search are partly encouraging and partly discouraging.

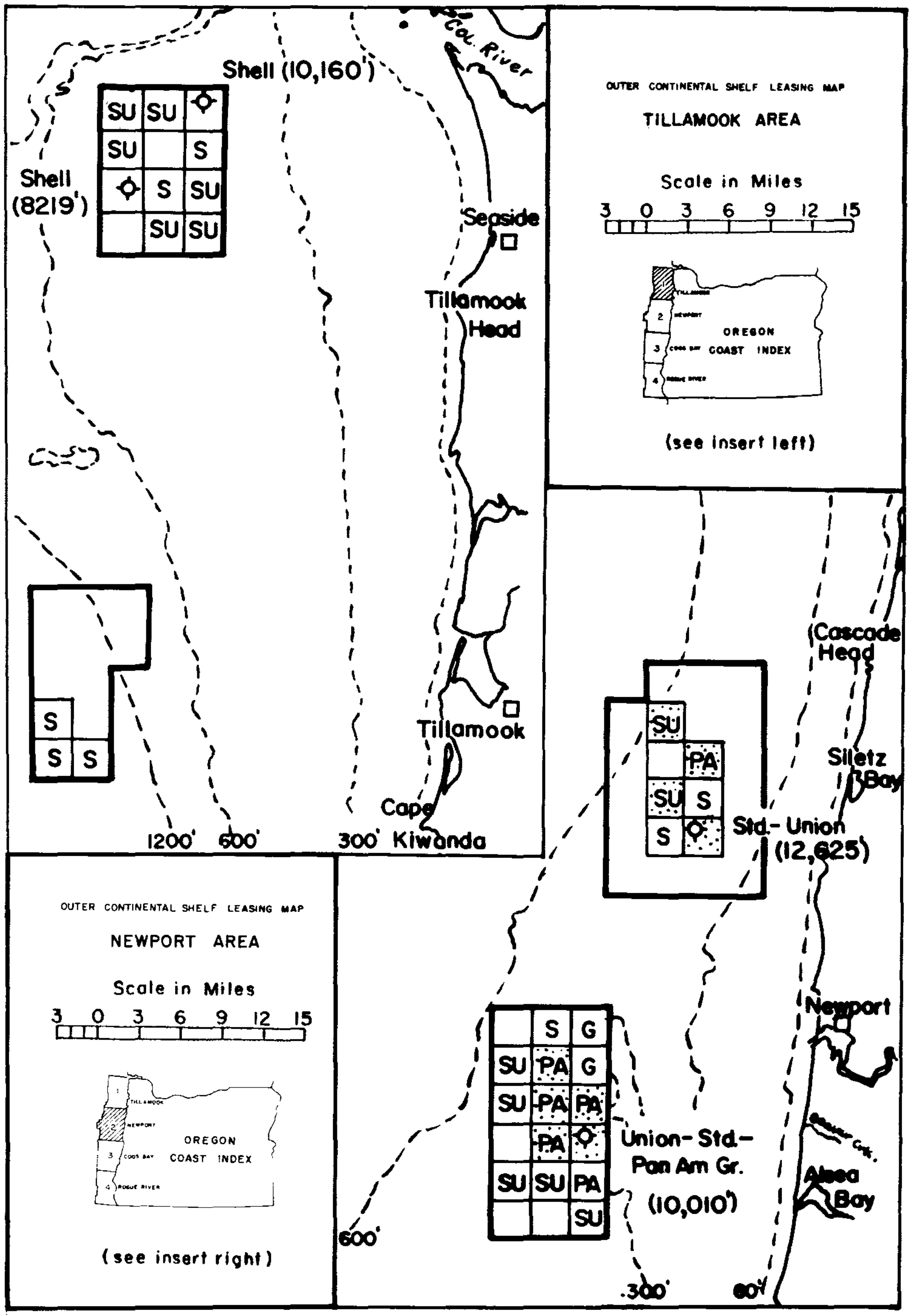
Benefits Accrued

What gain has the offshore work been to the Oregon economy? Lease bonus payments and rentals totalling $43 million have gone into the U. S. Treasury with no compensation paid the states. Nonetheless, Oregon has benefited from the $30 million expended in exploration studies offshore in



Atlantic-Richfield	AR	Shell Oil Co.	S
Gulf Oil Corp.	G	Standard Oil and Union Oil	SU
Pan American Petrol.	P	Superior and Pan American	SP
Pan American Petrol. Group . .	PA	Texaco, Inc. and Mobil Oil	TM
		Texaco, Atlantic-Richfield, Mobil . .	T

[Stippled areas indicate cancelled federal leases, and lined areas show state leases.]



Atlantic-Richfield	AR	Shell Oil Co.	S
Gulf Oil Corp.	G	Standard Oil and Union Oil	SU
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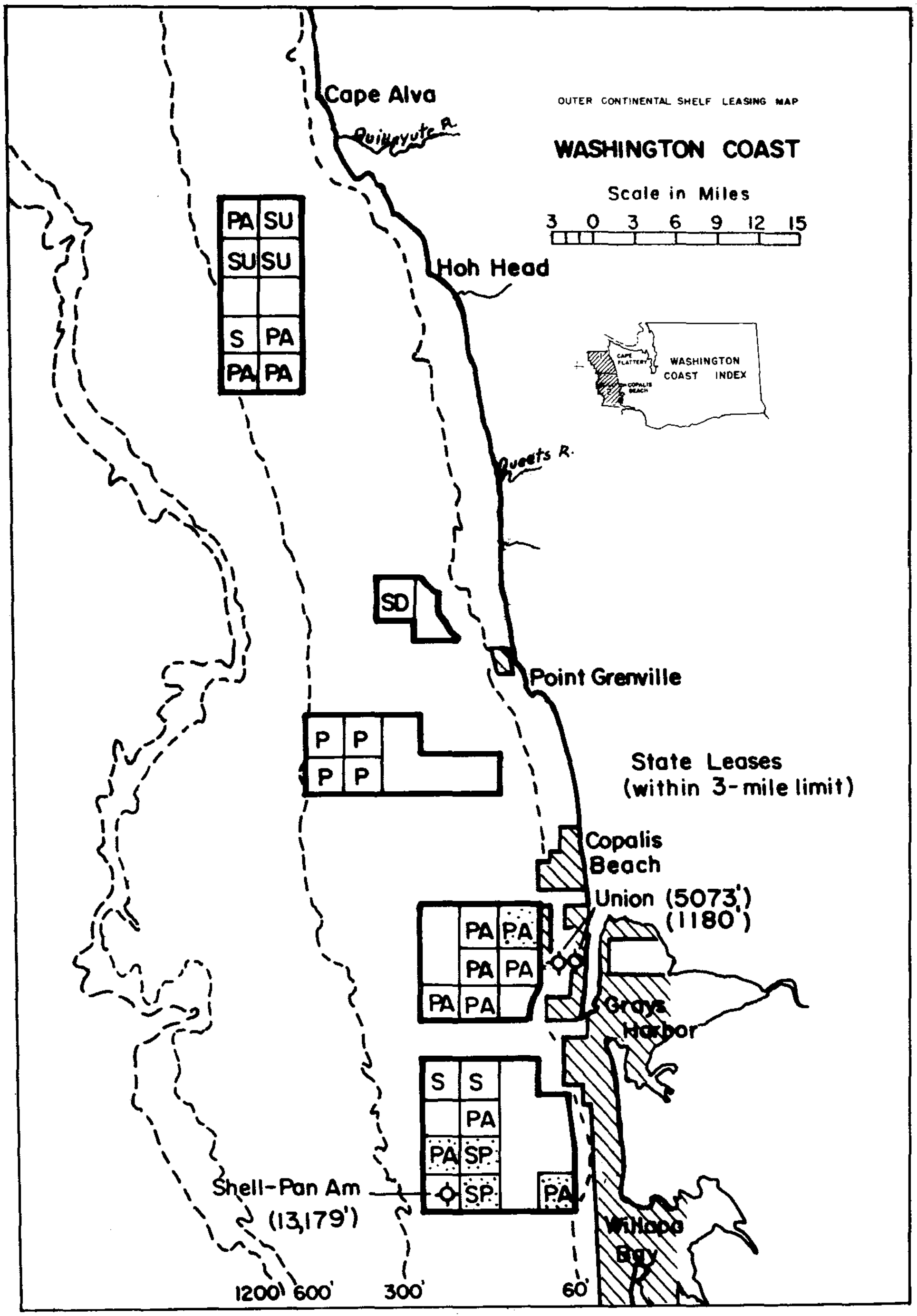

Atlantic-Richfield	AR	Shell Oil Co.	S
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[Stippled areas indicate cancelled federal leases, and lined areas show state leases.]

the Northwest. For the past five years the ports of Astoria, Coos Bay, and Newport have been the headquarters for supplies and services for the seismic and drilling fleets. The fleet used in offshore exploration consisted of: 1 floating platform, 1 heavy drilling ship, 6 light drilling ships, 7 supply ships, 12 auxiliary boats, and 14 seismic boats.

Several other recent industrial developments may be an indirect result of the value expressed by oil companies in offshore prospects. Oregon industries were made aware of prospective business opportunities associated with the offshore activity through efforts of this Department and through cooperative projects with the Oregon Division of Planning and Development. Whether or not such apprising of industry influenced its actions is not known, but industrial development related to petroleum resources has occurred within the last year or two. Northwest Natural Gas Co. constructed more than $11 million worth of new pipelines in 1965-66 to the coastal areas of the state. Shell Oil Co. completed a $10 million nitrogenous fertilizer plant in the summer of 1966 near St. Helens on the Columbia River in northwestern Oregon. The plant utilizes natural gas and atmospheric nitrogen. Annual production is estimated to be valued at $9 million. The Albina Engine & Machine Works of Portland has received several contracts for work on offshore drilling platforms. The company remodeled a self-elevating drilling platform for the J. C. Marthens firm in 1966 at a cost of $1.2 million and performed general repairs on the Brown & Root Co. Alaskan fleet early in 1967 (figure 1).

In October of last year, the American Pipe & Construction Co. received its third contract to build a large development platform for use in Alaska. Earlier in 1966, American P&C completed work on the 3900-ton "Monopod" and a four-legged platform of equivalent size. Building of each unit involved a multimillion-dollar contract requiring employment of 500 construction workers. Construction was done in the Vancouver, Wash., shipyards, but the firm's main office is in Portland.

What other gain has come from offshore work? There is no doubt but that the state's offshore mineral resources look more interesting. Successful drilling in deep ocean waters off the coast of Oregon has demonstrated that equipment is now available to exploit shelf minerals. This advance in technology has increased the potential value of shelf lands lying off the Oregon shore. Besides proving the feasibility of deep-water operations, offshore oil exploration has supplied valuable geologic data which can be used in future development.

Expenditures Estimated

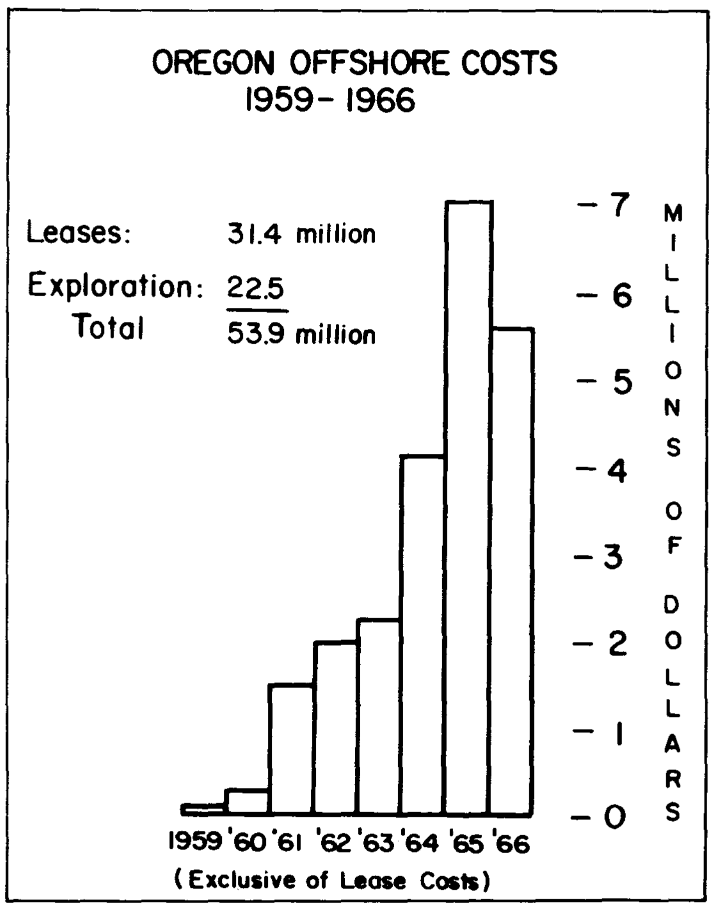
The most costly items of offshore exploration include seismic studies, bottom sampling, lease acquisitions, and deep drilling. Of the estimated $73 million spent on these activities off the coasts of Oregon and Washington, Shell Oil Co. has expended perhaps as much as 35 percent, while 16

Figure 1. Brown & Root Co. 500-ton crane shown installing the "Monopod" platform at Cook Inlet, Alaska, last summer. The $9 million drilling platform was built in Vancouver, Wash. shipyards by the American Pipe & Construction Co. of Portland. After erecting the "Monopod" and completing work on other structures in the inlet, the B & R fleet of four barges, two tugs, and three utility boats moved to Portland for repairs at the Albina Engine & Machine Works. (Photograph courtesy Brown & Root Co., Houston, Tex.)

other major companies have accounted for the remaining 65 percent. Of the 16 firms, Pan American Petroleum, Union Oil Co., and Standard Oil Co. of California are the main contributors.

Lease bonuses and yearly rentals amount to $43 million, while geophysical and geological studies probably cost $16 million in the five-year period, 1961-1966. Deep drilling is estimated to have cost more than $14 million. The first year of drilling (1965) was inordinately expensive because there had been no prior experience in this region; costs ranged between $100 and $300 per foot. As sea conditions became known, later operations experienced less difficulty and footage costs averaged $60 (Montgomery, 1966).

Expense of seismic work and bottom sampling was figured using a weekly crew cost for the different types of equipment: geophysical, $15,000; bottom sampling with rotary, $20,000; bottom sampling with drop barrel, $2000; and geological party, $2000. Overhead is estimated to have been between 20 and 30 percent, depending on the type of work done. The accompanying graph shows yearly expenses for Oregon offshore exploration.



Exploration Work Recounted

Drilling operations were conducted by Shell Oil Co. on a year-around basis off the Northwest coast from August 1965 to the end of October 1966. Working offshore through the winter months was hazardous and expensive for Shell. A large helicopter was lost while transferring crew members during a winter storm, but fortunately the men were rescued by the U.S. Coast Guard. On another occasion, huge waves and hurricane winds forced the 9800-ton drilling platform, Blue Water II (figure 2), off location and nearly two months were lost in repairing casing and wellhead equipment. Blue Water II, however, proved itself capable of deep-water operation in the North Pacific by drilling six deep holes in 14 months and deepening a seventh hole from 5600 to 10,000 feet. No winter drilling in the Northwest was planned for 1966-67.

Union and Standard, using Western Offshore Drilling & Exploration Co. drilling barge No. 3, put down two deep holes off the Oregon coast in 1965 within a six-month period. Costs per foot were much higher for WODECO III than for the Blue Water II during the Oregon operations, but more drilling would probably have lowered footage costs for the large drillship.

Formation tests were made on the Shell-Pan American group Willapa Bay hole, but company officials did not confirm discovery of any commercial zones in the well. No shows were reported from any of the other seven test holes (table 2).

Table 2. Deep Offshore Wildcats

Company	Area Name	Water Depth	Drilled Depth	Status
Shell-Pan Am. et al.	Willapa Bay	237'	13,179'	Abandoned 6/4/66. 7" csg set at 10,000'; oil shows tested.
Shell	Seaside	470'	8,219'	Abandoned 3/14/66.
Shell	Seaside	400'	10,160'	Abandoned 7/2/66.
Shell	Heceta Head	330'	3,348'	Abandoned Sept. 1965.
Shell	Heceta Head	330'	8,353'	Abandoned 10/17/65.
Standard-Union	Siletz Bay	425'	12,625'	Abandoned 8/5/65.
Union-Standard-Pan Am. et al.	Alsea Bay	200'	10,010'	Abandoned 10/13/66.
Union	Heceta Head	400'	12,285'	Abandoned 8/24/66.

During 1963 and 1964, prior to the lease sale, most of the firms did extensive bottom sampling to supplement geophysical data. Hundreds of samples were taken by simply dropping a heavy steel tube to bottom and punching out a "biscuit" of rock from the sea floor. Where bedrock was not exposed it was necessary to drill through the recent unconsolidated material with rotary drilling equipment to obtain fresh rock samples. Cores were studied to determine the nature of the sediments and to date the age of the rock by paleontological means. In spite of great difficulty from ocean currents and swells, operators of light drilling ships were able to obtain the information they sought. A fleet of six drilling ships was used in these operations; two ships utilized dynamic positioning equipment which allowed drilling to be done without setting anchors.

Geophysical studies began in June 1961 following passage of the Oregon Submerged Lands Act. Explosive and non-explosive equipment was employed in seismic work by the oil companies (table 3). It was believed that penetration of sound waves deep into the shelf rocks could be obtained only by use of explosives. Early surveys were met with a great deal of opposition from fishermen, who felt their livelihood was being jeopardized by the seismic work. Careful supervision of the seismic operations by the State Fish and Game Commissions proved that no harm to the fisheries industry resulted from the operations (figure 3). After the lease sale in October 1964, seismic work diminished to an occasional survey.

Land ownership and locations of the holes drilled off Oregon and Washington are shown on the accompanying maps. The major portion of state submerged lands shown under lease off the Washington coast was acquired in 1961 because of the discovery of oil near Ocean City by the Sunshine Mining Co. Later submerged land auctions in Washington did not generate much competition.

Economic Factors Described

The possibility of finding oil and gas on the continental shelf bordering Oregon must be evaluated by industry in context with the prospects of all other areas open to exploration by United States firms. Such a comparison is understandably difficult, and for each oil company a different set of controlling factors affects the decision of where to look for new resources and how much money to spend.

If a discovery is made in a new area, the whole oil industry must decide whether or not to rush in and obtain land rather than allow one or two firms to control a significant amount of production. It is this sort of competition that can drain exploration capital away from one prospective area to another in a matter of a few months.

The offshore search for oil in Oregon and Washington was initiated in 1960, three years before the Shell-Standard-Richfield discovery in the Cook Inlet, Alaska, and five years before the U.S. Supreme Court awarded

Figure 2. Blue Water II, a huge floating platform owned by the Santa Fe Drilling Co., is shown being towed to one of the drilling sites off the Oregon coast. The equipment was used to drill six of the seven deep holes off the Northwest coast during 1965-1966. (Photograph courtesy Crowley Launch & Tugboat Co., San Francisco, Cal.)

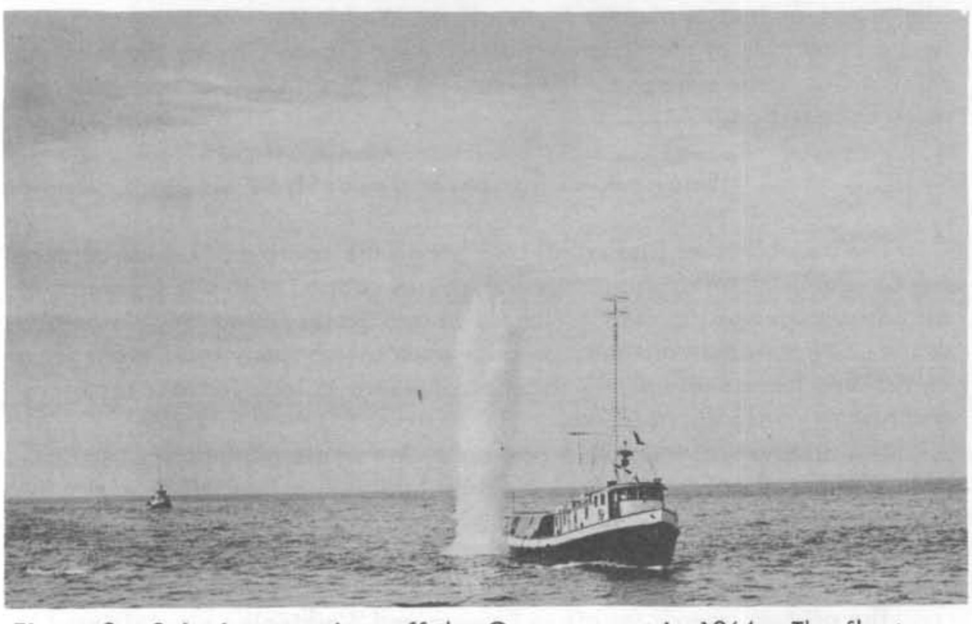


Figure 3. Seismic operations off the Oregon coast in 1964. The fleet consisted of a data recording boat (not shown), an explosives boat, and a fisheries observation boat. (Photograph courtesy of Shell Oil Co.)

Table 3. Estimated Geological and Geophysical Activity Offshore in Oregon and Washington

Company	Type Survey	Crew Weeks	Core ship & Contractor	Date
Atlantic-Richfield Co.	seismic	12	La Ciencia-	1963-65
	bottom sampling	7	← Global Marine Expl.	1963
	coastal geology	7		1963-64
	geochemical	2		1964
Atlantic-Richfield-Mobil	bottom sampling	12	Exploit-Submarex Corp.	1964
Continental Oil	seismic	2		1965
Gulf Oil Corp.	seismic	15		1961
	bottom sampling	4	(?)	1961
	coastal geology	12		1961
Humble Oil & Ref.	seismic	8		1964
	bottom sampling	3	Submarex-Global Marine Expl.	1964
Mobil Oil Co.	seismic	11		1964
*OSU & Scripps Inst.	seismic	2		1965
Pan American Petrol.	coastal geology	18		1964
Shell Oil Co.	seismic	215		1961-66
	bottom sampling	102	Eureka-Shell Oil	1961-64
	coastal geology	25		1961-63
Standard Oil Co.	seismic	17		1961-66
	coastal geology	15		1961-63
Standard-Union	bottom sampling	12	Caldrill-Caldrill, Inc.	1964
Standard Group I: Humble, Pan American, Superior, Marathon	aeromagnetic	5		1961

(continued)

* This work was not included in coast estimates.

Table 3. Continued

Company	Type Survey	Crew Weeks	Core ship & Contractor	Date
Standard Group I, continued				
Texaco				
Mobil				
Phillips				
Richfield				
Standard Group II				
Humble	seismic	12		1962
Pan American				
Superior				
Marathon				
Texaco				
Superior	gravity	12		1962
	seismic	17		1962-64
Superior-Pan American	bottom sampling	8	Submarex-Global Marine Expl.	1964
Texaco, Inc.	seismic	4		1964
Texaco-Humble	bottom sampling	7	Western Explorer-Global Marine Expl.	1964
Union Oil Co.	seismic	18		1961-62
	bottom sampling	7	La Ciencia-Global Marine	1962
Union-Standard	bottom sampling	8	Exploit-Submarex Corp.	1963

submerged lands lying between the mainland of southern California and offshore islands to the federal government. Undoubtedly the important discovery in Alaska diverted attention from the Oregon and Washington programs and forced immediate appropriations by oil firms to compete for production in the Cook Inlet. Several hundred million dollars have been expended over the past three years in the Alaskan development.

The first federal sale off the coast of southern California was held in December 1966 and record per-acre bonuses were paid for one lease ($10,-600 per acre for one tract off Carpinteria, Santa Barbara County). The lease bordered an oil field which is on state submerged land. More OCS sales are expected on the southern California shelf. Had the settlement of the disputed shelf lands off southern California been made at a later time, capital now allocated for that region would have been available for Oregon. It is the press of competition for productive lands in California and Alaska, accompanied by the drilling of six dry offshore holes, that has dampened the activity in Oregon.

Conclusions

The results of drilling in the Northwest to date are not as discouraging as they appear to be. Sedimentary rocks exist on the shelf in great thickness and areal extent. The prospective shelf region off Oregon and Washington covers at least 9000 square miles to a water depth of 600 feet. Although sands reportedly have been lacking in the holes drilled to date, they do occur at many places on shore along the coast. Two or three wells on the shore at Ocean City, Wash., have produced significant amounts of oil and the E. M. Warren "Coos County 1-7" drilled in 1963 a few miles south of Coos Bay obtained shows of oil and gas.

Statistically, Oregon has as good a potential for oil discovery as any other wildcat area. The probability of finding oil in a prospective area is 1 chance in 10, and 1 chance in 50 that a field larger than 1 million barrels will be discovered. Western Alaska offers a fair comparison with Oregon on a statistical basis, as far as oil and gas exploration is concerned.

	Prior to Discovery			Since Discovery		
	Expl. costs	Total holes	Holes 5000'+	Expl. costs	Total holes	Holes 5000'+
Alaska	$80 million	121	17	$720 million	257	240
Oregon	$75 million	177	25	-	-	-

Alaska's Swanson River Field was discovered in 1957 by Richfield Oil Corp. Middle Ground Shoals Field was discovered in Cook Inlet six years later by a consortium of Shell, Richfield, and Standard Oil Companies. In 1966 an average of 12 drilling rigs operated in the Cook Inlet; of these 5 were of the floating type and 7 were bottom supported. The rapid transition of the Cook Inlet within a three-year period from a wildcat test to an important producing province points out the necessity of competing in new areas. Exploration programs of oil companies must be flexible enough to allow large diversions of capital to new developments. Thus the work offshore from Oregon is subject to the fluctuation of oil company commitments, especially those on the West Coast.

If the right geologic conditions exist in a region, and we believe they exist in Oregon, the discovery of oil and gas is directly related to the number and depth of holes drilled. If 25 additional deep holes were drilled in the state, an oil discovery would very likely be made. Controlling factors outside the state will determine the future of such test drilling.

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METALS AND MINERALS COMING TO PORTLAND

The Pacific Northwest Metals and Minerals Conference will convene at the Sheraton Motor Inn April 19, 20, and 21. The conference, which was first held in Portland 19 years ago, was originally sponsored solely by the Oregon Section of the American Institute of Mining and Metallurgical Engineers. Because of the success of the conference over the years, cosponsorship by the American Society for Metals and the American Welding Society has been added. The conference meets in Portland every third year, with Spokane and Seattle hosting the meet in turn. Last year the conference was invited to Vancouver, B. C.

The theme selected for this year's meeting is "Materials for Inner and Outer Space." Papers stressing the problems and solutions to the conquest of interplanetary "outer space" and the "inner space" beneath the waves and under the ground will be presented by speakers from industry, private research organizations, and state and federal agencies.

First technical session of the conference will be the Marine Mining meeting held Wednesday afternoon, April 19. Numerous plant tours and field trips are also scheduled for the opening day. Technical sessions to be held on Thursday include Welding, Electric Furnace, Mining and Geology, three Material Science sections, and Minerals Beneficiation. On Friday the third Gold and Money Session will start with the delivery of a series of papers by internationally recognized authorities on the problems of gold.

Following the Gold and Money Luncheon, a panel composed of the morning speakers will explore the papers read in greater depth. Other technical sessions scheduled for Friday include Welding, Material Science, and Petroleum.

The conference will also feature exhibits by manufacturers and service organizations, a full two-day program for ladies, and an after-the-papers-are-over social evening Friday which will include a cocktail party, banquet, and dancing.

CONFERENCE CALENDAR

Wednesday

8:00 - 5:00	Registration and Exhibits.
9:00	Ladies' Hospitality and registration
11:00 - 6:00	Field trip to Albany exotic metals plants.
12:00	No-host luncheon.
1:00 - 4:00	Field trip to Oregon Steel Mills.
	Field trip to Port of Portland dredge.
1:00 - 4:00	Field trip to Portland Dock Commission bulk ore-handling facility.
1:00 - 4:00	Ladies cruise of Portland Harbor.
	Field trip to West Hills twin-bore tunnel.
1:30 to 4:30	Marine Mining Technical Session.

Thursday

7:30 - 8:30	Speaker's Breakfast.
8:00 - 5:00	Registration and Exhibits
8:30 - 10:00	Ladies Hospitality Room open.
8:30 - 11:30	Material Science Technical Sessions.
8:30 - 11:30	Welding Technical Session.
8:30 - 11:30	Electric Furnace Technical Session.
8:30 - 11:30	Mining and Geology Technical Session.
10:00 - 4:45	Ladies Tour of Portland, Fashion Lunch.
12:30	National President's Luncheon.
1:30 - 4:30	Material Science Technical Sessions.
	Welding Technical Session.
	Minerals Beneficiation Session.
7:00 - 9:30	ESCO Plant Tour.

Friday

7:30 - 8:30	Speaker's Breakfast.
8:00 - 5:00	Registration
9:00	Ladies Hospitality Room open.
8:30 - 11:30	Material Science Technical Sessions.
	Welding Technical Session.
	Gold and Money Session.
12:00	Ladies' Travel Luncheon.
12:30	Gold and Money Luncheon.
1:30 - 4:30	Gold and Money Panel.
	Welding Technical Session.
	Petroleum Technical Session.
5:00 - 6:00	Cocktail Party.
7:00 - 9:00	Banquet.
9:00 - 12:00	Dancing.

TECHNICAL SESSIONS

Marine Mining Session
Wednesday, 1:30 to 4:30 P. M.

Chairman: Arthur P. Nelson, Research Director, Marine Minerals Technology Center, U.S. Bureau of Mines, Tiburon, Cal.

"Mining Diamonds off South West Africa," by Norman A. Grant, Production Manager, International Exploration and Production Division, Tidewater Oil Co., Los Angeles, Cal.

"Offshore Tin Exploration and Dredging in Indonesia and Thailand," by Dr. Rudolph Osberger, Manager, Offshore Exploration and Mining, Indonesian Tin Mining Enterprises, Indonesian Government, Djakarta, Indonesia.

"Legal and Political Aspects of Mining the Sea," by William E. Grant, Pacific Coast Outer Continental Shelf Office, Bureau of Land Management, Los Angeles, Cal.

"Potential of Submersible Systems for Undersea Mineral Exploration and Exploitation," by Dr. Andreas B. Rechnitzer, Director, Ocean Sciences, Ocean Systems Operations, North American, Inc., Anaheim, Cal.

Mining and Geology Session
Thursday, 8:30 to 11:30 A. M.

Chairman: A. E. Weissenborn, Research Geologist, Branch of Resources Research, U.S. Geological Survey, Spokane, Wash.

"Machine Bored Tunnels and Raises: Their Application to Underground Mining," by R. J. Robbins and Donald L. Anderson, to be presented by R. J. Robbins, President of James S. Robbins and Associates, Seattle, Wash.

"Near Shore Heavy Metal Program of USGS in Southern Oregon and Northern California," by H. Edward Clifton, U.S. Geological Survey, Menlo Park, Cal.

"Bureau of Mines Research Using Simulated Lunar Materials," by Thomas C. Atchinson and David E. Fogelson, U.S. Bureau of Mines, Minneapolis, Minn.

"Land Conflicts in the Minerals Industry," by A. L. Service, U.S. Bureau of Mines, Spokane, Wash.

"Is the Mineral Leasable or Locatable?" by Russell Wayland, Assistant Chief, Conservation Division, U.S. Geological Survey, Washington, D. C.

"Bureau of Mines Participation in Developing Lunar Drill Systems," by James Paone, U. S. Bureau of Mines, Minneapolis, Minn.

Minerals Beneficiation Session
Thursday, 1:30 to 4:30 P. M.

Chairman: Horace R. McBroom, Mining Engineer, U. S. Bureau of Land Management, Portland, Ore.

"Gold Milling at the L-D Mines Operation," by A. J. Almquist, Mill Superintendent, Wenatchee, Wash.

"Magnesite Beneficiation from Pit to Finished Product," by Gene M. Kerns, Mill Superintendent, Northwest Magnesite Co., Chewelah, Wash.

"Big Rod Mill at Permanente," by Arnold Kackman, Project Engineer for Kaiser Engineers, Oakland, Cal.

"Mill Design Problems and Their Influence on Capital Costs," by R. S. Shoemaker, Chief Metallurgical Engineer for the Mining and Metals Division of Bechtel Corp., San Francisco, Cal.

"It's What's Up Front That Counts," by Leland Terry, Product Manager for Dredging, Esco Corp., Portland, Ore.

Gold and Money Session
Friday, 9 to 11:30 A. M.

Chairman: Hollis M. Dole, State Geologist, Portland, Ore.

Paper on Gold Reserves of the World, by Dr. Paul M. Kavanagh, Chief Geologist, Kerr Addison Mines, Ltd., Toronto, Canada.

"Is Gold as Good as the Dollar?", by Dr. Lorie Tarshis, Executive Head, Economics Department, Stanford University, Stanford, Cal.

Paper on The Fundamental Approach to the Monetary Problem as Between the Gold School and Management School, by Dr. John E. Holloway, former Secretary of Finance of the Union of South Africa, and former Ambassador to Washington, Johannesburg, South Africa.

Gold and Money Luncheon
Friday, 12:30 P. M.

Speaker: C. Austin Barker, Partner-Economist, Hornblower and Weeks-Hemphill, Noyes, New York City.

Subject: The Growing Need for Sound Monetary Policy.

Master of Ceremonies: C. B. Stephenson, Chairman of the Board, The First National Bank of Oregon, Portland, Ore.

Gold and Money Panel
Friday, 1:30 to 4:30 P. M.

Moderators: Dr. Donald H. McLaughlin, Chairman of the Board, Homestake Mines, San Francisco, Cal.,; and Henry L. Day, President, Day Mines, Inc., Wallace, Idaho.

Panelists: Dr. Paul M. Kavanagh, Dr. Lorie Tarshis, Dr. John E. Holloway and C. Austin Barker.

Subject: Topics presented during morning session.

Petroleum Session
Friday, 1:30 to 4:30 P. M.

Chairman: Vernon C. Newton, Jr., Petroleum Engineer, State of Oregon Department of Geology and Mineral Industries, Portland, Ore.

"Deep Water Drilling Operations off the Coasts of Oregon and Washington," by E. L. Shannon, President, Santa Fe Drilling Co., Santa Fe Springs, Cal.

"Trends in World Crude Oil Production and Reserves," by E. C. Babson, Consulting Petroleum Engineer, Pasadena, Cal.

West Coast Shelf Developments with Particular Reference to Oregon and Washington," by D. W. Solanas, Regional Oil and Gas Supervisor, U.S. Geological Survey, Los Angeles, Cal.

"Oil and Gas Prospects in Oregon and Washington," by H. J. Buddenhagen, Consulting Petroleum Geologist, Grants Pass, Ore.

"Progress of the Alaska Petroleum Industry," by J. A. Williams, Director of Division of Mines and Minerals, Juneau, Alaska.

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NEWBERRY CALDERA, OREGON: A PRELIMINARY REPORT

By Michael W. Higgins* and Aaron C. Waters**

Introduction

Newberry Volcano is a large shield volcano situated about 40 miles east of the Cascade crest in central Oregon (fig. 1). The volcano is about 40 miles long and 25 miles wide; the direction of its long axis is approximately N. 15° W., but its caldera is elongated at right angles to this trend. The shield occupies and conceals parts of the western extension of a broad belt of en echelon faults, locally called the Brothers Fault Zone (fig. 1). The exact boundaries of the Newberry shield are indefinite because it merges both to the southeast and northwest into other areas of approximately contemporaneous volcanic rocks. These rocks were erupted along the Brothers Fault Zone to the southeast, and from cones and dikes on the east flank of the Cascade Mountains on the west and northwest. In a general way the Newberry shield covers the area approximately bounded on the west by the Deschutes and Little Deschutes Rivers, on the north by hills in and near the city of Bend, on the northeast by Horse Ridge and Pine Mountain, on the southeast by Fort Rock Valley (a western extension of the Christmas Lake Desert), and on the south and southwest by a dissected volcanic complex which culminates still farther south in Bald Mountain, Stams Mountain, and the Walker Rim fault block (fig. 1).

The Crescent, Oregon map sheet (U.S. Army Map Service, NK 10-3, scale 1:250,000, published in 1955) shows the entire area of the volcano. Most of the shield and all of the caldera is covered by the Newberry Crater, Oregon quadrangle (U.S. Geological Survey, 1:125,000, 1931) topographic map. Parts of the volcano are shown in more detail by the following U.S. Geological Survey $7\frac{1}{2}$-minute topographic quadrangle maps: Spring Butte, 1963; Moffit Butte, 1963; Finley Butte, 1963; Paulina Peak, 1963; Lava Cast Forest, 1963; Anns Butte, 1963; Lava Butte, 1963.

Newberry Crater is the name given by I. C. Russell (1905) to the large caldera at the summit of Newberry Volcano. This caldera is essentially an oval depression, with step-like walls, which occupies the top of the shield. The central part of this depression is approximately five miles long by four miles wide, and the caldera walls on all but the low western side rise 1000 to 1600 feet above the floor. Two large lakes and a variety of volcanic features occupy the caldera floor (see fig. 2, numbers 1 to 15 inclusive, 18, and 23).

The purpose of this paper is to give a brief description of the volcano, and to report progress in the detailed mapping and petrologic study of its caldera. The increasing use of the Paulina and East Lake areas for recreation and nature study, and widespread interest in the geology aroused by NASA's use of the Newberry area as a

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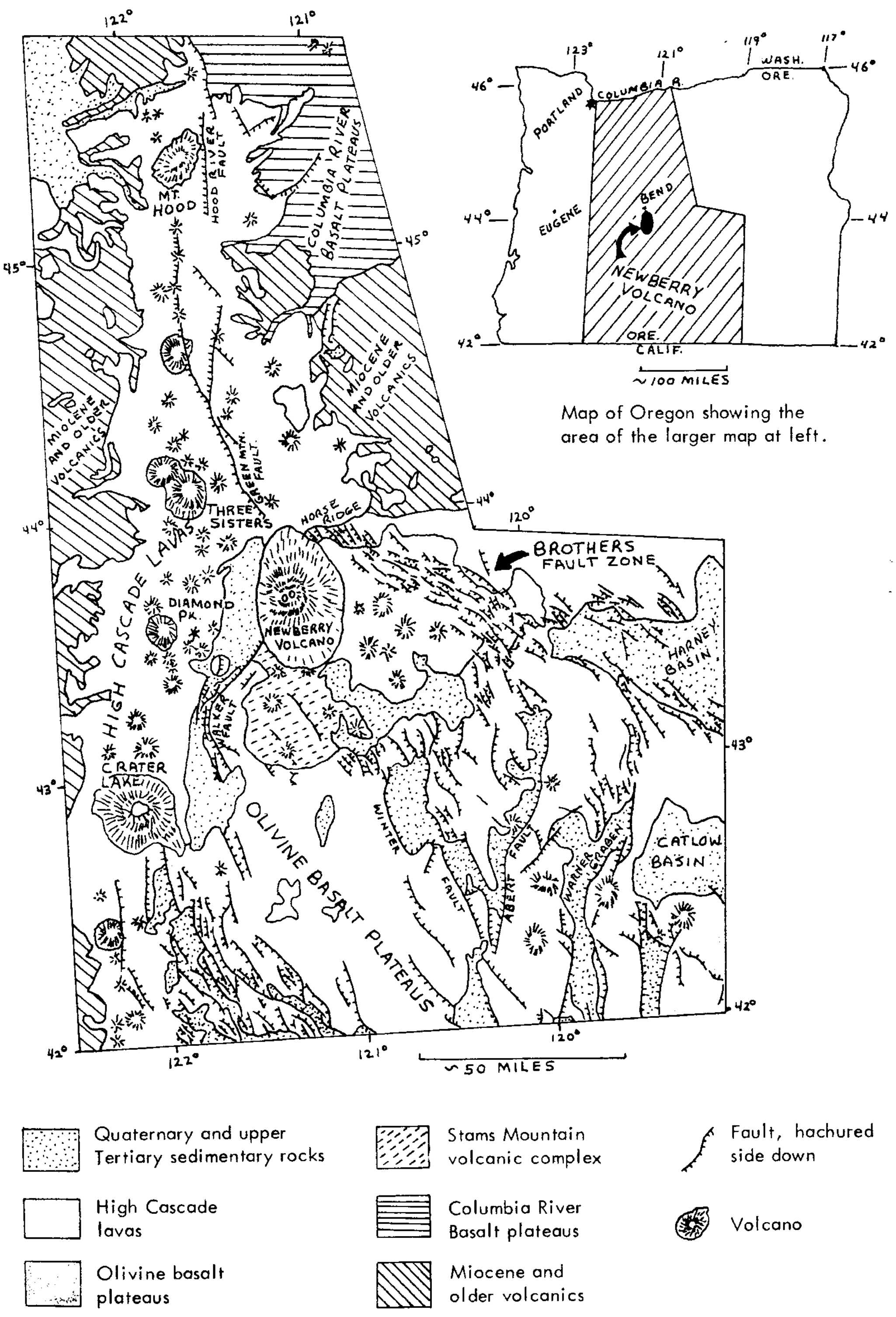


Figure 1. Maps showing the location and geologic setting of Newberry Volcano.

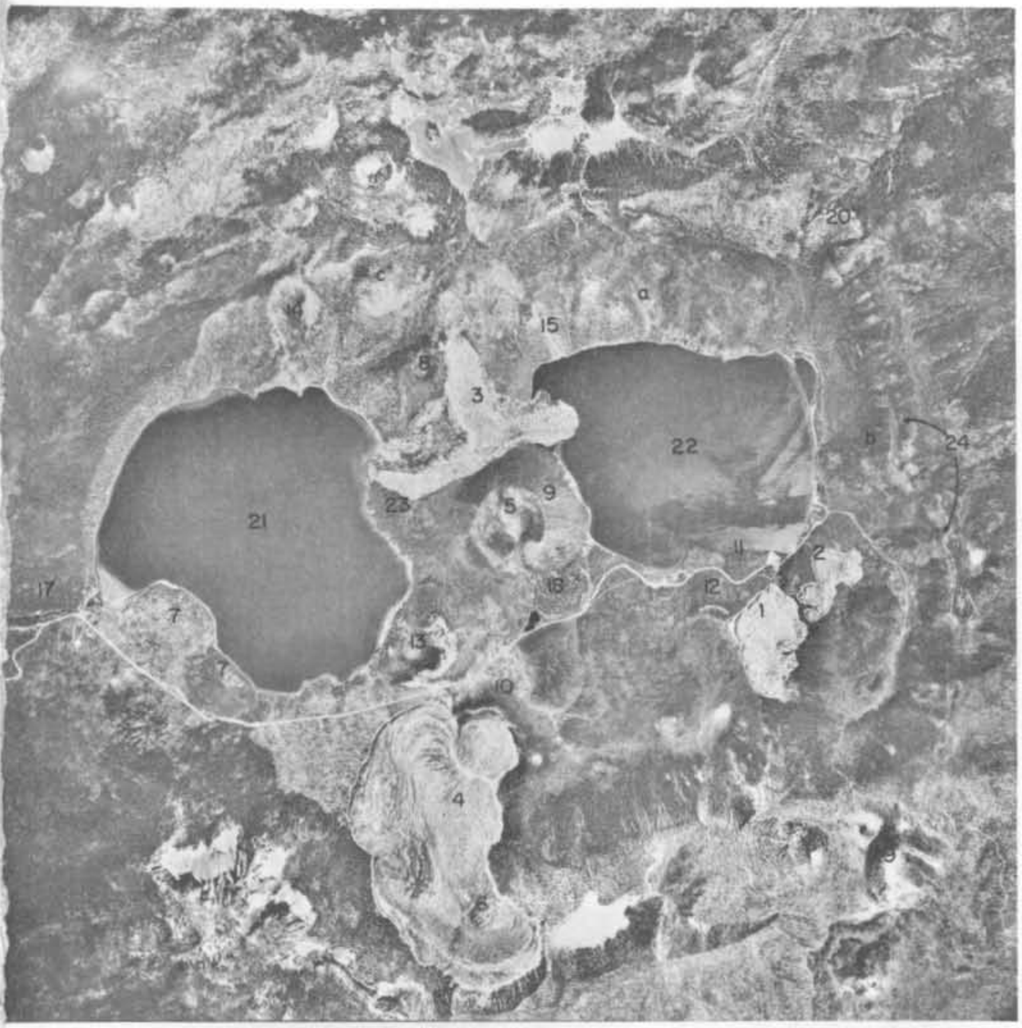


Fig. 2. Aerial view of the Newberry caldera from about 27,000 feet. Numbers on the photograph correspond to features listed below.

1,2 East Lake obsidian flows
3 Interlake obsidian flow
4 Big Obsidian flow
5 Obsidian plug dome in central pumice cone
6 Plug dome of the Big Obsidian flow
7 Paulina Lake obsidian domes
8 North pumice cone
9 Central pumice cone
10 South pumice cone
11 East Lake tuff ring
12 South tuff ring
13 Little Crater tuff ring
14 The Red Slide cinder cones
15 East Lake fissure
16 Paulina Peak rhyolite-obsidian complex
17 Paulina Creek falls
18 Game Hut obsidian flow
19 The Dome (cinder cone)
20 Northeast cinder cones
21 Paulina Lake
22 East Lake
23 Interlake basalt flow
24 Chain craters on fissures, top of east rim.

Letters refer to outcops of the mafic graded tuffs; see figures 4, 5, and 6.

training ground for the astronauts and by the field trip in connection with the State of Oregon Lunar Geological Field Conference, merits a preliminary report before completion and publication of the detailed petrologic studies in which the authors are engaged.

Previous geologic study

I. C. Russell first described Newberry Crater in 1905. He thought the depression containing Paulina and East Lakes lay between two adjacent volcanoes. The most complete study of the volcano to date was made by Howel Williams (1935). A.C. Waters and G. W. Walker contributed, mainly from unpublished field studies, the geologic information shown for Newberry Volcano and its surroundings on the Geologic Map of Oregon West of the 121st Meridian (1961), and on the Tectonic Map of the United States (1962).

The Foundations of Newberry Volcano

As Williams stated (1935, p. 258): "There is only meagre evidence concerning the foundations upon which the Newberry shield is built." He went on to note that the oldest rocks found in the immediate vicinity of the volcano are "coarse pyroxene andesites and andesitic basalts of Indian Springs and Amota buttes, and the basalts and rhyolites or dacites of the Pine Mountain fault block." Williams suggested (p. 258) that these rocks might be found immediately beneath the shield. He also suggested that Miocene Columbia lavas may lie beneath the volcano, because these rocks are found dipping to the east on the western side of the Cascades.

Recently, Hampton (1964) published the results of geologic mapping and well-core data from the Fort Rock basin immediately southeast of the volcano (the maps actually cover a part of the south edge of the shield). He presented a stratigraphic column (p. B5) of the rocks of the Fort Rock basin. These units extend beneath Newberry, and form at least the upper part of the basement beneath the southern edge of the shield. Unpublished work by G. W. Walker and by A. C. Waters shows that Eocene to Pliocene rocks underlie large areas northeast of Newberry Volcano, across the Brothers Fault Zone. These probably extend south and west beneath the volcano and beneath the rocks of Fort Rock valley. Among them are the Clarno Formation (Eocene), the John Day Formation (Oligocene-Miocene), the Columbia River Group (Miocene), and a variety of Pliocene-Pleistocene volcanic and volcaniclastic rocks of which high alumina basalts, such as those which disappear beneath the Newberry shield at Horse Ridge, are the most widespread. Rhyolitic and rhyodacitic tuffs, welded tuffs, tuffaceous sediments, and lesser amounts of lava are locally prominent.

Thus a wide variety of Tertiary and Quaternary rocks probably are represented in the basement beneath the Newberry shield, but these basement rocks do not occur in a simple undeformed stratigraphic succession. Their structure is undoubtedly greatly complicated by the faulting, volcanism, and intrusion that accompanied the development of the Brothers Fault Zone, as well as by the fissuring and faulting that occurred during the growth of Newberry Volcano and its caldera.

The Brothers Fault Zone

The Brothers Fault Zone (fig. 1), 2 to 20 miles wide, is a group of interlacing en echelon faults. It extends across central Oregon on a general N. 75° W. course from the Harney Basin to Newberry Volcano, a distance of more than 100 miles. Along its southern margin, the large north-south faults that define Steens Mountain, Abert Rim, and other young fault blocks of the Basin and Range Province in southern Oregon split up into strands which then bend abruptly westward and merge into the Brothers Fault Zone. Quaternary lavas have risen to the surface along the Brothers Fault Zone, forming complexly interfingering alignments of low lava shields and flows. Many faults are surmounted by rows of cinder cones, some of which have been broken by renewed faulting. Southeast of Newberry Volcano, however, most of the faults in the Brothers Fault Zone are hidden by these young volcanic outflows, and by the rocks of the Newberry shield. Nevertheless, the faults can be seen in great numbers where they bypass the northeast margin of the Newberry shield through Horse Ridge, Pine Mountain, and the southern end of the Bear Creek Buttes. Equal or greater numbers of early faults must lie hidden beneath Newberry in the basement rocks. Some continued to be active during growth of the shield as shown by the presence of dikes, fissures, and rows of cinder cones on the surface of the Newberry shield which have the same alignment as the faults of the Brothers Zone.

The continuation of the Brothers Fault Zone west of the Newberry shield is not well known because it is mostly hidden beneath young volcanic rocks from the High Cascades. Apparently, however, it turns abruptly to the northwest beneath Newberry. This change of direction is best seen in the faults so well exposed on Horse Ridge and in the southern part of the Bear Creek Buttes just northeast of the Newberry shield, but it is also apparent in the fissures and the rows of cinder cones perched on the shield.

Some strands of the fault zone emerge from beneath the late lava cover west of the Deschutes River, and here they bend northward to join the belt of north-south trending normal faults east of the Cascade Crest that define the Bald Peter and Green Mountain fault blocks along the headwaters of the Metolius River, and the fault scarps which form the east wall of the Hood River valley farther north.

Newberry Volcano, therefore, appears to be located where the Brothers Fault Zone bends sharply to the north. It is interesting that the volcano is also directly in line with the large fault that defines Walker Rim (fig. 1). The Walker fault trends about N. 40° E., nearly at right angles to the faults of the Brothers Zone where they bend to the north. Lineaments with this trend can also be seen on the Newberry shield, especially on its southern and northeastern parts. Evidence will be given later that they are present within the caldera as well.

Sequence of Rocks in the Caldera Walls

The Newberry shield is so recent in age that streams on its flanks have cut only insignificant canyons. Moreover, earlier canyons have been inundated and filled by recent lava flows. Even Paulina Creek, which drains the caldera, exposes few rock units along its course except at Paulina Falls where a thickness of about 100 feet of rocks is exposed beneath the lip of the waterfall, and at the lower falls on the creek where about 70 feet of rocks are exposed. Therefore, the only exposures that reveal a continuous section of rocks more than 100 feet thick are found on the walls of the caldera.

The detailed structure of these caldera sections is not everywhere clear because of complexities due to faulting and extrusion accompanying subsidence of the caldera, and also because the rocks are masked in many places by talus and younger air-fall pyroclastics. Nevertheless, an unusually regular sequence of stratigraphic units can be recognized, and they record an orderly succession of events in the building of the upper part of the volcano. This sequence belies the impression gained from traveling over the flanks of the volcano that it is a simple shield made up almost entirely of basalt.

Rhyolite

The oldest rocks exposed in the caldera walls are rhyolite flows. They occur as continuous exposures (except where covered by minor landslides) along the base of the north wall, and as discontinuous exposures at the base of the south wall (see geologic map, fig. 3, p. 48-49). At all localities observed, the rhyolites dip into the walls at 20° to 25°. The maximum observed thickness of rhyolite is about 375 feet, but the base is never seen. Rhyolites are not found on the east wall, where younger rocks occur at the level of the caldera floor.

Most rhyolites are gray and platy, with pinkish-white and white spherulites arranged parallel to the platy structure. Tiny laths of plagioclase are also oriented parallel to the platy structure, and are one of the most important elements in defining it. Although this is the characteristic kind of rock, variations are more the rule than the exception; colors range from black to pink, structures from massive to platy, and textures from glassy to microporphyritic. In many places variations occur within a 10- to 12-foot distance along the strike; vertical variations in color, platiness, crystallinity, and vesicularity are also common. Bands of lustrous black obsidian occur at certain horizons; they generally have breccia zones at their base, and may pass upward into breccia or into contorted platy rhyolite. In general, the rhyolites have the appearance of sticky lavas which were erupted from nearby sources and piled up immediately around the vents. Indeed, it is possible that they may be remnants of flows erupted from ring fissures formed during an early stage in the growth of the shield.

Although, following Williams (1935), these rocks have been loosely designated as rhyolite, the abundance of plagioclase and absence of silica minerals in some thin sections indicates that the more detailed petrographic and chemical work now in progress may show that this stratigraphic unit contains rhyodacite and dacite, and even some rocks that are transitional to the platy andesites next described.

Platy andesite

Directly above the rhyolites on the north and south walls of the caldera are black to gunmetal-gray lava flows with marked platy jointing and contorted flow banding. These are aphanitic and mostly nonporphyritic augite andesites and olivine-augite andesites. Platy andesites also form the base of the east wall, and they are present at the lower falls on Paulina Creek west of the caldera. The stratigraphic unit of andesite varies in thickness from about 375 feet to less than 30 feet. No evidence for any extensive time interval between the andesite and the rhyolite below it was seen. The andesite thins to the west and is thickest on the east wall, suggesting that the east side of the volcano may have been lower than the west side when it was erupted.

Fig. 4. Outcrop of the mafic graded tuffs on the north wall of the caldera, approximately above the center of East Lake (marked as A on figure 2). Note the numerous thin beds and the dip into the wall.

In outcrop the andesites vary from exceedingly fine-grained splintery rocks to platy-jointed flows that weather into thin chips. The upper parts of some flows show highly contorted flow banding and zones of rewelded autobreccia. Small chips of rhyolite, derived from the unit below, were found in some andesite flows.

In thin section most andesite flows have a pilotaxitic texture marked by a strong alignment of andesine microlites, and also by a well-developed platy structure. The platy joints follow collapsed vesicles and have also developed where thin zones of markedly oriented microlites of somewhat larger size than those of the pilotaxitic groundmass have grown along shears that opened and rewelded during a late stage in flow of the lava. The platy joints may lie parallel with the flow banding, or may cross it at any angle. An unusual feature of these andesites is their nearly holocrystalline texture, but unusually fine grain size. Andesine laths are generally less than 0.07 millimeters long, and most pyroxene grains are only 0.01 to 0.03 millimeters in diameter. Tiny euhedral opaques are scattered through the rocks in unusually large amount--they constitute up to 4 percent by volume of many rocks. Olivine is a minor constituent of more than half of the andesites sectioned, but it rarely exceeds 1 percent by volume. It generally occurs in resorbed and partly to completely iddingsitized grains. In general, the andesites are nonporphyritic, but glomeroporphyritic clots and small cognate xenoliths are not rare. Most of these are composed of labradorite and monoclinic pyroxene, with or without a little olivine. They are identical to the phenocrysts and clots that occur in many of the high-alumina olivine basalts of the Newberry shield.

Scoria

At all contacts observed the dense platy andesite is followed by 30 to 50 feet of red and red-brown scoria. Bombs and cinders in this scoria were pasty enough to stick together, and at many localities the scoria welded into a fairly coherent agglutinate. Evidently the violently fountaining vents through which the bombs and lapilli were expelled were not far from the outcrops observed.

Mafic tuffs with graded bedding

Immediately above the red scoria on the north, south, and east walls, and also in the gorge of Paulina Creek outside the caldera, is a widespread series of graded beds composed of buff to brown mafic tuff. Over 150 individual graded beds of tuff and tuff-breccia can be counted in some outcrops (figs. 4 and 5). The base of each bed is composed of fragments of andesite or basalt as large as blocks or lapilli; this is usually followed by lapilli- to ash-sized particles. Then there is a fairly sharp break followed by fine to very fine granular ash. In addition, the entire accumulation of tuffs is graded -- coarse portions of the lower beds are much coarser than in analogous beds near the top. Large blocks have fallen into some of the finer beds, producing prominent bomb sags (fig. 6). The thickness of the entire unit is estimated at about 175 feet maximum, although there is no single outcrop where both the base and the top can be observed. The unit appears thinnest on the southwest, but whether this is due to original topography at time of deposition or to other causes is not known. The beds dip into the caldera walls at all points observed.

Neither field nor petrographic studies have yet progressed to the point where the origin of these graded tuffs can be stated with assurance. Their uniform distribution in all three walls of the caldera, their even bedding, and the draping of the beds over minor irregularities, suggests an air-fall origin. Most fragments of the tuff, however, are bits of sideromelane-like glass in various stages of alteration to palagonite, clay minerals, and zeolites. This evidence of chilling and alteration indicates that the magma which fed the tuffs came into contact with surface water or else with copious supplies of ground water which quenched and granulated it to a sideromelane breccia. Indeed, the general field appearance of these mafic tuffs is very similar to exposures of bedded palagonites making up the tuff ring of Fort Rock, which grew upward from the floor of a late Pleistocene lake. Moreover, the kind of graded bedding, and particularly the superimposed upward grading of the entire assemblage of graded tuffs, is strongly reminiscent of pyroclastics erupted under water, and then distributed outward by gravity flow (Fiske, 1964; Fiske and Matsuda, 1964).

On the other hand the abundance of coarse blocks and bombs in some of the finer beds and the marked sagging without disruption of the beds beneath them (fig. 6), suggests that these projectiles were airborne, but that they fell not into a fluffy accumulation of dry pyroclastics, but instead into sticky water-soaked beds capable of sagging and dewatering beneath impact and load, but coherent enough to retain their bedding almost undisrupted.

These problems of origin cannot be resolved until further field and laboratory studies (to be undertaken in the summer of 1967) are completed. As a tentative speculation, it is suggested that the mafic graded tuffs record the appearance of an early but shallow caldera lake. This allowed entry of surface waters into the andesitic and basaltic vents which had been erupting the underlying red-brown scoria and agglutinate as an air-fall deposit. Underwater eruptions from the same vents now projected chilled and granulated bits of volcanic glass and fragments of the underlying rock; the more violent steam explosions probably drove eruption clouds into the air far above the water surface. Debris falling back into the water gradually built up a tuff ring

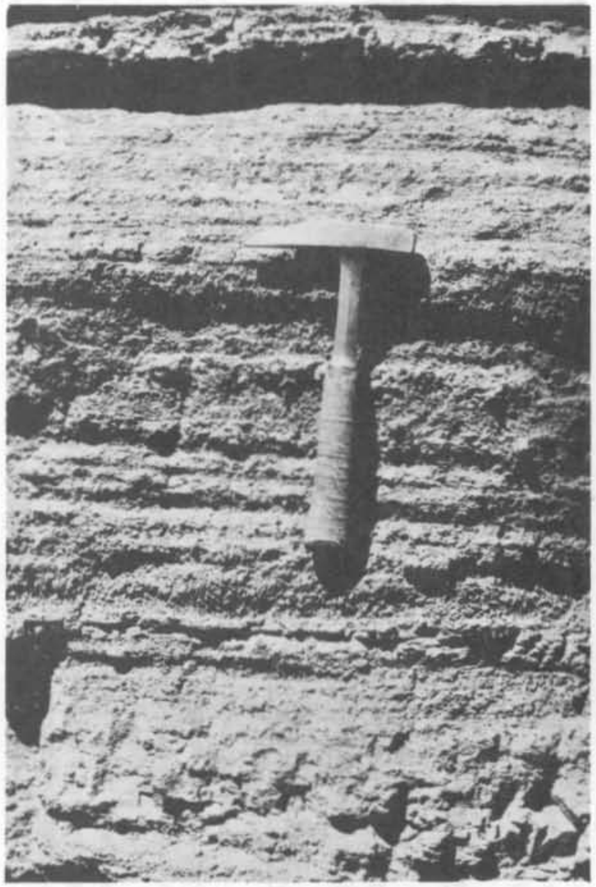


Fig. 5. Details of beds of mafic graded tuff in an outcrop on the north wall of the caldera (marked C on figure 2).

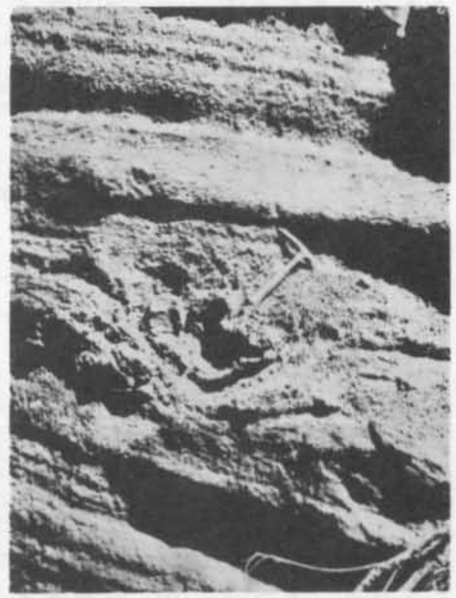


Fig. 6. Beds of the mafic graded tuff on the east wall, showing depression of beds by a bomb that hit before they were consolidated.

which filled the shallow lake and continued to grow above the water surface just as the cones of Surtsey, off the shore of Iceland, and Anak Krakatau, on the submerged edge of the Krakatau caldera, are building up today (Decker, 1961). Much of the debris, blown high in the air by the more violent explosions, was deposited on land as a wet, sticky air-fall tuff.

Welded tuff

Welded tuff overlies the mafic graded tuffs on the east wall, and on part of the north wall of the caldera. On the east wall it is 60 to 70 feet thick, and thins both to the north and to the south. Large pumice fragments in the tuff have been completely collapsed; in outcrop they resemble streaks and bands of lustrous black obsidian enclosed in a gray, aphanitic matrix, but in thin section collapsed bubble walls and compaction features around phenocrysts are clearly visible, and the rock shows slight reddish oxidation and other evidence of devitrification. The gray matrix is a heterogeneous assemblage of flattened shards, shreds of pumice, broken crystals, and abundant fragments of andesite, basalt, and other rocks, all showing effects of oxidation, welding, and devitrification. Both the collapsed pumice and the matrix materials are intensely compacted and welded around the basalt and andesite inclusions. Eutaxitic texture indicating final forward creep of the welded but still plastic mass (Swanson and Schmincke, 1967) is apparent in parts of the welded tuff.

Red andesite and olivine-poor basalt

On the low west wall of the caldera, and in the gorge of Paulina Creek, the mafic graded tuff is overlain by andesite (Williams, 1935, p. 263) and by olivine-poor basalt ranging in color from gray to brick red. The typical rock is a reddish flow with large phenocrysts of plagioclase, but in the gorge of Paulina Creek the variety most prevalent is a red andesite breccia. These oxidized rocks have been only cursorily examined under the petrographic microscope. They are coarser grained, contain more phenocrysts of plagioclase and olivine, and are much more oxidized and altered than the platy andesites of the caldera walls and the lower falls of Paulina Creek.

Brown scoria

In the south wall of the caldera, near Paulina Peak, the mafic graded tuffs are followed by about 60 feet of brown basaltic scoria. Many large bombs in the scoria indicate that the vent from which they came was not far away.

Rhyolite of Paulina Peak

Rhyolite underlies Paulina Peak and spreads downslope to the southwest for a distance of at least three miles. It is mostly platy rhyolite, but contains interlayers of obsidian and of frothy to pumiceous material. In the larger outcrops it is quite variable, ranging from black to pink or white in color, from massive to platy in structure, from porphyritic to spherulitic and felsitic in texture, and from hemicrystalline to glassy and pumiceous in crystallinity. Some welded tuff may be present near the base of this stratigraphic unit.

The rhyolite rests unconformably upon the brown basalt scoria on the south wall of the caldera. Here, in its easternmost exposure, it is only about 60 feet thick. It thickens rapidly to the west, and at Paulina Peak over 1300 feet is exposed in the caldera wall. From various features (streaky flow banding and platiness, overturned folds in the flow banding, lineations, pulled out tensional cracks across flow bands, drag structures due to differential flow band movement, and large ramp structures) the rhyolite and associated obsidian appears to have spread outward in somewhat lobate tongues from a point somewhere north of the present caldera rim where it slices across Paulina Peak. Yet, similar rhyolite at this stratigraphic position is missing across Paulina Lake on the north wall of the caldera, indicating that the rhyolite probably did not emerge from the old summit area of the volcano. The rhyolite may have risen along ring fractures associated with an early stage of caldera collapse, and was then cut by later movement of the same faults. On a later page evidence is given that it probably poured out at or near the junction of such ring fractures with a major north-south fault which downdropped the western part of the top of the shield.

Other units

Several other thin local units are present in the caldera walls, but will not be described in this preliminary report of the generalized wall sequence.

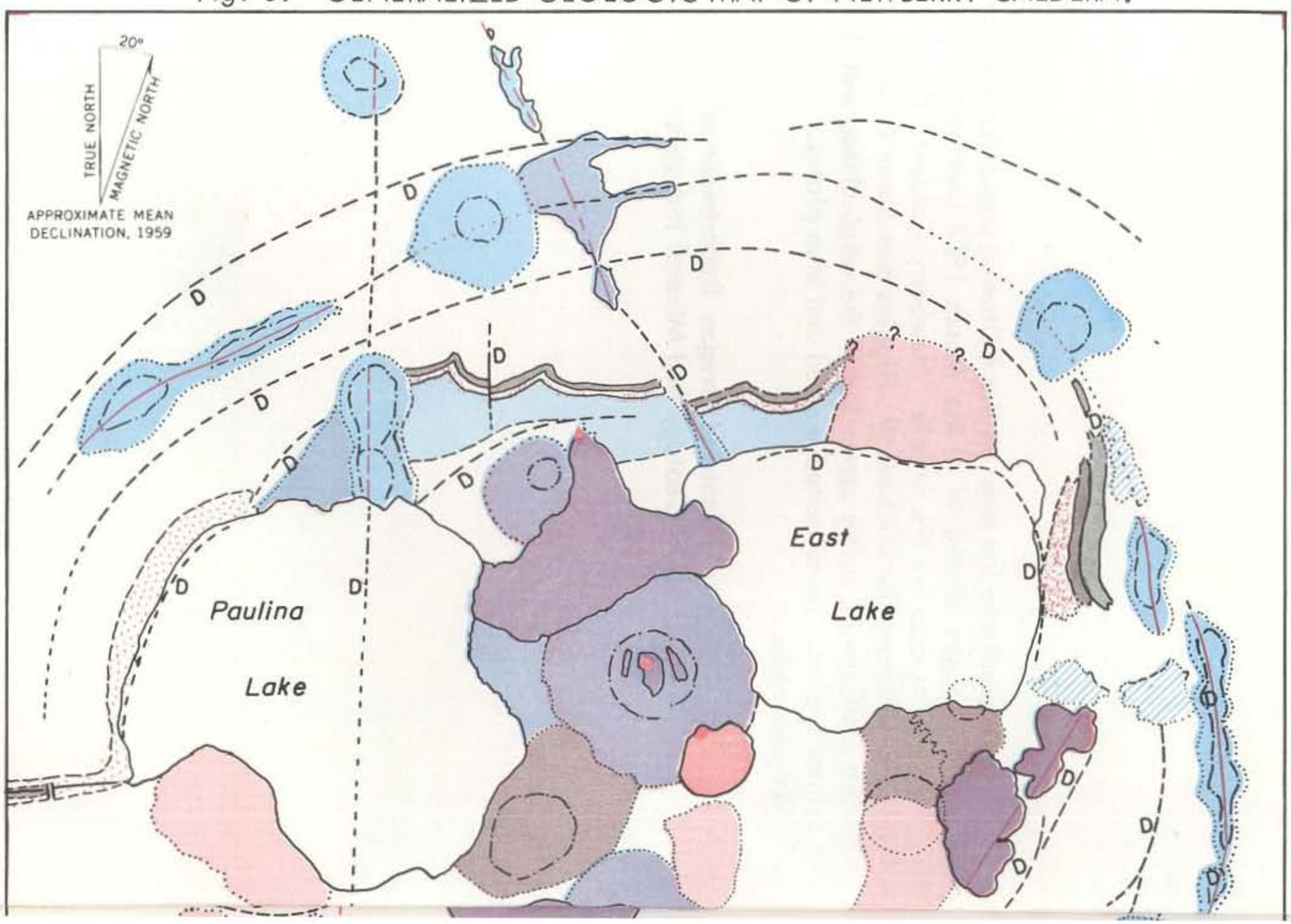
The Formation of the Caldera

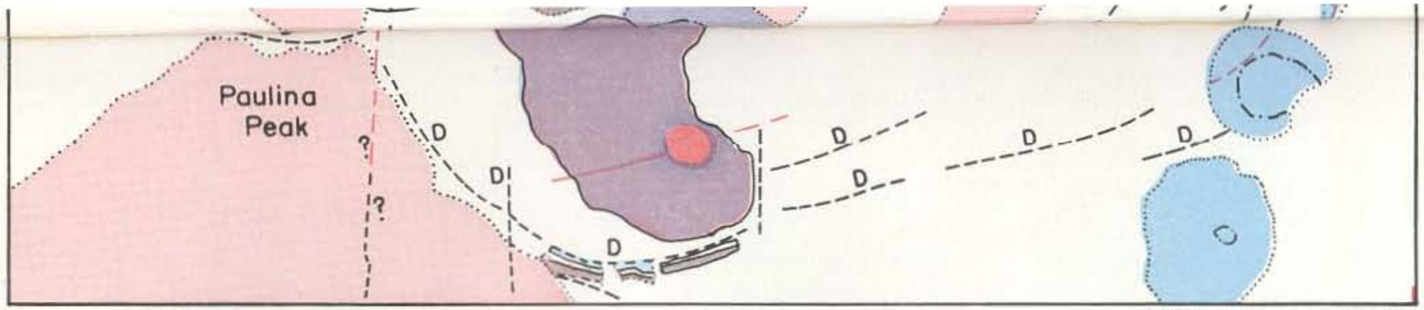
As already mentioned, one of the caldera walls at Newberry Crater cuts (or beheads) the Paulina Peak rhyolite flows -- therefore, final subsidence of the caldera occurred after this rhyolite (and those units under it) were emplaced. In places the caldera contains about 15 to 20 inches of Mazama ash easily identifiable by its high percentage of well-formed crystals of pyroxenes and plagioclase (Powers and Wilcox, 1964; Fryxell, 1965). This Mazama ash, erupted just before the formation of the Crater Lake caldera, has been dated at 6,600 years ago. Whether the Mazama ash fell after collapse of the Newberry caldera or fell earlier and was spilled into the caldera along with the old summit, is not yet known.

Subsidence of Newberry caldera probably began with downdropping of a large, roughly circular block -- much larger than the present caldera -- along ring fractures. The outline of this early caldera can be seen as a "step" about a mile and a half from the present inner caldera walls. Successive "circular" downdrops with increasingly greater displacements, but with smaller diameters, resulted in the present "nested" or stepped arrangement of the caldera walls (figs. 7, 9, and 10). We cannot, however, be sure as yet when movement on these outer faults actually started, because even after formation of the present inner caldera the old faults defining the earlier and larger, but probably much shallower calderas, continued to be active. From these fractures issued late andesite and basalt flows, and the fountaining of scoriaceous lava from the fissures built up levee-like spatter banks and small cones of cinders and bombs along the fissures (fig. 7), only to be cut and displaced in turn by still more recent movements. The pyroclastics and flows now visible along these fractures are not covered by Mazama ash, and must, therefore, be less than 6,600 years old.

The cause of caldera formation at Newberry is open to speculation. Did the caldera form, as Williams (1935, p. 267) suggested, after large volumes of basaltic lavas had been erupted from vents far down the slopes of the shield, thus draining the upper levels of the magma conduits and withdrawing support for the roof of the shield?

Fig. 3. GENERALIZED GEOLOGIC MAP OF NEWBERRY CALDERA.





Base from aerial photograph.

Geology by M. W. Higgins and A. C. Waters, 1967.

1 mile

Explanation

- Landslide deposits, areas covered by pumice, and areas not yet mapped
- Obsidian flows
- Basalt and/or andesite cinders with some thin flows and agglutinates
- Late andesite flows on the floor and rims of the caldera
- Pumice cones
- Basalt flows
- Rhyolite flows and domes with some obsidian
- Mafic tuff rings
- Welded tuff
- Andesite and/or olivine-poor basalt
- Mafic graded tuffs
- Platy andesites of the caldera walls
- Old rhyolites of the caldera walls
- Crater
- Obsidian dome and/or vent
- Fault with down-dropped block marked "D". Dashed where inferred.
- Fissure which acted as a vent. Dashed where inferred.
- Contact, dashed where approximate. Dotted where gradational or inferred.

This appears likely, but the eruption of the welded tuff on the east wall of the present caldera, and the eruption of copious flows of rhyolite forming Paulina Peak may also have been contributing factors, and so may movements of the basement rocks along the complex assemblage of en echelon faults that comprise the Brothers Fault Zone where it passes beneath the volcano.

Post-Caldera Activity

East Lake and Little Crater tuff rings

After foundering of the caldera to its present depth was essentially completed, post-caldera volcanic activity brought about many changes on the caldera floor. Among the earliest events was the growth of three mafic tuff rings formed mainly under water. Whether all three erupted concurrently or separately is not known at this time. Therefore, the order of description has no chronological or stratigraphic significance.

East Lake tuff rings

Two mafic tuff rings are present on the south shore of the present East Lake. For purposes of description, the ring nearest the lake is called the East Lake tuff ring, and the ring just southwest of the East Lake ring is called the South tuff ring (fig. 2 and fig. 3). Neither ring is complete.

About half of the East Lake tuff ring is present now, but the draping of the beds over the old rims indicates that the center was beneath East Lake approximately 100 yards off the south shore. Coincident with this deduced center are active hot-springs and fumaroles in the lake.

The South tuff ring is also represented by about half of the original cone. The southern half was overwhelmed by a later obsidian flow erupted from a vent about a third of a mile to the south.

The beds and rocks of both rings are very similar. Both are composed of hundreds of thin (from less than half an inch to about six inches thick) beds of palagonitic lithic tuff. Many beds are graded, and the size of the lithic fragments ranges from about an inch and a half in diameter to lapilli and fine ash. Many larger fragments up to $4\frac{1}{2}$ feet across are sporadically distributed through the beds. The matrix is a fine basaltic ash. Fragments of rhyolites and of hypabyssal rocks are not rare.

The glassiness of most fragments, the formation of palagonite and clays, and the nature of the "draping" of the beds over the old rims, suggest that the tuff rings were formed by rhythmic phreatic eruptions from vents in a shallow lake.

Little Crater tuff ring

Little Crater tuff ring lies at the southeast shore of Paulina Lake on the neck of land separating the two lakes (figs. 10 and 11). It is complete, and shows a draping of beds over its rims, similar to the East Lake rings and to other aqueous tuff rings (for example, Fort Rock). Like the East Lake rings it has many "foreign" inclusions, but not of such variety as the East Lake rings. It also probably formed from rhythmic eruptions in shallow water.

Wall deposits from the tuff rings

On the north wall, thin beds of palagonite tuff, identical to those forming the tuff rings, are locally present. They are bedded parallel to the steep walls, and must have been wet and pasty to have had the consistency to maintain their bedded position on slopes as high as 50°. In other words, they must have been "plastered" there, as air-fall deposits of wet sticky material.

Relative age of the tuff rings

The South tuff ring has been overrun in part by one of the East Lake obsidian flows (fig. 3). Since beds from the two East Lake rings are intercalated with one another, they are assumed to be roughly the same age. Thus, both rings are probably older than the East Lake obsidian flows. All three rings are mantled by pumice from one or more of the pumice cones and thus are older than these pumice cones.

East Lake obsidian flows

Two obsidian flows are present on the southeast side of East Lake (fig. 7 and 8). The flows are tentatively considered to be of the same age and to have been erupted from the same fissure (fig. 8). Because the westernmost flow overran part of the apron of the South tuff ring, the flows are considered younger than the tuff rings. Both flows are mantled by as much as two feet of pumice erupted from pumice cones within the caldera.

Interlake basalt flow

The interlake basalt flow (fig. 2) was erupted from a vent or fissure at approximately the center of the neck of land dividing the two lakes (now covered by the central pumice cone). The flow emerges from beneath the pumice apron of the central pumice cone, and covers the western part of the neck of land between the lakes. Numerous lobes extending to the eastern shore of Paulina Lake indicate that the direction of flow was towards the lake. Oxidation, alteration, and brecciation of the basalt at the shore of the lake, the probable projection of many of the lobes into the lake, and the fact that the flow locally overlies semi-consolidated lake deposits, indicates that the flow entered the lake. To the north the flow is overlain by the interlake obsidian flow.

In hand specimen the rock is a scoriacious or vesicular olivine basalt. Thin sections have not yet been studied.

Pumice cones

There are three main pumice cones on the floor of the caldera (figs. 9, 10, and 11). One, informally called the north pumice cone, lies at the northeast corner of Paulina Lake at the foot of the north wall (fig. 9). The largest (central pumice cone) lies in the middle of the neck of land between the two lakes. The third (south pumice cone) is now represented by half of the original cone, and lies just south of the Interlake road.

The north cone is nearly perfect and has a crater more than 100 feet deep (fig. 9). It is composed entirely (at least as far as can be seen) of pumice ranging from

Fig. 7

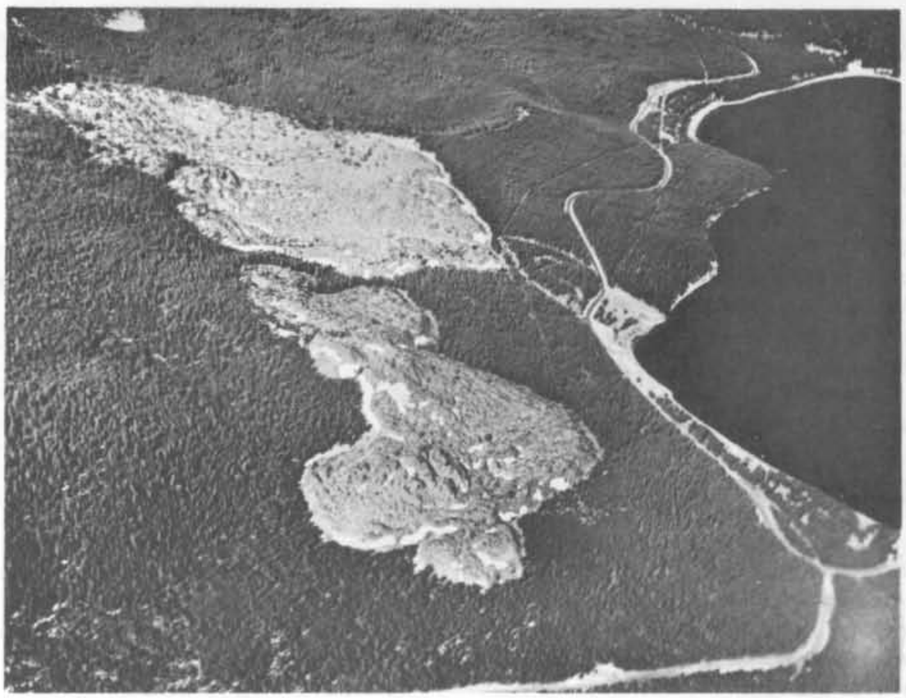


Fig. 8

Fig. 7. The stepped south wall of the Newberry caldera culminates in the rhyolite pile of Paulina Peak (right skyline). Two late obsidian flows, erupted from a single NE-SW trending fissure are in the center of the picture, just left of the southeast corner of East Lake. Big Obsidian flow spills over the lower step of the caldera rim in front of Paulina Peak. The top of the east caldera rim, angling across the left foreground of the photograph, is marked by an open fissure along which lie numerous chain craters, some of whose rims are dimly outlined by the cover of new-fallen snow. (Oregon Dept. of Geology and Mineral Industries photograph)

Fig. 8. The East Lake obsidian flows. Both were erupted, probably contemporaneously, from a NE-SW trending fissure whose trace can be seen as a line of discontinuous cracks across the highest parts of the flows. (Oregon Dept. of Geology and Mineral Industries photograph)

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blocks to fine lapilli along with some fragments of older rhyolites.

The central pumice cone rises more than 700 feet above the lake. It is symmetrical, but with a deep cleft running across the crater in a north-south direction (figs. 9 and 11). This crater, more than 200 feet deep, contains a small obsidian dome which barely emerged through the crater floor. Another small obsidian dome poked up through the southeast margin of the cone and spread for a quarter of a mile to the east, southeast, and south. The central cone is composed mostly of pumice, but several "interbedded" obsidian layers can be seen in the walls of the crater.

The south pumice cone is partly obliterated by a lobe of the Big Obsidian flow which inundated its western half and spilled into its crater (fig. 10). The remaining half of the cone is composed entirely of pumice and fragments of rhyolite.

The pumice sheets that spread out as airfall deposits from the three cones have not yet been divided in the field (if, indeed, they are divisible). Airborne pumice from these cones extends as a continuous blanket for at least 20 miles to the east. At the thickest point on the southeast wall this pumice blanket is 18 to 20 feet thick.

In addition to the airfall pumice deposits, there are at least two pumice-lapilli ash flows in the caldera. These pumiceous ash flows are divided by and overlain by interbedded airfall pumice. Both pumice flows contain charcoalized logs. A log from one of the flows has been dated at 2054 ± 230 years ago (Peterson and Groh, 1965, p. 11).

Interlake obsidian flow

The interlake obsidian flow issued from a point near the base of the north wall and flowed down the neck of land between the two lakes until it encountered the base of the central pumice cone which divided it into two branches (fig. 9). One branch flowed towards East Lake and filled the narrow valley that existed between the central pumice cone and the north wall. The other branch was channeled into the narrow valley between the central pumice cone and the north pumice cone (figs. 9 and 11). In this course it encountered and overrode the ridge-like lobes of the interlake basalt flow. Whether either branch entered water or not is not known. There is some indication that the lakes either had drained, or stood at a much lower level during this time.

Because it was deflected by the central and north pumice cones, has no pumice cover, and overrode the interlake basalt flow, the interlake obsidian flow is clearly younger than the pumice cones.

Fig. 9

Fig. 10

Fig. 9. The cleft top of the central pumice cone is in the center of the view. The interlake obsidian flow, whose source is just left of the center of the bottom edge of the picture, split into two forks when it reached the central pumice cone. One fork flowed left into East Lake, the other right into Paulina Lake. The north pumice cone with its perfectly formed crater lies just to the right of the vent that fed the interlake obsidian flow. The Big Obsidian flow occupies the upper right corner of the picture. Two steps in the south caldera wall can be seen, one behind the source, and the other left of the Big Obsidian flow. (Oregon Dept. of Geology and Mineral Industries photograph)

Fig. 10. The Big Obsidian flow occupies the central part of the view. Behind it lies the curving southwest wall of the Newberry caldera, emphasized by a dusting of new-fallen snow. The stepped nature of the caldera rim can be clearly seen. In the background numerous cinder cones dot the south slope of the Newberry shield. Little Crater tuff ring is in the left foreground on the shore of Paulina Lake. Above it a lobe of the Big Obsidian flow has overtopped and nearly filled the crater of the south pumice cone. (Oregon Dept. of Geology and Mineral Industries photo)

Big Obsidian flow

The largest, and most spectacular, of the Newberry obsidian flows issued near the south rim of the caldera and spread as a broad lobate tongue for about a mile and a half towards the center of the caldera (figs. 7, 9, 10, and 11). Its front stopped just short of the Little Crater tuff ring. Absence of air-fall pumice on the Big Obsidian flow indicates that it formed later than the pumice cone activity. Although the lack of vegetation makes it possible that this flow is younger than the interlake flow, the differences in vegetation may only reflect differences in availability of water to the two flows. The position of the interlake flow between the two lakes, essentially mounted on East Lake's underground drainage, may be one cause of its thicker vegetation.

The blocky surface of the obsidian flow is diversified by ridges 10 to 15 feet high and 20 to 30 feet apart. They consist of jumbled blocks of grayish partly-frothed obsidian. In troughs between the ridges blocks of lustrous black obsidian have been brought up from beneath the frothy flow top by ramps that extended into the pasty lava below. On the sides of the flow these swales and ridges have been pulled, squeezed, and autobrecciated into closely spaced ridges parallel with the flow margin.

The last event in the development of the flow was the rise of a dome of obsidian. It projects out of the vent to a height of 20 to 60 feet above the flow surface, forming a deeply fractured and jagged-topped spine (fig. 12).

Other features

Other volcanic features and flows present on the caldera floor are still being investigated and will not be discussed in this paper.

Post-Caldera Faulting

In addition to the post-caldera movement on ring fractures already mentioned, other faults have significantly modified the caldera and the shield since caldera formation. Some of these faults are only recognizable by the alignment of cones on them, or of flows from them. Others have scarps and show displacement of flows.

Fig. 11

Fig. 12

Fig. 11. The central part of Newberry caldera, looking northeast. The low but broad crater of the Little Crater tuff ring is in the center of the view, just to the left of the interlake road. Most of the bulk of this underwater volcano is below the level of the lakes. Steep-sided central pumice cone rises behind Little Crater. The front of the main lobe of Big Obsidian flow rises 60 feet above the timbered pumice plain in the right foreground. Across the caldera, near the upper north corner of the photograph, the source of the interlake obsidian flow can be seen at the foot of the north wall of the caldera. This obsidian flow, central pumice cone, and Little Crater tuff ring form the land bridge that divided a former large caldera lake into Paulina Lake (left foreground) and East Lake (center background). (Oregon Dept. of Geology and Mineral Industries photograph)

Fig. 12. A low plug dome with a fissure across its left edge marks the final stage in the development of the Big Obsidian flow. (Oregon Dept. of Geology and Mineral Industries photograph)

Still others can be recognized only by displacement of the stratigraphic sequence in the caldera walls.

North-south trending faults

Williams (1935, p. 268) first suggested that downfaulting might be the cause of the absence of a wall on the west side of the Newberry caldera. The evidence we have accumulated indicates that this is indeed the case.

Contrary to Williams' tentative correlation, however, the andesite and olivine-poor basalt overlying the mafic graded tuff at Paulina Falls (the upper falls) does not match anything on the caldera walls. Andesites on top of the east wall of the caldera are post-caldera in age and were erupted from late ring fractures, whereas the andesite and olivine-poor basalt at Paulina Falls is pre-caldera in age and was erupted from one of the central vents.

On the other hand, the platy andesite cropping out at the lower falls on Paulina Creek does correspond to the platy andesites in the caldera walls, and the mafic graded tuff overlying the platy andesite along Paulina Creek between the lower and upper falls (Paulina Falls) corresponds to the mafic graded tuffs overlying the platy andesites in the caldera walls.

One major fault (although possibly not the only fault involved which accounts for this downthrow of the western wall) trends north-south across the caldera. It extends through the Red Slide on the north wall above Paulina Lake, and intersects the south wall just east of Paulina Peak, where, however, its exact position is obscured by the fact that the Paulina Peak rhyolites probably rose through a vent or vents developed at the intersection of this fault with the fault defining the rim of the caldera. The evidence for the existence of this fault is as follows:

1. The stratigraphic sequence (rhyolites, platy andesites, red scoria, and mafic graded tuffs -- present in both north and south walls of the caldera) ends abruptly at this fault, but it is found again (same sequence, identical rocks) in the valley of Paulina Creek. The stratigraphic throw of corresponding stratigraphic units on the two sides of the fault amounts to 400 to 600 feet.

2. North of Paulina Lake the fairly even top of the caldera wall drops abruptly about 200 feet in elevation just west of the Red Slide, reaching the level of the west rim in half a mile. On the south wall of the caldera, however, this is not the

case, for Paulina Peak, the highest point on the caldera rim, lies just west of the supposed fault line. Just east of where the fault is believed to cut the south wall of the caldera, the rhyolites, platy andesites, red scoria, mafic graded tuffs, and brown scoria of the pre-caldera sequence, which have maintained a fairly constant dip, causing them to appear as nearly horizontal layers on the wall as they are followed from east to west, are bent downward toward the west. In the next outcrop to the west of this bend the younger rhyolites of Paulina Peak occupy the steep face of the wall in place of the pre-caldera sequence, and are continuous clear to the level of the caldera floor. The exact junction of the pre-rhyolite units with the younger rhyolite is covered by a talus slope, hence the fault itself is not visible. Our interpretation of this relation is that the rhyolites forming Paulina Peak were erupted concurrently with or shortly after, the western block began moving down along this fault. Thus the intersection of the north-south fault with the ring fault of the caldera probably determined the location of the vent, or at least one of the vents, from which the rhyolite erupted. The fact that the younger rhyolite extends to the caldera floor suggests that it may have filled a valley formed by the faulting.

3. The alignment of other volcanic features along this fault scarp appears to be more than coincidental. Among them are cinder cones on both the north and south slopes of the shield.

4. Although he did not attribute the downdropping of the western part of the caldera to a large fault at this particular line, Williams (1935, p. 271) recognized a break through the Red Slide on the north wall of the caldera. He wrote: "These cones, known locally as the 'Red Slide', apparently lie on a north-south fissure, which opened downward as activity progressed, for the latest outflow was a short stream of basalt that escaped from near the base of the younger cone."

5. Numerous faults with less displacement parallel this line. They can be seen on both the north and the south walls of the caldera; a few have displacements of as much as 100 feet. Also troughs and elongate cones or spatter ridges with north-south trends are discernable on the contour map of the bottom of East Lake.

Northwest-southeast trending faults

Many northwest-southeast alignments are noticeable on the Newberry shield. This structural trend is also common within the caldera. The most visibly continuous of the northwest-southeast trending faults is locally known as "The Fissure." This fault is seen as an open scar on the north wall above the northwestern corner of East Lake. It can be traced, though, with numerous small en echelon offsets, from the water's edge at East Lake to several miles northwest of Lava Butte, a total distance of more than 30 miles. It is an open fissure where crossed by U.S. Highway 97 near the southeast corner of Lava Butte. From the fissure numerous flows have been erupted (Peterson and Groh, 1965, p. 9). It has been stated that the fissure extends south of East Lake to Devils Horn, but this is in error; Devils Horn is on one of the north-south lineaments.

Displacement of the stratigraphic units by this fault on the north caldera wall probably amounts to 200 to 300 feet. The eastern block dropped down relative to the western block. This displacement is one factor that accounts for the occurrence of the platy andesite, instead of the older rhyolite, along the base of the east wall of the caldera. This downfaulting may also have lowered the east rim enough to provide the trough that channeled the ash flow which formed the welded tuff. If so, the fault was active just before the caldera collapse. It also has been active since the caldera was formed, as shown by fountaining of basalt scoria out of this fissure to form spatter ramparts upon its rims near the northwestern corner of East Lake, and by lava flows that emerged from it at several points on the northwestern flank of the shield.

Relations of the north-south faults to the northwest-southeast faults

Although the junctions between the north-south faults and the northwest-southeast faults have not been observed directly in the field, the nature of their meetings as seen on aerial photos, and particularly the nature of their intersections shown on the bottom contour map of East Lake, indicate that the two trends belong to the same system. Instead of two intersecting fault systems, it is believed that these two trends represent one contemporaneous set of faults bending sharply or splitting off from north-south trends to northwest-southeast trends, just as the Brothers Fault Zone bends in this region.

Northeast-southwest trending faults

Many small (both in the sense of length,-width, and displacement) faults with northeast-southwest trends are also discernible in the Newberry Volcano, particularly in the caldera. These faults generally appear as enlarged joints on which small displacements have occurred. They never account for major offsets of strata or of the topography of the walls, and probably they represent slight adjustments to recent movement of old faults beneath the caldera floor. Nevertheless this is the trend of the prominent Walker Rim fault, which has a displacement of more than 1500 feet. The Walker Rim fault gradually decreases in throw to the northeast before it disappears beneath the young lavas on the southern rim of the Newberry shield.

Differentiation at Newberry Volcano

Newberry Volcano has been cited as a good example of the so-called "basalt-rhyolite association" (Williams, 1935, p. 300-303; Turner and Verhoogen, 1960, p. 279, 286-287) because it was thought that here large volumes of mafic lavas and silicic lavas were present, with a paucity of lavas of intermediate composition. Pending thin sectioning of hundreds of inclusions collected from many cones and flows on the caldera floor and on the shield, little can be said about the rocks that make up the huge unexposed bulk of the shield. From the rocks exposed on Paulina Creek and in the caldera walls, however, it appears that intermediate lavas are perhaps nearly as voluminous as the more mafic and siliceous varieties. Platy andesites and andesite tuffs are prominent components of the caldera walls and of parts of the shield; they appear to show gradations toward both the basalts and to the less siliceous of the "rhyolites." Platy olivine andesites are the chief shield-forming lavas of the Medicine Lake Highlands (Anderson, 1941), an area which has many similarities to the Newberry Volcano.

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PAISLEY CLAIMS LEASED TO HANNA FOR EXPLORATION

Exploration of 83 claims south of Paisley in Lake County as a potential area for minerals development will be undertaken by the Hanna Mining Co. of Cleveland, Ohio, under terms of a memorandum of option agreement signed by that firm and owners of the claims, it was announced by Ross Foster, one of the principal owners. The site is along the face of the mountain south of Paisley, and involves an area about three miles long and more than a mile wide. Foster said minerals included copper, gold, lead, zinc, silver, and mercury.

Together with Con O'Keeffe of Twin Falls, Idaho, a Westside rancher, and Kenneth Faulk of Lakeview, he has been prospecting, staking, and exploring the Paisley region for about two years and has an interest in most of the claims and claim groups leased to Hanna. Others involved in claim ownership are Coy Amacker, Don Tracy, Don Fitzgerald, Ross Colahan, Bertron Daron, Paul DuBose, and their families.

The lease, filed with the Lake County Clerk February 27 by Attorney T. R. Conn, provides for the agreement to expire December 31, 1969, unless continued by other agreements. (Lake County Examiner, March 2, 1967)

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GEOLOGY OF STATE PARKS NEAR CAPE ARAGO, COOS COUNTY, OREGON

By Judi Ehlen*

Introduction

One of the most beautiful and geologically interesting parts of the Oregon coast is in the vicinity of Cape Arago near Charleston, 10 miles west of Coos Bay. Three very fine state parks have been developed here. They are (from north to south): Sunset Bay, Shore Acres, and Cape Arago State Parks (see plate 1). Sunset Bay State Park is situated near sea level in the valley of Big Creek, which flows into Sunset Bay. This park has a large camping area as well as places for picnics. Shore Acres and Cape Arago are perched about 100 feet above the ocean, but trails lead down to coves at water level; both parks have viewing and picnic sites. A surfaced road leading southwest from Charleston connects the parks.

At all three parks, erosion of tilted and faulted sandstone beds of varying hardness has resulted in a peculiar rocky scenery that has no counterpart anywhere else on the Oregon coast (figure 1). In addition to the rocks, fossils, and other geologic features, the area possesses a wide variety of plants and animals and an interesting historical background.

Previous work

Geologists who have studied the area include Diller (1899, 1901), Dall (1909), Schenck (1928), Turner (1938), Weaver (1942, 1945), Allen and Baldwin (1944), Moore (1963), Dott (1966), and Baldwin (1966). Except for direct quotations, the normal system of geological reference is used sparingly in this paper, but all references consulted are listed at the end of the article.

History

The first people to visit Cape Arago were probably the ancestors of the Coos Indians. No one knows how far back in history their sojourns in this area go, but, from the size of the shell mounds they left behind them, they must have gathered and prepared clams here for centuries. All that remain today of their activities in the

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* Judi Ehlen is a graduate student and assistant in the Department of Geology at the University of Oregon. Her report on the State Parks at Cape Arago is the result of a cooperative arrangment between the State of Oregon Department of Geology and Mineral Industries and the State Parks and Recreation Divison of the Highway Department to present the geology of the area in a way that will be interesting and understandable to park visitors.

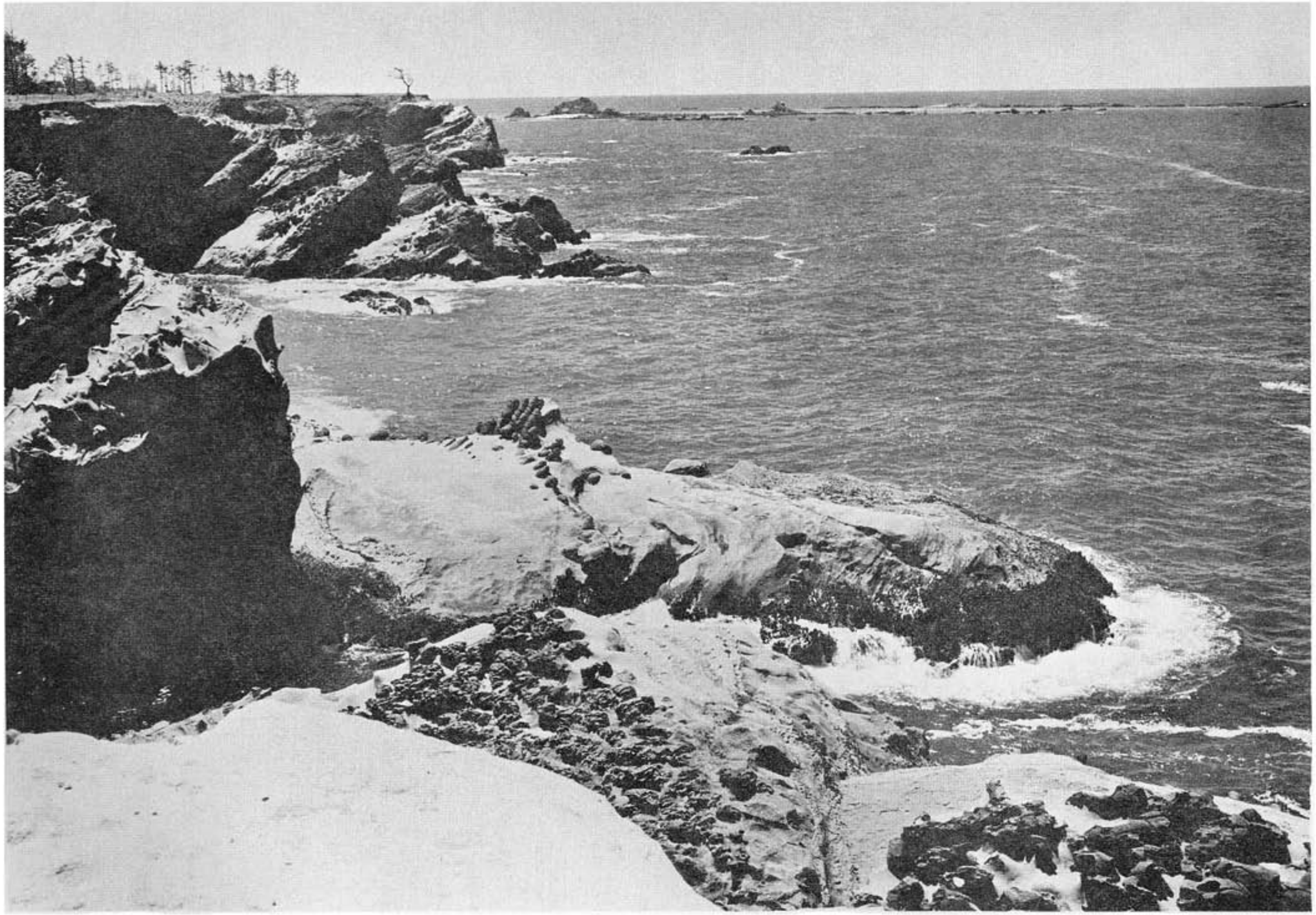

Figure 1. Etching of tilted sandstone beds of varying hardness by waves produces these peculiar features near Cape Arago.

Cape Arago region are the whitish layers of shells now buried under soil and vegetation, and in places, such as Lighthouse Point and Mussel Reef, exhumed by wave erosion.

Cape Arago may have been seen as early as 1775 by Spanish explorers sailing along the coast, but if the Spaniards saw the cape they failed to note its location. The first person to take a sight on the cape from the sea was Captain James Cook, who charted its location on March 12, 1778, while searching for the "Straits of Anian," a mythical connection between the Atlantic and Pacific Oceans. He named the headland "Cape Gregory" in honor of the saint of the day. This name was lost, however, and when the first survey of the Oregon Coast was made in 1850, Cape Gregory was renamed "Cape Arago." The name "Gregory Point" is now applied to Lighthouse Point on topographic maps.

Since the days of the Indians and explorers, many people have visited Cape Arago with its scenic grandeur and recreational potential.

Plants and Animals

There are many types of plants and animals native to the Cape Arago region. Among the mammals are black-tailed deer, Roosevelt elk, raccoon, beaver, and muskrat. In the vicinity of Shore Acres and Cape Arago many domestic cats, abandoned by their owners, have gone wild. Among the fish caught off the coast in this area are red-tailed perch, salmon, ling cod, and smelt. Smelt dipping is done in a small cove south of Mussel Reef. Abundant marine life in the tide pools of Sunset Bay and Cape Arago includes starfish, sea anemones, crabs, and sea urchins. Seals and sea lions swim or sun themselves on rocks off Cape Arago, and spouting whales are sometimes observed. Murres, cormorants, and other sea birds nest on the offshore rocks.

An unusual mature stand of timber can be seen in the area behind the University of Oregon Marine Biology Station near Charleston. It includes Douglas fir, Port Orford cedar, western hemlock, and Sitka spruce. Common shrubs in the area are red and blue elderberry, salal, salmonberry, thimbleberry, rhododendron, Oregon grape, gorse, and Scotch broom. Lupine, wild strawberry, nettles, trillium, skunk cabbage, wild iris, and many types of ferns are abundant.

Physiographic Features

The area around Cape Arago is an excellent place to study physiography, the science of land forms. One can see countless examples of the way varying hardness and structure of bedrock have controlled erosion by streams and waves, thus producing a diversity of physiographic features.

The higher hills in the area are formed of resistant sandstone and the stream valleys of softer, siltier rock. Big Creek, which flows into Sunset Bay, is an excellent illustration of how a stream will form a broad valley where it follows a softer bed and a narrow valley where it crosses a resistant layer. Many streams and bays in the area follow weak strata. South Slough, however, does not follow weak rock but lies in the axis of the South Slough syncline (a downfold in the bedrocks) and is, therefore, structurally controlled.

A short distance off the coast there are numerous sea stacks of various shapes and sizes. Some are typical conical masses. Some take the form of blocks of rocks, such as at Lighthouse Point, while others are ridges which parallel the shoreline, such as at Sunset Bay and Shore Acres. Sea stacks are composed of resistant rock which was at one time connected to the coast proper, but because this connection was softer, it has been removed by wave action. One of these stacks, Squaw Island, located near Sunset Bay, is unusual in that it is connected to the sea cliff by a thin strip of sand. This strip, called a tombolo, is visible even at high tide. The reefs in this area, such as Simpson Reef off Cape Arago and Baltimore Reef off Lighthouse Point, were also formed by this type of differential erosion.

Along the strand line itself are more land forms related to the bedrock. Many of the bays, such as the coves at Sunset Bay and Shore Acres, are surrounded by steep cliffs made of resistant material. These coves were made by the ocean eroding along a zone of weakness caused by faulting. The large beaches develop wherever easily eroded rocks occur. Examples are Bastendorff Beach, formed in shale, and Lighthouse Beach, formed in silty strata. The headlands in this area, such as Cape Arago and Coos Head, are composed of resistant sandstone which retards erosion.

Sequence of Sedimentary Rocks

The consolidated rocks of the Cape Arago area were formed from sediments deposited in marine, near-shore, and terrestrial (lagoon) environments. Ages of these rocks range from late Eocene to Pliocene. The environment of deposition can be inferred from the presence of marine fossils and sedimentary structures indicative of wave action and shallow water, and from the presence of coal beds and fossil remains of continental origin. Total thickness of these sedimentary rocks in the map area is about 11,700 feet.

Geologists have divided the sedimentary rocks into a series of fairly distinctive units (geologic formations), as shown on the stratigraphic column of plate 1. In the order in which they were deposited, from oldest to youngest, they are: Coaledo Formation, made up of lower, middle, and upper members, Bastendorff Formation, Tunnel Point Formation, and Empire Formation.

The strata have been folded into a large syncline, the axis of which trends northward under South Slough (see cross section A - A' on plate 1). Overlying the eroded edges of the tilted rocks is a nearly horizontal blanket of unconsolidated sands and silts of Pleistocene age. Although formal names have been applied to these sediments in some areas, they are generally referred to as terrace deposits. Each of the above units is described below.

Coaledo Formation

The Coaledo Formation of Eocene age is divided into three parts -- lower, middle, and upper. The whole formation is about 6000 feet thick and crops out from the southern end of the map to the southern end of Bastendorff Beach (plate 1). The three members of the formation are nearly conformable.

Lower Coaledo: The lower member of the Coaledo Formation forms the rugged coastline between the southern end of the map and the north side of Lighthouse Point (Gregory Point) (figure 2), and the trend of the coastline is nearly parallel to the regional strike of the beds. The unit comprises alternating strata of massive, buff-colored sandstone, thinly laminated gray siltstone, and silty sandstone (figure 3). Many of the beds contain small pieces of charcoal; one light-green bed exposed at Squaw Island and in the sea cliff at Shore Acres State Park contains many of these fragments. There is also some coal in the lower member of the Coaledo Formation.

Figure 2. Type section of the lower Coaledo Formation at Lighthouse Point. Cape Arago Lighthouse in background.

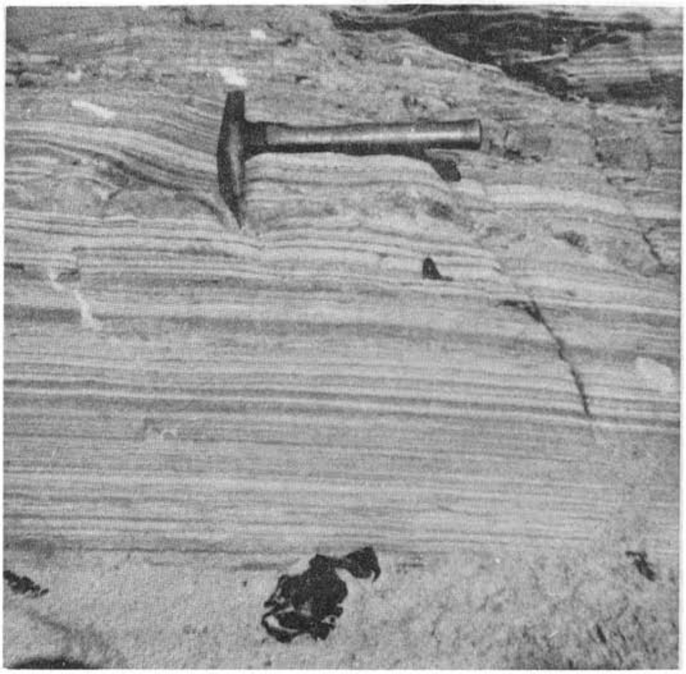

Figure 3. Typical sedimentary structure in lower Coaledo Formation.

Allen and Baldwin (1944) describe the lower Coaledo as follows:

> "Blue-gray medium- to coarse-grained nodular sandstone predominates with some grit and intercalated fine-grained sandy shale beds which are usually darker in color than the sands. The sandstone, which weathers to a characteristic buff color, is tuffaceous, and many of the pebbles in the few conglomerate lenses are of fine-grained basaltic material."

They also state that the matrix is in places calcareous. Dott (1966) likens the depositional environment to that of a delta. Among the interesting sedimentary features in the lower Coaledo beds are beautifully developed cross bedding which can be seen at Sunset Bay, intraformational truncation, and details of flame structures and sole markings, all exposed in the sea cliff of North Cove, Cape Arago. Fossils in the lower Coaledo include the pelecypods Pachydesma aragoense (Turner) and Venericardia hornii (Gabb), the scaphopod Dentalium, and the gastropod, Turritella uvasana (Conrad), as well as shark teeth.

Middle Coaledo: The middle member of the Coaledo Formation crops out along Lighthouse Beach. The contact with the lower Coaledo on the southwest is marked by the steep cliff of massive sandstone of the lower Coaledo Formation at Lighthouse Point. To the north, however, the contact with the upper Coaledo is gradational. In this report, the upper contact is placed on the south side of the southernmost outcrop of massive sandstone near Mussel Reef (Yokam Point). The middle Coaledo is distinguished by being much siltier than either the upper or lower members. It consists of thin beds of sandstone, silty sandstone, and siltstone and contains no coal. Allen and Baldwin (1944) describe the middle Coaledo as "... a medium gray tuffaceous shale with some sandy lenses."

Upper Coaledo: The upper member of the Coaledo Formation crops out at Mussel Reef, the type locality of the upper member. It extends from the last prominent sandstone outcrop on Lighthouse Beach to the west end of Bastendorff Beach. Massive buff-colored sandstone is predominant. To the southwest, however, the unit becomes more and more thin bedded and gradational with the middle Coaledo. As described by Allen and Baldwin (1944), the upper Coaledo is "...a gray medium- to fine-grained tuffaceous sandstone which contains less indurated carbonaceous shale and coal. Concretions, as well as coarse sandstone, grit, and coarse grit lenses, occur in places." According to Allen and Baldwin (1944), a bed of sub-bituminous coal which crops out at Mussel Reef may be an extension of the Beaver Hill bed which was successfully mined near the town of Coos Bay. A six-foot-thick layer containing fossil bivalves is exposed above one of the coal beds on the south side of Mussel Reef. The upper contact of the Coaledo is marked by a layer of black-weathering, concretionary sandstone about one foot thick, below which is a thin, pebbly bed. Concretions in the black material commonly contain many fossils, generally very small pelecypods and gastropods.

Bastendorff Formation

The Bastendorff Formation of late Eocene and early Oligocene age crops out along Bastendorff Beach from Mussel Reef to Tunnel Point. Along the beach, the Bastendorff Formation is very weathered and does not form a sea cliff. It is about

2300 feet thick and lies conformably on the Coaledo Formation. The rock is a thinly laminated siltstone which weathers to light buff, but on fresh exposure along the coast it is dark gray. Schenck (1928) used the name "Bassendorf shale" for this "...thinly laminated blue to steel gray shale with some strata of carbonaceous sandy shale and feldspathic sandstone." The Bastendorff Formation contains abundant microfossils.

Tunnel Point Formation

The Tunnel Point Formation of Oligocene age crops out near the middle of Bastendorff Beach. The formation, which is 800 feet thick, lies conformably on the Bastendorff Formation. The Tunnel Point consists of fine-grained, massive, buff-colored sandstone with some fossiliferous layers in the lower part (at the southern end of its exposure) at Bastendorff Beach. The lower part of the formation is commonly iron stained. The Tunnel Point Formation is described by Schenck (1928) as follows:

> "At the base of the formation, on the west side of Tunnel Point, is a massive concretionary bed composed chiefly of quartz and feldspar with an admixture of tuffaceous material and glauconite. Near the top, the sandstone is interbedded with brittle shale and a thin bed of tuff, in which glass shards are conspicuous."

The contact of the Tunnel Point Formation with the Empire Formation is covered with thick underbrush, but the relationship appears to be an angular unconformity because of the change in dip.

Unnamed Miocene beds

No Miocene beds were known until about 1950, when samples containing fauna of Miocene age were dredged from Coos Bay (Moore, 1963). Until recently, no outcrop was known on land. John Armentrout, who is doing a master's thesis at the University of Oregon on the Empire Formation, has found a concretionary, fossiliferous sandstone bed of Miocene age near Sitka Dock in Coos Bay (plate 1). According to Baldwin (1966), there is probably a lower Miocene equivalent of the Nye Mudstone of the Newport area below the newly discovered Miocene formation.

Empire Formation

The Empire Formation of Pliocene age extends from the northeastern third of Bastendorff Beach into the South Slough area. Around the town of Empire it is covered with terrace deposits, but it does crop out in a low sea cliff along Coos Bay. The Empire Formation lies unconformably on the Tunnel Point Formation, where it is present, and elsewhere on the Bastendorff and Coaledo Formations. It is about 1600 feet thick at Coos Head. Baldwin (1964) describes the Empire Formation as "...massive, poorly bedded sandstone with minor interbeds of siltstone...." The sandstone is jointed, and there is much iron staining along the joints.

Fossils in the Empire Formation include Patinopecten. Some very thin fossiliferous layers are exposed on the south side of Coos Head. The most interesting occurrence of fossils, however, is in the Coos Conglomerate, a member of the Empire Formation. The Coos Conglomerate crops out at Fossil Point on Coos Bay. Here such fossils as the clams Cerastoderma sp. and Marcia angustifrons (Conrad) and the

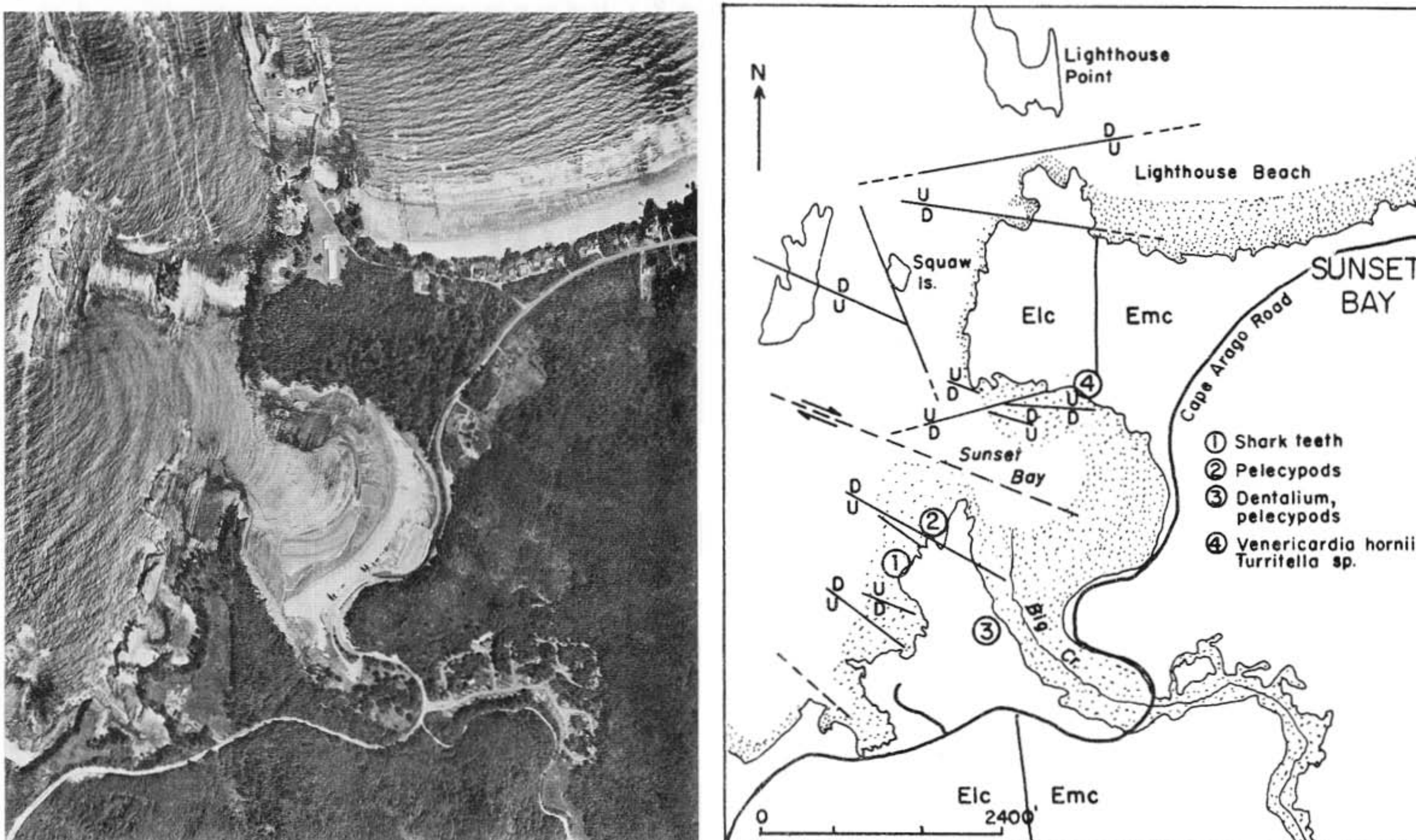

Figure 4. Aerial photograph of Sunset Bay and geologic sketch map of corresponding area.

gastropod Crepidula princeps (Gabb) are abundant. The sand dollar, Anorthoscutum oregonense (W. B. Clark) is another distinctive fossil of the Coos Conglomerate. In addition, there are pieces of whale and sea-lion bone of reddish-brown color. Boulders within the conglomerate are quite soft and are also fossiliferous. There has been much discussion as to the origin of the Coos Conglomerate; the best explanation appears to be that it is very similar to a channel deposit.

Terrace deposits

Lying unconformably above the Empire Formation are Pleistocene terrace deposits which range in thickness from about 6 feet to 20 feet. These terrace deposits have been called by many names, Elk River Beds being the most commonly used. They can be seen lying horizontally above all of the formations in the area mapped. They consist primarily of unconsolidated sand, and cross bedding is evident in them. The terraces themselves have been given several names: the Whiskey Run Terrace being the youngest and lowest, followed by the Pioneer Terrace, which, in turn, is followed by the higher terraces. The terraces are at different elevations because of differential movement of the South Slough syncline.

Structure of the Rocks

The regional trend of bed rocks in this area is about N. 15° W. and the dips vary from 30° in the Empire Formation to about 75° in the Bastendorff and Tunnel Point Formations. The dominant structure in the map area is the South Slough syncline (plate 1). This fold had a complex development, beginning in the middle to late Oligocene with folding of the Coaledo, Bastendorff, and Tunnel Point Formations. Extension caused faulting on the west limb of the fold, as illustrated by the numerous transverse faults between Sunset Bay and Cape Arago. These faults are discussed in more detail later in the report. Folding was renewed again after the deposition of the Pliocene Empire Formation.

The Cape Arago fault and parallel faults (figure 12, page 78) are not transverse to bedding and therefore are probably not related to the transverse faults on the limb of the South Slough syncline. They may have formed about the same time, however. The small syncline off Cape Arago, here called the Simpson Reef syncline, and the small Cape Arago anticline belong to this period of deformation but probably formed prior to faulting.

Description of the State Parks

Sunset Bay

Sunset Bay State Park is located 3 miles southwest of Charleston, Oregon on Cape Arago Road. Facilities in the park include a picnic area with covered sinks and stoves, three large parking lots, and a well-kept campground with 127 camping and trailer sites. Camping sites are attractive and private, and restroom facilities are clean and spacious.

The inner part of Sunset Bay is located in the middle Coaledo Formation and the narrow entrance is cut through the lower Coaledo Formation. Both the lower and middle members are quite fossiliferous in this area, containing shark teeth, a few crab claws, Venericardia hornii (Gabb) [a clam], Dentalium [a scaphopod, or tooth shell],

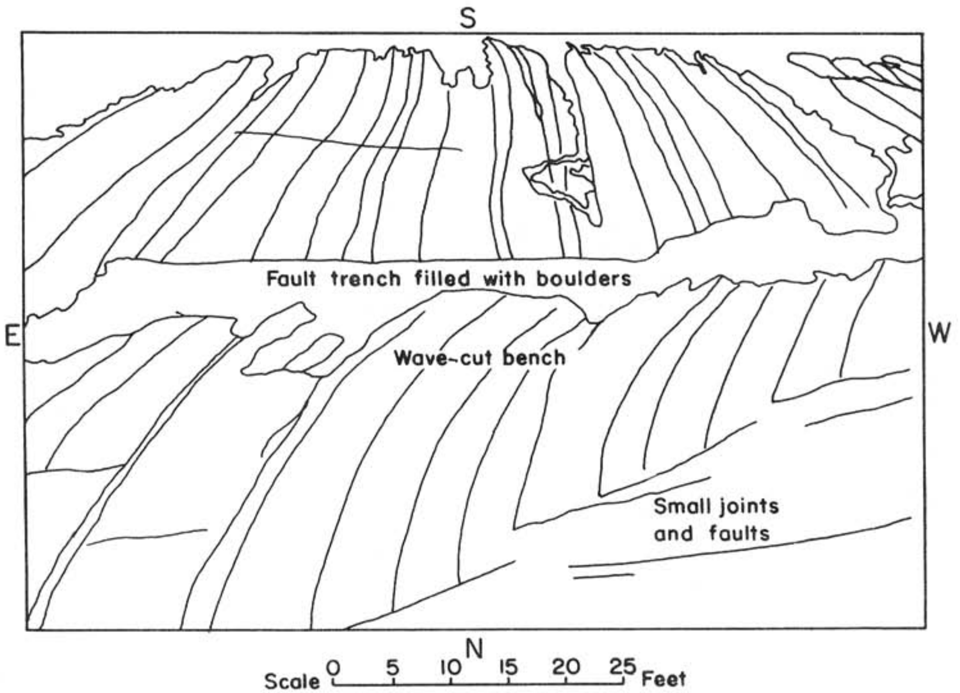

Figure 5. Sketch showing drag folding visible at low tide on wave-cut bench, north side of Sunset Bay.

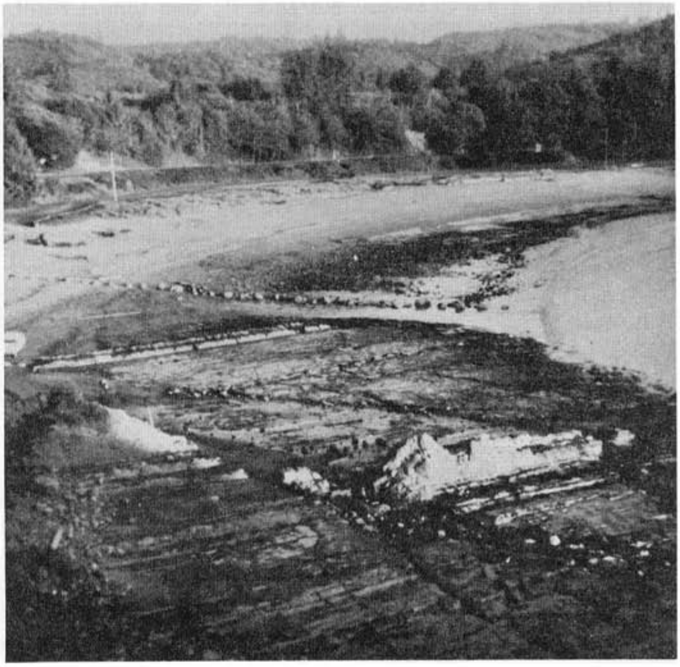

Figure 6. Faults and displaced beds on the wave-cut bench, north side of Sunset Bay.

Figure 7. Small fault on the wave-cut bench at Sunset Bay. The car is parked on the side of the fault that moved up.

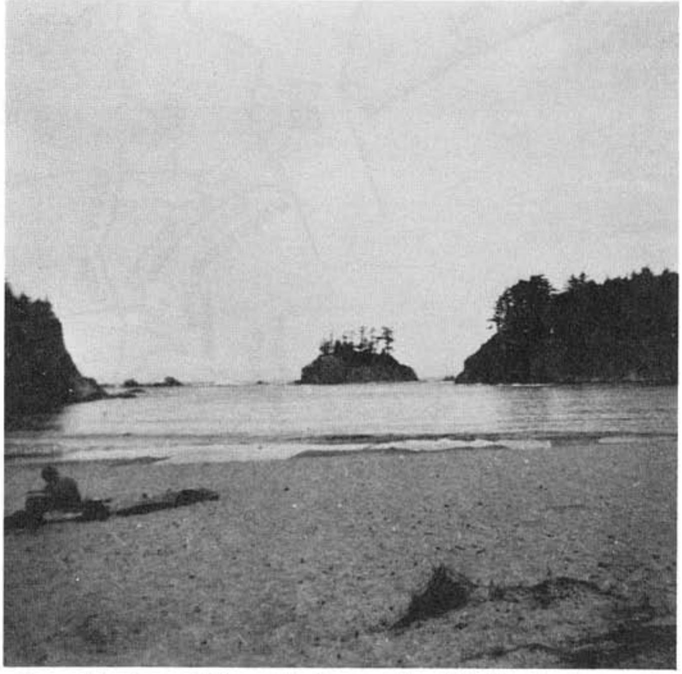

Figure 8. Sunset Bay with Squaw Island in the background.

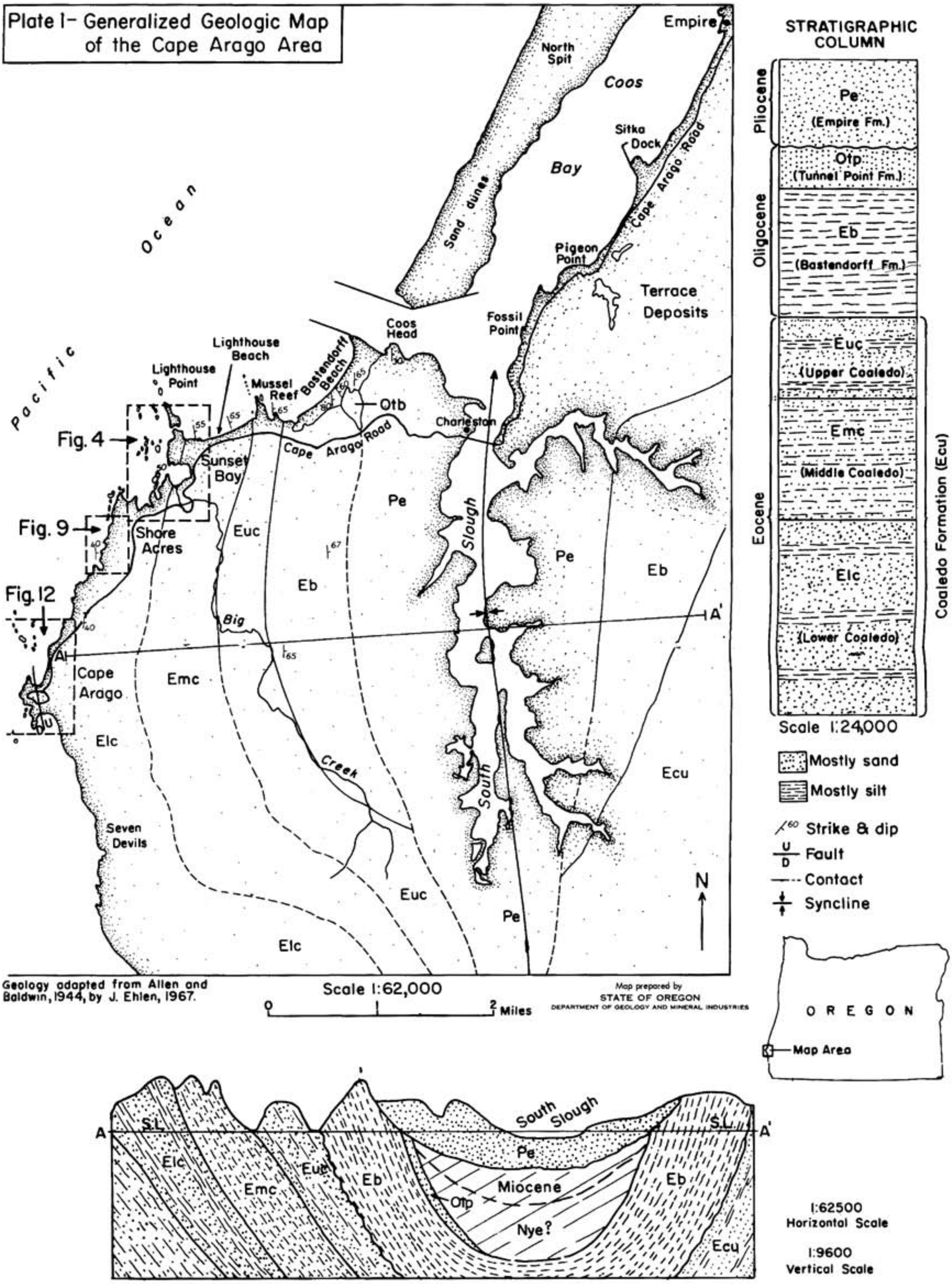
Plate I- Generalized Geologic Map of the Cape Arago Area
STRATIGRAPHIC COLUMN
Pliocene
Pe (Empire Fm.)
Otp (Tunnel Point Fm.)
Oligocene
Eb (Bastendorff Fm.)
Euc (Upper Coaledo)
Emc (Middle Coaledo)
Eocene
Elc (Lower Coaledo)
Coaledo Formation (Ecu)
Scale 1:24,000
Mostly sand
Mostly silt
Strike & dip
Fault
Contact
Syncline
Empire
North Spit
Coos
Bay
Sand dunes
Sitka Dock
Cape Arago Road
Ocean
Pacific
Pigeon Point
Terrace Deposits
Fossil Point
Coos Head
Lighthouse Beach
Lighthouse Point
Mussel Reef
Bastendorff Beach
Otb
Charleston
Fig. 4
Sunset Bay
Fig. 9
Shore Acres
Fig. 12
Cape Arago
Big
Creek
Slough
South
Seven Devils
Pe
Euc
Eb
Emc
Elc
Ecu
A
A'
N
Geology adapted from Allen and Baldwin, 1944, by J. Ehlen, 1967.
Scale 1:62,000
0
2 Miles
Map prepared by STATE OF OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
OREGON
Map Area
South Slough
S.L.
Miocene
Nye?
Otp
1:62500 Horizontal Scale
1:9600 Vertical Scale

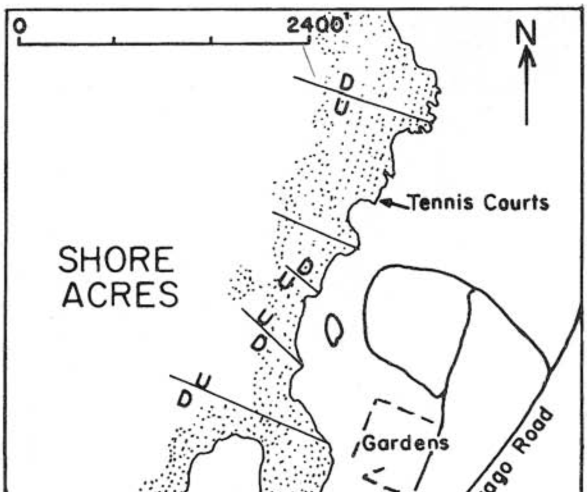

Figure 9. Aerial photograph of Shore Acres and geologic sketch map of corresponding area. Map shows location of faults and direction of movement (D = down; U = up) on either side of fault.

Turritella sp. [a gastropod], and other mollusks in easily accessible localities, which are shown on figure 4.

One outstanding feature of the bay is the complicated system of faults, well exposed on the wave-cut bench. This bench is formed by the waves in the bay wearing back the cliff. On the basis of orientation of drag folds, movement on the faults was oblique slip. The fault on the bench on the north side of the bay shows this type of drag (figure 5). Apparently the block to the south of the fault moved down and seaward. Details of movement on other faults have not been worked out. Further study of this topic is needed, since it may provide important information about the stresses (forces) which deformed the whole area. There is probably a strike-slip fault below sea level in the center of the bay, also transverse to bedding. Evidence of such a fault is seen in the prominent drag folding on either side of the bay.

As one walks along the north side of the bay, either on the wave-cut bench or on the path on the sea cliff, he may see many other interesting features. Most of the faults on this side of the bay (and at Shore Acres and Cape Arago State Parks) are marked by lines of boulders in small trenches eroded along weak beds or fault zones (figures 6 and 7). The contact between the middle and lower Coaledo is located near the first knob of resistant sandstone which sticks out from the sea cliff. The beds west of here are much sandier and crop out more prominantly than those to the east. Squaw Island, located further west, is connected to the mainland by a narrow strip of sand called a tombolo, one of the few along the Oregon coast (figure 8).

Walking from the north side of the bay to the south side at low tide, one can see the roots of trees imbedded in the beach sand in several places. These roots are evidence that sea level was once much lower than it is today. The majority of the roots are found on the south side of the bay, but the one or two on the north side are more interesting because they are associated with peat which is exposed at very low tide.

Continuing along the south side of the bay, one crosses the mouth of Big Creek, which flows into Sunset Bay from the south; it is the same stream that flows through the campground. This area is lower and flatter than the cliffs which surround the bay, because the rock was less resistant to erosion. As one moves west and back toward the ocean, he may see long ridges in the wave-cut bench which are parallel to the strike of the beds. These ridges are made of resistant sandstone, and the troughs between are cut in softer, siltier sandstone that is more easily eroded. In the same area, one can also see the beautiful cross bedding in the sea cliff mentioned earlier.

A delightful feature of the Sunset Bay area is the abundant animal life in the tide pools on the wave-cut benches. At low tide, one can find sea anemones, sea urchins, several kinds of crabs, and starfish as well as worms, tunicates, and algae in these tide pools. Many people think these are nice souvenirs to take home, but collecting here is illegal. A number of areas along the Oregon coast have been depopulated by heavy collecting and are now restricted. Sunset Bay and Cape Arago are two of the off-limit areas. Permission to take these animals for scientific study may be obtained from the Oregon Fish Commission.

Shore Acres

Shore Acres State Park is located 4 miles southwest of Charleston, Oregon on Cape Arago Road (figure 9). There is a small view house on the terrace immediately above the sea cliff, and there are picnic facilities with convenient restrooms. One of the outstanding features of the park is the formal and sunken garden built by the

Figure 10. Sunken gardens at Shore Acres State Park.

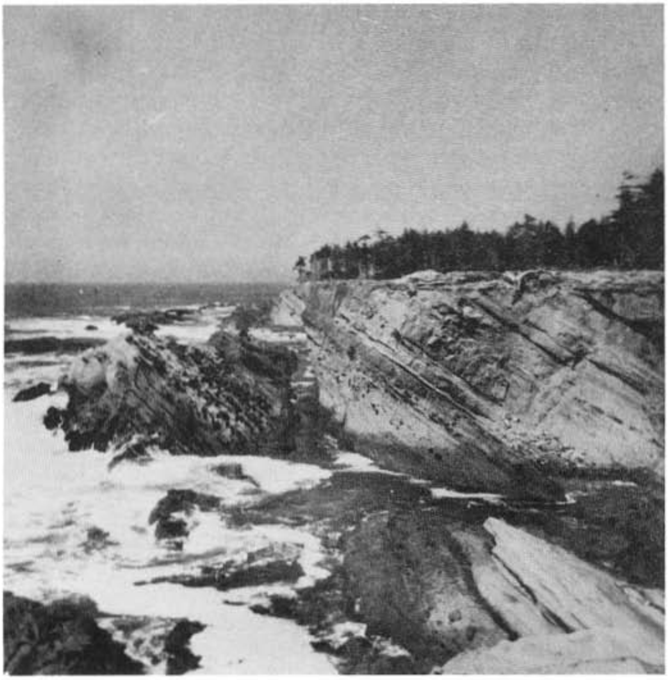

Figure 11. Tilted beds of lower Coaledo Formation north of view house.

Louis Simpson family. Both native plants and specimens brought here from all over the world can be seen in these gardens (figure 10). The gardens are now being tended by the Parks Division of the State Highway Commission. A greenhouse immediately east of the sunken garden contains large and beautiful begonias raised and cared for by the park manager, Bruce Barker. The residence of the park manager, who supervises all three parks, is situated here.

Shore Acres was developed as an estate by the Louis Simpson family, prominent in lumbering and shipbuilding in the Coos Bay area. A manor house built on the present site of the small viewhouse is described by W. A. Langille (1947b): "This large, unpainted three-story structure was over one hundred feet long, had fifteen guest rooms, a large living room, with a huge fireplace..." Located in the basement was a swimming pool, and north of the house was a tennis court. The manor house burned in the late 1930's and another was started to replace it, but in 1942 the Simpson family donated the property to the State. From 1943 to 1945, the area was occupied by the coast defense forces. Some of their gun mounts can still be seen on the terrace between Shore Acres and Cape Arago. During World War II, the gardener from Cape Arago State Park, Anton Jensen, tended the gardens so that they still retain much of their original beauty. Since it was never completed, the manor house was torn down by the State after the war. Part of it, the playroom of the Simpson children, was salvaged and moved, and is now the residence of the park manager.

Shore Acres lies in the lower Coaledo Formation and, as at Sunset Bay, there are many faults transverse to bedding. Each of the five small coves in the park area has developed along faults where waves have differentially eroded these zones of weakness. The faults are probably normal, with little displacement. The largest is located in the southernmost cove, directly west of the gardens. The plane of this fault dips 54° S. and the block to the south has moved down. The movement did not offset the terrace, showing that faulting occurred long before the terrace was formed.

Interesting features at Shore Acres include ridges like those at Sunset Bay. These ridges are again parallel to both the coastline and the alignment of beds, and are also made of resistant sandstone (figure 11). On their sloping backs are roundish dark shapes which stand out from the surface of the rock (figure 1). These objects are called concretions, and are composed of sandstone which is much harder than the surrounding rock. Differential erosion by the breaking waves causes them to stand out in relief. The concretions can be seen from the view house and also from an observation point west of the tennis court.

Cape Arago

Cape Arago, the southernmost and largest of the three state parks, is located about 5 miles southwest of Charleston at the end of the Cape Arago Road (figure 12). Cape Arago State Park is divided into three parts -- North Cove, Middle Cove, and South Cove. Each of these three areas has picnic facilities with spectacular views of the ocean. There are also restrooms and a large parking area. The terrace is about 100 feet above sea level, and well-made paths with steps lead down into the coves.

Cape Arago was originally part of the Simpson estate mentioned earlier; the Simpson family donated it to the State in 1932. Improvements on the original 134-acre tract were made by the Civilian Conservation Corps during the winter months of 1934 to 1937. According to W. A. Langille (1947a), park historian, these improvements included "...the park road and trails, fire breaks, fire hazard reduction, clearing the picnic areas, setting up tables and stoves, providing a water system and

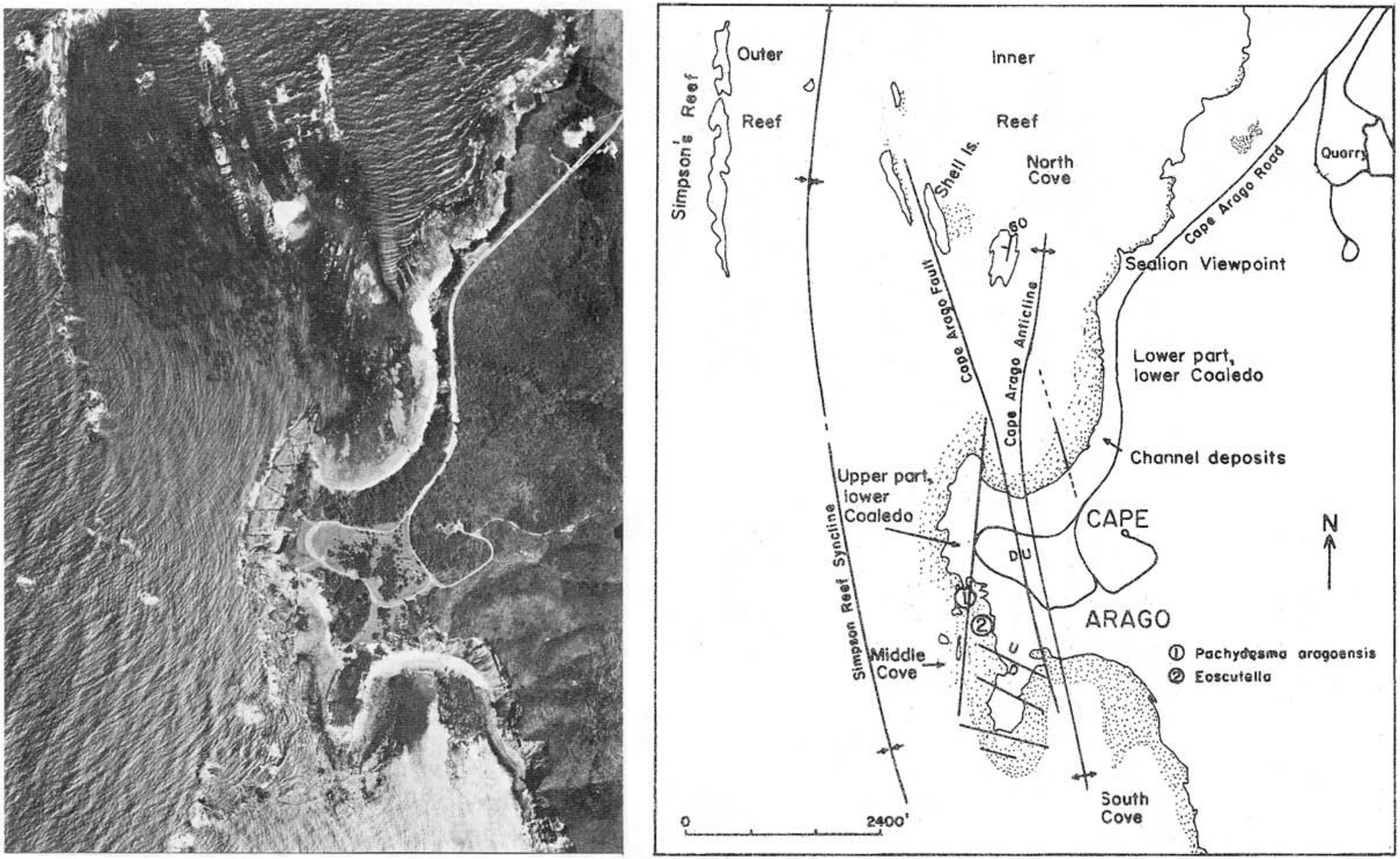

Figure 12. Aerial photograph of Cape Arago and geologic sketch map of corresponding area.

the erection of a park residence." The State Parks Division has since added parking space and restrooms.

The lower Coaledo Formation is the bedrock exposed in the park. The geology here is more difficult to interpret than at either Sunset Bay or Shore Acres because of the complex structural pattern. The dominant feature is the Cape Arago fault, which cuts through the cape (see figure 12). It is a normal fault down-dropped on the west with several hundred feet of displacement, so that beds on the east side of the break are appreciably older than those on the west. Another large fault runs through Middle Cove and appears to intersect the Cape Arago fault in North Cove. A set of faults transverse to bedding, similar to those at Sunset Bay and Shore Acres, is located on the neck of land between Middle and South Coves and smaller ones (not shown on figure 12) on the wave-cut bench on the west side of the cape.

In addition to the faults in this area, there are two large, north-trending folds called the Cape Arago anticline and the Simpson Reef syncline in this paper. The anticline underlies the terrace from South Cove to North Cove. The syncline axis, on the other hand, lies between the inner and outer parts of Simpson Reef, off the cape itself. Both fold axes are indicated on figure 12.

While walking along the beach in North Cove, one sees many interesting things. In the walls of the sea cliff are ancient channel deposits marked by beds thickening and pinching out. As one continues northward, he soon sees an unusual waterfall. Most waterfalls have a tendency to wear back into a cliff, forming an indented surface. This one sticks out from the cliff itself. This may be due to alternate wetting and drying of the cliff on either side of the falls in contrast to the constant wetness of the rock under the waterfall. Cementing minerals are loosened in the rock that is wetted and dries, making it more vulnerable to erosion than rock that is constantly wet.

Next to the waterfall is a small alcove in the cliff. On the walls of this alcove can be seen flame structure, so called because the silt patterns resemble flames (figure 13). The flames are dark gray and were formed by sandy sediment being deposited above silty sediment. The sand was heavier and coarser, and so it sank into the silt, causing the fine, dark-gray particles to squeeze upward. On the ceiling of this same alcove are sole markings. They show up as an uneven surface on the bottoms of the layers of rock and represent places where sand scoured a small hole and then filled it in. Flame structures and sole markings are some of the small sedimentary features that had their origin during the deposition of the lower Coaledo Formation back in Eocene time.

In Middle Cove (figure 14) there is more to be seen. Pieces of rock can be found that look scraped and polished on all sides. These marks, called slickensides, were produced by movement along the fault that cuts the rocks in the middle of the cove. Also, one can find several varieties of fossils in Middle Cove. Inside some of the concretions are sand dollars replaced by calcite. Another distinctive fossil found here is Pachydesma aragoensis Turner, a small clam about 2 inches across, which is unique in that it has retained some of its brown and black coloring.

Several other geological features can be seen in South Cove. As one walks east along the beach, he may encounter a large block of rock about 15 feet high. This rock is called a shale pebble conglomerate, and it is unusual because shale is generally too soft to last long enough to form a conglomerate. Some geologists believe that there was a shale sea cliff nearby at the time this material was being deposited and that the cliff crumbled faster than the sea could destroy it, thus the chunks of shale accumulated to form a conglomerate. There is another outcrop of the shale conglomerate in North Cove. Farther east, on the wave-cut bench which

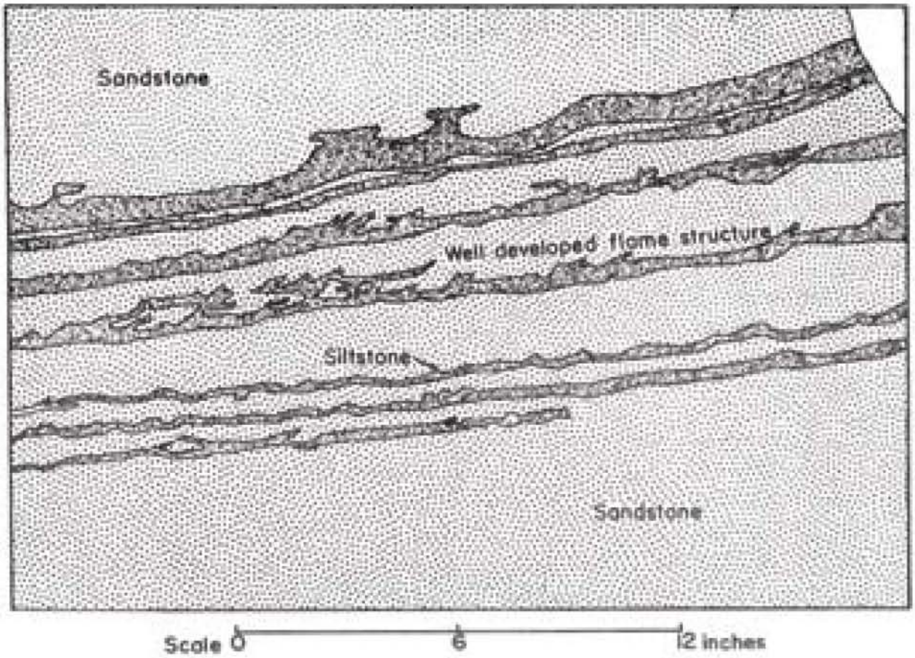

Figure 13. Sketch of flame structure near waterfall in North Cove at Cape Arago.

Figure 14. View of Middle Cove at Cape Arago.

is visible only at low tide, is a rhombic pattern of joints. This unusual pattern may be unrelated to the faulting in the cove.

Sea lions spend much of their time on Shell Island, and sometimes one can see seals on the outer reef. They can be observed from the Sea Lion Viewpoint just north of the road leading into the park proper, and their barking can be heard all along this part of the coast.

Summary of Geologic Events

The regional setting of western Oregon and Washington during the Eocene epoch, about 50 million years ago, was a long marine embayment, or geosyncline, extending from the southern boundary of Coos County northward to Vancouver Island, and eastward under what is now the Cascade Range.

During Eocene time, thousands of feet of marine sediments and submarine lavas accumulated in this slowly subsiding trough. In late Eocene time, the embayment became more restricted in size. As described by Snavely and Wagner (1963), ".... areas of local uplift and active volcanism divided the geosyncline into several separate basins and reduced the area of marine deposition." Coal swamps developed in the Coos Bay area and intermittent downwarping produced interfingering marine and nonmarine sediments of the Coaledo Formation.

By Oligocene time, about 30 million years ago, the marine embayment had withdrawn northward, but in the Coos Bay area a small arm of the sea still existed in which the Bastendorff and Tunnel Point Formations were laid down.

After deposition of the Tunnel Point Formation, the South Slough syncline began to form as a downfold in the Eocene and Oligocene strata. The transverse faults so prominent in Sunset Bay and at Shore Acres probably occurred during this period of warping. Miocene sediments were then deposited in the area, but erosion apparently removed all but the beds in the axis of the syncline before the Empire Formation was deposited.

In Pliocene time, about 10 million years ago, sands of the Empire Formation were laid down in the small marine basin that still existed in the Coos Bay area. The whole region was uplifted, and in Pleistocene time, about a million years ago, waves began to attack the new coast line, bevelling off the tilted strata and forming the level benches, or marine terraces, now so prominently displayed along the Cape Arago coast. Pleistocene sands deposited on the terraces can be seen lying unconformably on older rocks; that is, the sands are virtually horizontal, whereas the bedrock is tilted.

There is evidence in the terrace levels that the South Slough syncline is still active. The terrace at Cape Arago is about 100 feet above sea level; this same surface is near sea level at Charleston 5 miles to the northeast. This shows that there has been warping since the Pliocene epoch.

Of more recent occurrence is the drowning of the mouths of the Coos River and Big Creek to form Coos Bay and Sunset Bay. Drowning is the result of melting of the continental glaciers and consequent rise in sea level during the Pleistocene epoch. Other recent geologic events in the area include the building of the long sand spit and dunes which hem in the lower portion of Coos Bay, and the wearing away of rocky headlands to form sea stacks and reefs.

To sum it up, the deposition of the rocks, their deformation, and finally their erosion by the waves are what make the scenic geology we enjoy at Sunset Bay, Shore Acres, and Cape Arago State Parks.

Acknowledgments

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OAK MINE DRIVING CROSSCUT

The Oak Mine, Inc., of Grants Pass is running a new 280-foot crosscut at the Oak Mine to intersect a copper-zinc ore zone 100 feet below previous development work on the 150-foot level. Plans are to drift in both directions in order to develop ore indicated by a surface gossan, ore shoots developed on the 150 level, and induced-polarization geophysical interpretations.

The 5-by-7-foot crosscut being driven on the 250-foot level is planned as a main haulageway for a proposed selective flotation mill. The development work is being supervised by L. E. Frizzell, mining geologist of Grants Pass. The Oak Mine is 10 miles north of Grants Pass in the Greenback mining district, Josephine County.

* * * * *

FEDERAL MINING WITHDRAWALS ANNOUNCED

At the request of the U.S. Forest Service, the U.S. Bureau of Land Management has announced the proposed withdrawal of eight parcels of land from mineral entry in southwestern Oregon. The withdrawals amount to 434 acres. Three of the areas requested by the Forest Service are for tree seed farms, the remaining five are for campground and recreational use. Withdrawn lands are in Josephine and Curry Counties.

In Benton County the Bureau of Land Management has proposed the withdrawal of 132 acres in the Alsea Falls area from mineral entry to protect the recreational use and to safeguard the existing and planned government investments there.

* * * * *

THESE WITHDRAWALS ARE FOR THE BIRDS

The U.S. Bureau of Sports Fisheries and Wildlife has requested the withdrawal of a total of 346.06 acres for nesting grounds and landing strips for off-shore waterfowl. The withdrawal embraces dozens of coastal off-shore rocks, stacks, and pinnacles extending from Tillamook Head to Cape Blanco. If the withdrawal is granted, no appropriation under the mining laws will be permitted. The lands would be subject to the mineral leasing laws, however.

* * * * *

OREGON ACADEMY OF SCIENCE ELECTS NEW OFFICERS

At its 25th annual meeting held February 25 at Willamette University, the Oregon Academy of Science elected the following officers for the 1967-1968 period: President, Dr. Donald Schafroth, Portland State College; Vice-President, Dr. Anton Postal, Oregon College of Education; Secretary, Dr. Keith F. Oles, Oregon State University (second year of a two-year term); and Treasurer, Dr. Darwin Reese, Oregon State University.

Co-chairmen of the geology-geography section are: Dr. Cyrus W. Field, Department of Geology and Dr. Robert E. Frankel, Department of Geography, both of Oregon State University.

* * * * *

DEPARTMENT PUBLISHES TUALATIN VALLEY BULLETIN

The State of Oregon Department of Geology and Mineral Industries has just published a study of <u>The engineering geology of the Tualatin Valley region</u>. Authors are H. G. Schlicker, Department geologist, and R. J. Deacon, consulting geologist, Portland. This study was aided financially by the Urban Renewal Administration 701 Program of the Housing Act of 1954. The report, Bulletin 60 of the Department, is composed of a text of 103 pages, accompanied by a multicolored geologic map and cross sections, a bedrock contour map on the basalt, and a hazards map showing landslides, flood areas, and high ground-water levels.

The text discusses the geology and engineering characteristics of the rock and soils units which occur in the area. Laboratory data for quarry rock, gravel, and soils are presented in tables and discussed in the text.

The report will sell for $5.00 at the Department's office at 1069 State Office Building, Portland, Oregon 97201.

State of Oregon
Department of Geology
and Mineral Industries
1069 State Office Building
Portland, Oregon 97201

The ORE BIN
Vol. 29, No. 5
May 1967

GEOLOGY OF CAPE LOOKOUT STATE PARK, NEAR TILLAMOOK, OREGON

By Doris Mangum*

Introduction to the Park

Cape Lookout is probably the most striking and scenic headland on the Pacific Coast. The two-mile-long cape is a narrow wedge of basaltic lava with vertical sea cliffs 800 feet high. Extending north from it is Netarts Spit, a six-mile-long, dune-covered ridge of sand that separates Netarts Bay from the open ocean. North of Netarts Bay is Cape Meares, another basalt headland.

Cape Lookout State Park provides excellent recreation facilities on the fine beaches of Netarts Spit adjoining Cape Lookout. The park is situated on the northern Oregon coast off U.S. Highway 101 southwest of Tillamook. It may be reached from Tillamook by way of Netarts and Whiskey Creek roads, a total distance of 12 miles (figure 1).

Overnight camping facilities include 53 trailer sites, with hookups for water, sewage, and electricity, and 196 tent sites. Fresh water, firewood, laundry, and showers are available near campsites. Sheltered electric stoves are provided in the day-use area at nominal charges. Group camping by reservation will accommodate 100 people, thus permitting organized groups to convene apart from the main-use area. Park facilities are generally available to the public year-round according to public demand and weather conditions. Other parks (including federal, state, and county) with overnight camping facilities are available in the proximity of Tillamook; their general locations are shown on figure 1.

There are many interesting and scenic places for the park visitor to see at Cape Lookout and in the surrounding areas. Four trips, including both hikes and drives, to points of interest are outlined in this report. Their locations are shown on figure 1. But first, a review of the geographic setting and the geology of the region should help make these excursions more enjoyable.

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* Doris Mangum is doing graduate work in soil science and geology at Oregon State University. Her report on Cape Lookout State Park is the result of a cooperative arrangement between the State of Oregon Department of Geology and Mineral Industries and the State Parks and Recreation Division of the Highway Department to present the geology of the area in a way that is interesting and understandable to park visitors.

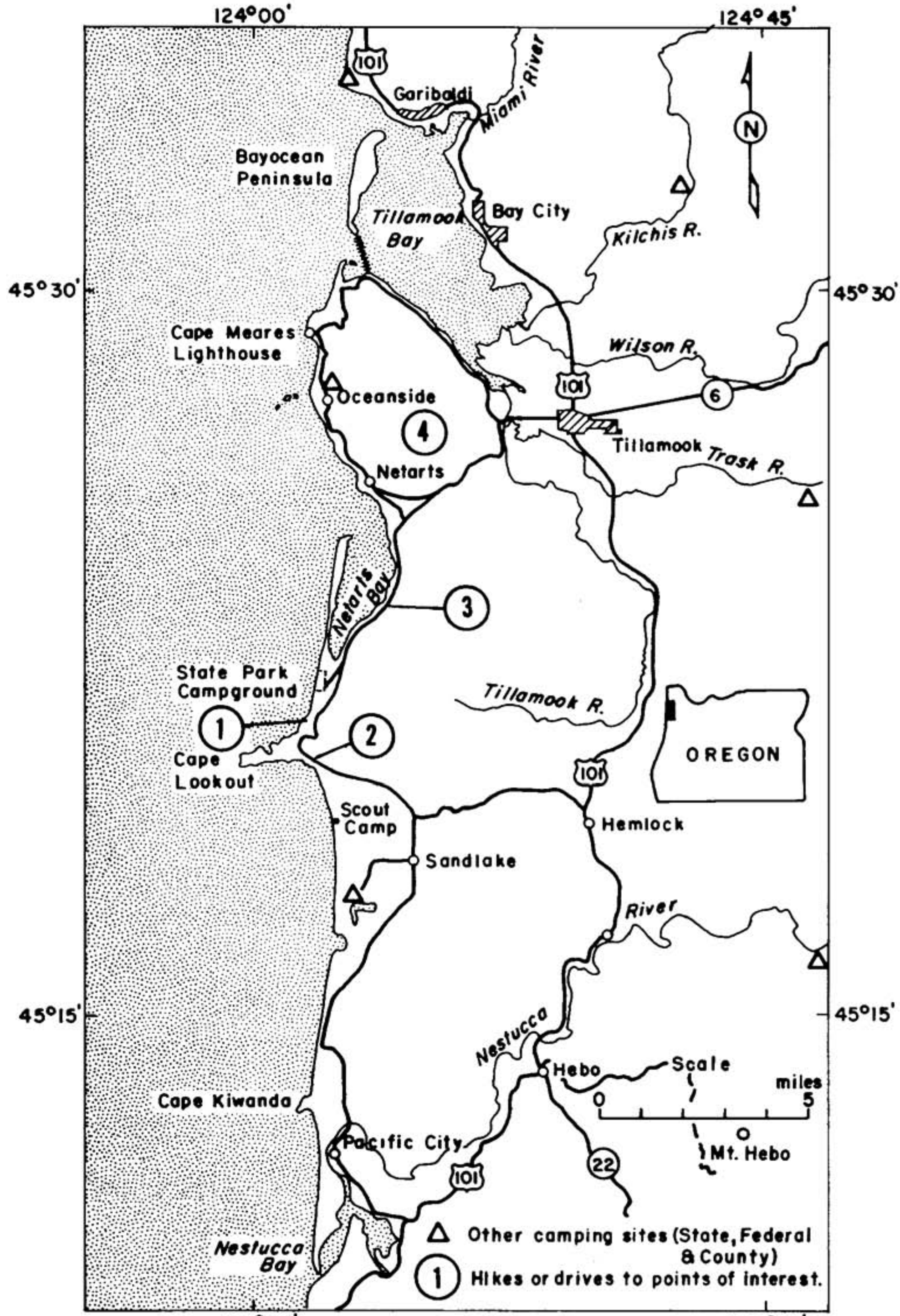


Figure 1. Index map of the Tillamook region, showing location of Cape Lookout State Park and other geographic features. Numbers 1 through 4 refer to hikes and drives described in text.

Geographic Setting

History

Historians claim that in 1788 John Meares, an English sea captain, applied the name "Lookout" to the present Cape Meares 10 miles to the north. Then, through some misunderstanding, the Coast Survey adopted the name Cape Lookout on its charts of 1850-53 for a point 10 miles south of Meares' original location and the name still stands (Armstrong, 1965).

Tillamook, which means "Land of Many Waters," was the name of a large tribe of Salish Indians who lived in the area south of Tillamook Head. Early explorers writing in their journals spelled the name Killamook, Callemex, and various other ways, but finally the present spelling was adopted. In 1853 Tillamook County was created by territorial legislature, and in 1866 a post office named Tillamook was established.

The first 20 years were difficult ones for the settlers, especially since they had to pack all of their supplies in from the north over the treacherous Neahkahnie Mountain. Several shipping attempts failed. Thirty-two shipwrecks (Orcutt, 1951) between Neahkahnie Mountain and the Nestucca bar attest to a dangerous Pacific Coast.

Climate and vegetation

The Tillamook area is located in a marine climate typical of the west coasts of continents between 40° and 50° latitude. The average January and July air temperatures are 42° and 59° respectively. Tillamook records about 90 inches of rain a year, with the months November through March receiving more than 10 inches, while July and August each average less than 2 inches. The warm Japanese current passes the Aleutian Islands and continues south along the Pacific Coast. Ir provides moisture as clouds and fog which are channeled upward by the Coast Range, where they cool to produce rain. The prevailing winds are from the southwest during the winter and the northwest during the summer.

A humid transition vegetation zone extends from the Pacific Ocean to the middle slopes of the Cascades. Major trees are the western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), Douglas fir (*Pseudotsuga menziesii*), and Sitka spruce (*Picea sitchensis*). Species of maple, alder, Pacific yew, salal, red elderberry, huckleberry, salmonberry, thimbleberry, and trailing blackberry form a dense understory. Many fern species abound in the cool, moist shade.

Physiographic features

The Tillamook area lies in the Coast Range physiographic province, which extends from the Columbia River on the north to the Coquille River and the Klamath Mountains on the south and to the Willamette Valley on the east (Highsmith, 1957). The average elevation of the Coast Range is about 1,500 feet, but peaks such as Mount Hebo south of Tillamook rise about 3,000 feet. The narrow coastal plain is interrupted by headlands mainly of basalt, which is more resistant to erosion than sedimentary rocks such as sandstones and shales. Cape Lookout and Cape Meares are fine examples of basaltic headlands surrounded by softer, more easily eroded rock.

The work done by ocean waves is well illustrated in the Cape Lookout-Cape Meares area. Waves have a tendency to straighten out the coast line by eroding

Figure 2. Aerial view of seaward end of Cape Lookout.

headlands and building sand spits, such as Netarts Spit. These long ridges of sand are connected at one end with the mainland. They form when waves meet the shore at an angle and move sand along it. Wind accentuates the height of the spits by blowing the dried sand into dunes.

Waves are constantly eating away any rock that juts into the ocean at Cape Lookout and Cape Meares. Erosion is accomplished in several ways. When a wave washes over a rock, air becomes trapped and compressed in cracks and joints; when the water leaves, the air expands explosively and acts like a wedge to break the rock. When waves hurl sand, gravel, and boulders against the rock they chip it away. The force of the waves is tremendous. Pieces of rock have been thrown as much as 200 feet up the cliffs at Cape Meares and have damaged the lighthouse. When the lower part of the sea cliff is undermined by the waves, the upper portion loses its support and breaks off. During this process, caves sometimes develop where the rock is weak. Retreat of the sea cliff forms a wave-cut bench. The end of Cape Lookout has both a cave and a bench (figure 2). When a portion of a headland is cut off from the mainland, sea stacks, like those at Cape Meares, are created (figure 3).

Geologic History

Most of the rocks that underlie the Tillamook area were laid down in seas during Eocene, Oligocene, and Miocene epochs (see geologic map on plate 1-A). These rocks consist of lava flows and sediments, some of which contain marine fossils. At various times in the geologic history of the area the strata were uplifted from the sea, gently folded, faulted, and eroded. The old marine beds and lavas are now overlain in places by terrace deposits, dunes, and river silts of Pliocene, Pleistocene, and Recent age.

Eocene epoch

About 60 million years ago (see geologic time chart), during the early part of the Eocene epoch, a huge trough-like basin or geosyncline occupied the site of the present Olympic Mountains, Coast Range, and Puget-Willamette lowland. It extended from Vancouver Island in the north to the Klamath Mountains in the south. Sediments were eroded from the adjacent land and accumulated in the basin. At the same time, lava erupted from vents on the sea floor. At places the lava piled up to form volcanic islands, perhaps like the Hawaiian Islands today.

Tillamook Volcanics: In the northern Coast Range these rocks are known as the Tillamook Volcanics. They are the oldest rocks exposed in the Tillamook area and are, in part, equivalent to the Siletz River Volcanics in the central and southern portions of the Coast Range (Baldwin, 1959). The Tillamook Volcanics may be seen east of Tillamook in the Wilson, Trask, Nehalem, and Nestucca drainages (see geologic map, plate 1). They are dark greenish and gray, fine-grained to porphyritic (contain visible crystals) basalts with pillows, breccia, and related structures. Circulating chemical solutions have altered the basalts and have precipitated zeolites, quartz, and calcite in cavities. Tuffs, agglomerates, and water-laid marine sediments are interbedded with these lavas.

The Tillamook Volcanics continued to accumulate during middle Eocene time. The basalts attained thicknesses of 20,000 feet at several centers of volcanism, one of which was northeast of the present Tillamook area (Snavely and Wagner, 1963).

Figure 3. Erosional features in the Cape Meares headland. Cape Lookout can be seen in the distance.

Figure 4. Pillow lava in basalt flows at Cape Lookout along cape road.

Geologic Time Chart

Era	Period	Epoch	Beginning
Cenozoic	Quaternary	Recent	0.011 million years ago
		Pleistocene	1
	Tertiary	Pliocene	13
		Miocene	25
		Oligocene	36
		Eocene	58
		Paleocene	63
Mesozoic			230
Paleozoic			600
Pre-Cambrian			4,600

Nestucca Formation: By late Eocene time the geosyncline was divided into several basins, and volcanism and sedimentation continued in the marine water surrounding volcanic islands. The early and middle Eocene rocks in the highlands were eroded and contributed basaltic and arkosic sands to form about 5,000 feet of the Nestucca Formation. Contemporaneous basalt flows formed pillows and breccias as they poured onto the basin floor from local vents. Tuffaceous siltstones of the Nestucca Formation crop out along the Mount Hebo road.

Oligocene epoch

During Oligocene time, a large land mass rose above sea level east of Tillamook. The uplifted rocks were attacked by erosion and the sediments were redeposited on the sea floor to the west. Several thousand feet of tuffaceous mudstones, siltstones, and micaceous sandstones accumulated in the area. These marine sedimentary rocks now crop out in the hills along U.S. Highway 101 both north and south of Tillamook. Fossils equivalent to those found in the Keasey Formation of Columbia and Washington Counties have been reported from the Oligocene sediments (Warren, Norbisrath, and Grivetti, 1945).

Miocene epoch

Fairly early in Miocene time, the Coast Range was elevated and the older Tertiary rocks were folded and faulted along northerly trends. Most of western Oregon was then above sea level, excepting its western margin, where local downwarps resulted in shallow marine embayments. One of these embayments was in the Tillamook area. Others were situated in the Astoria, Newport, and Coos Bay regions. Sediments eroded from the adjacent uplifted land were deposited in these bays along with shells of mollusks and other marine animals. These beds have been named the Astoria Formation after outcrops in Astoria where the formation was first described.

While the Astoria Formation was being deposited, basalt was extruded onto the sea floor from a north-trending group of submarine volcanic vents. This volcanism was contemporaneous with the outpourings of Columbia River Basalt in the Columbia Gorge region. In the Tillamook area there were two centers of volcanic extrusion --

Figure 5. Basalt columns on south side of Cape Lookout.

Figure 6. Sloping surface on Cape Lookout, showing predominant 10° dip.

one at Cape Lookout and the other at Cape Meares.

Since Cape Lookout State Park and the surrounding area are almost entirely underlain by these Miocene rocks, the two formations are described in detail below.

Astoria Formation: In the Tillamook area, the Astoria Formation is composed of massive, micaceous sandstone and tuffaceous, sandy shale. It is gray on fresh exposure, but the typical weathered rock is yellowish and iron stained. The massive sandstone crops out along the south side of Tillamook Bay where it forms vertical cliffs. It underlies basalt on the south side of Cape Lookout, where it is well exposed in cuts along the cape road now under construction. Another place where the massive sandstone crops out is in Cape Kiwanda near Pacific City (figure 1). Here it forms one of the few headlands along the Oregon coast that is not made of basalt (Snavely and Vokes, 1949).

Tuffaceous sandy shale beds of the Astoria Formation underlie most of the area between Cape Meares and Cape Lookout (see geologic map, plate 1). They are exposed in a road cut at the Netarts-Cape Lookout junction. Small patches of Astoria sandstone and siltstone lie high on the flanks of the basalt mass east of Cape Lookout (plate 1-B). These sediments interfinger with the lavas and are exposed in the sharp curves of the new cape road. Astoria sands (not mapped) also occur on Cape Meares.

According to Warren, Norbisrath, and Grivetti (1945), the Astoria Formation in the Tillamook area is about 2,000 feet thick.

Fossils typical of the Astoria Formation have been collected from several places along the Oregon coast. These include the Cape Lookout-Cape Meares area, Cape Kiwanda, Beverly Beach, and Coos Bay. In the vicinity of Cape Lookout and Cape Meares there are at least two fossil localities. One is in the sandstone cliff near road level on the south side of Tillamook Bay across from the oyster-processing plant. The other is on the south side of Cape Lookout in road cuts through the sandstone on the new cape road. Following are some of the species identified from the latter location by W.D. Addicott of the U.S. Geological Survey (written communication, 1967).

Gastropods: *Nassarius* cf. *N. arnoldi* (Anderson); *Tectonatica vokesi* Addicott?; and *Searlesia carlsoni* (Anderson and Martin).

Pelecypods: *Anadara* sp.; *Macoma* sp.; *Macoma albaria* (Conrad)?; and *Spisula albaria* (Conrad).

Columbia River Basalt: In the Tillamook area the Columbia River Basalt is a dark gray, fine-grained lava. It forms the two large, resistant masses of rock that make up Cape Meares and Cape Lookout (see geologic map, plate 1-A). In both areas the basalt intrudes and interfingers with the Astoria Formation.

In places the lava flowed under water into the soft marine sediments of the Astoria Formation, while in other places the lava piled high enough to build islands above sea level. At Cape Lookout subaerial (on land) lava flows can be traced into pillow lavas interbedded with marine sediments. There are good examples of pillow lavas at the base of Cape Lookout both on the north and south sides and in cuts along the cape road (see figure 4).

Whereas pillow structures are usually associated with subaqueous (under water) volcanism, columnar-jointed basalts are considered subaerial flows. After cooling and solidifying, columnar jointing occurs when shrinkage cracks form in the basalt perpendicular to the cooling surface over which the lava flowed. Figure 5 shows

Figure 7. Sand dunes in the Sand Lake area south of Cape Lookout. Forest in background is growing on stabilized dune.

Figure 8. Looking north toward Cape Meares and Three Arch Rocks from grass-covered dune between campground and beach.

basalt columns on the south side of Cape Lookout that look like a long row of closely packed telephone poles, perhaps as much as 100 feet high and more than half a mile in length.

Columbia River lavas are quarried and used for road construction. Two quarries beside the road along Netarts Bay and one on the road between Oceanside and Cape Meares show good exposures of the basalt.

Pliocene epoch

There are no marine beds of Pliocene age in the Tillamook area, and so it is probable that the shore line was farther west than it is now.

During the Pliocene epoch the Coast Range was elevated to its present height and the Miocene strata were deformed. A small downwarp or syncline may have developed in the Tillamook area, its axis trending east-west through Netarts Bay between the two capes (Wells and Peck, 1961). In the high slopes behind Cape Lookout, flows of Columbia River Basalt -- once horizontal -- can be seen dipping at about a 10° angle toward the northwest (figure 6). Out on the end of the cape the layers of basalt dip northward (figure 2). If the strata in Cape Meares tilt in the opposite direction (toward Cape Lookout), it is possible that the two masses of basalt are joined at depth beneath an upper member of the Astoria Formation.

Pleistocene and Recent epochs

After deformation and uplift of the coastal region in Pliocene time, erosion became the dominant geologic process. Coast Range streams excavated their present valleys, and softer rock materials were carried westward into the ocean leaving the harder volcanic rocks in bold relief. Erosion of tilted lava flows on Cape Lookout has produced a topographic feature that is similar to a cuesta, with a steep cliff on one side and a gentle dip slope on the other (figure 6).

Former levels of the ocean are visible as remnants of terraces perched above sea level and covered by layers of sand, clay, peat, and wood. These Pleistocene terrace deposits occur in sea cliffs south of the town of Cape Meares and south of Cape Lookout State Park and are particularly evident along the east side of Netarts Bay (plate 1-B).

During and since Pleistocene time, the relative position of the ocean and land has been oscillating very slowly. At the present time the coast in the Tillamook area is one of submergence. Melting of continental glaciers of the ice age (Pleistocene) has gradually raised the sea level. As a result, waves are cutting away portions of the land to form stacks, caves, arches, sea cliffs, and narrow beaches. Mouths of rivers have drowned and bays have formed. Submerged tree roots and layers of peat now occur below tide level. Old dunes, once stabilized by vegetation, are being sliced into by the waves and reactivated. Cooper (1958) has shown that Netarts Spit and Bayocean Spit are the eroded remains of two elongate dunes that trended northeasterly. Their northern ends were joined to the mainland and their southern ends were the outlets for drainage to the sea. A large dune mass (figure 7) in the Sand Lake area is being cut away at its southern end by the advancing sea.

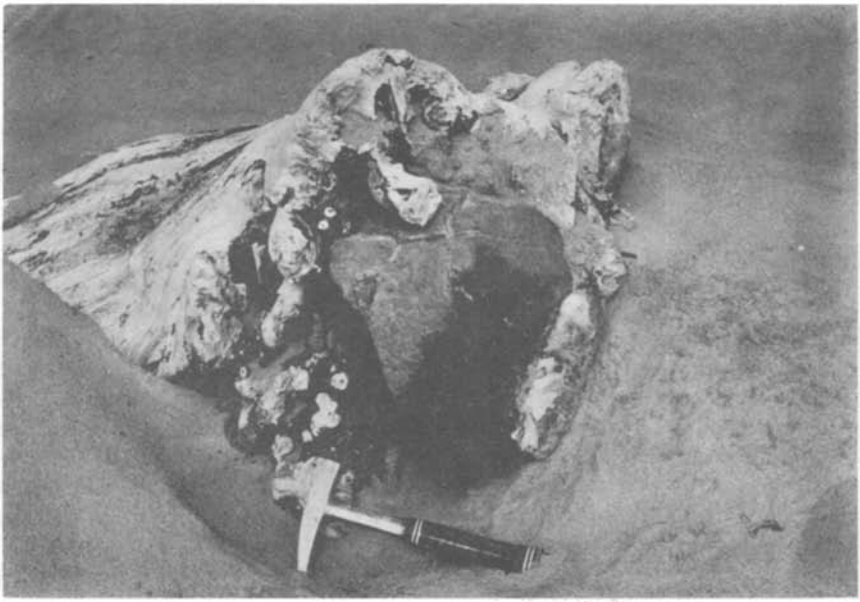


Figure 9. Tree-rafted rock carried onto beach by a high tide.

Figure 10. Flame structure in sediments exposed in sea cliff at Cape Lookout.

1. Park area and beach hike

A short and interesting hike may be taken along the beach and sea cliffs beginning at the day-use parking lot. See the enlarged inset of local area on the geologic map of Cape Lookout (plate 1-B) for route of this hike.

A. South of the day-use area parking lot there is a rain forest with huge Sitka spruce and western red cedar trees. There are winding trails, bridges that cross meandering streams, and picnic tables located in the deep shade under the big trees. Many of the large spruce trees began as seedlings which obtained their nourishment from fallen, decaying red cedar logs. Some of the "mother" cedars have rotted away and have left the spruce trees standing on roots exposed above ground.

B. A large sand dune (figure 8) between the park and the ocean extends most of the length of Netarts Sand Spit. This dune protects park visitors from storm tides and some of the ocean breezes. It is important to help preserve these dunes, for when they are eroded away the park will have to go also.

C. The beach, which is the area between high and low tide, has five distinct zones, each with its own plant and animal communities (Zim and Ingle, 1955). The first and highest is the dry beach or dune area. The second is the uppermost beach, reached only by the highest tides, storm waves, and ocean spray. Next is the upper beach, which gets wet by tides twice daily, but plants and animals living on it are more adapted to land and air than to water. The middle beach is covered with water most of the time; plants and animals are less exposed to air and more harmed by drying. The lower beach is always submerged except during the lowest tides; it is exposed no more than twice monthly.

The tides result from the gravitational pull of the moon and sun, but because the moon is closer to the earth it has a stronger pull than the sun. The west coast has two high and two low tides each day, with about 6 hours between high and low tide, and they come about 50 minutes later each day.

High tide brings driftwood and other floating objects onto the upper beach. Figure 9 illustrates how rocks from distant places may come to rest on the beach. Tree roots sometimes grow around rocks, and when these trees become uprooted by floods and are washed to sea they carry the "exotic" rocks with them.

D. South of the creek, dune sands cap 20-foot cliffs of Pleistocene terrace and landslide debris. Waves have undercut the terraces and rocks have accumulated as talus. In the cavities of some of these rocks one can find silica, zeolite, and calcite fillings. Agates may form when some of the silica fillings fall out and become worn by the ocean waves.

E. At this location there are interesting sedimentary features in the terrace deposits (figure 10). The outcrop illustrates the flowing of coarse-textured sediments into finer textured ones causing a streaming or "flaming" of the lower unit into the upper one. The source of the coarse material appears to have been from the east, and deposition occurred when the finer material was still in a plastic state.

F. There is a small exposure of dark gray basalt with many prominent fractures and joints at this location. It represents an erosional remnant of Columbia River Basalt that makes up the cape, with terrace sediments deposited around it. Several zones in the terrace sediments contain fossil woody material that may be many thousands of years old. The old tree trunks and branches were deposited before the

GENERALIZED GEOLOGIC MAP OF THE TILLAMOOK REGION, OREGON

EXPLANATION

QUATERNARY — PLIOCENE-PLEISTOCENE-RECENT

Qal — Alluvium (River gravels, sands, and silts)

Qd — Dune, bar, and beach sands

Qt — Terrace deposits (Sands with layers of gravel, peat, wood, and clay capping wave-cut terraces)

TERTIARY — MIOCENE

Tcr — Columbia River Basalt (Submarine and subaerial volcanic flows from local vents; pillow lavas and columnar basalt characteristic)

Ta — Astoria Formation (Massive micaceous marine sandstone; tuffaceous siltstone interbedded with Tcr)

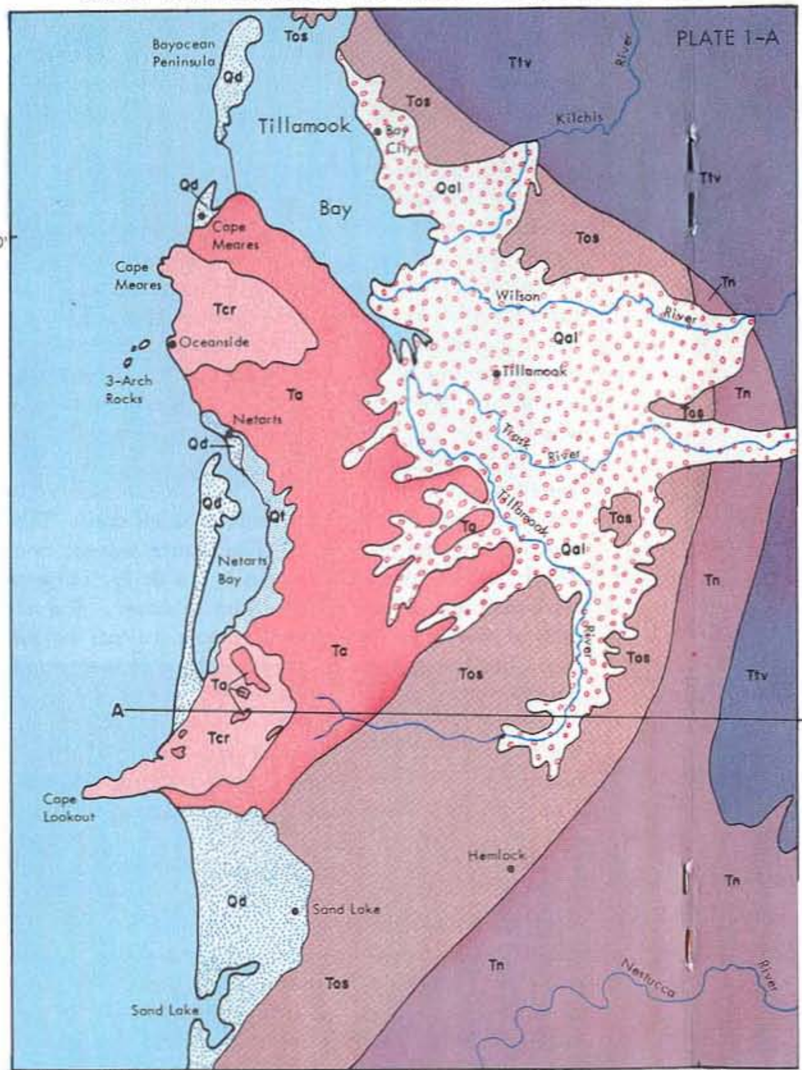
OLIGOCENE

Tos — Oligocene sediments (Tuffaceous marine siltstone, mudstone, and sandstone)

EOCENE

Tn — Nestucca Formation (Dark gray tuffaceous marine shale and thin-bedded sandstone with interbedded volcanic rocks)

Ttv — Tillamook Volcanics (Submarine basalt flows and interbedded sediments)

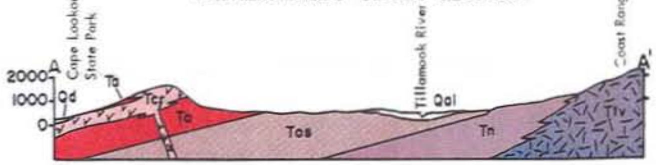


Geology modified from Wells and Peck, 1961

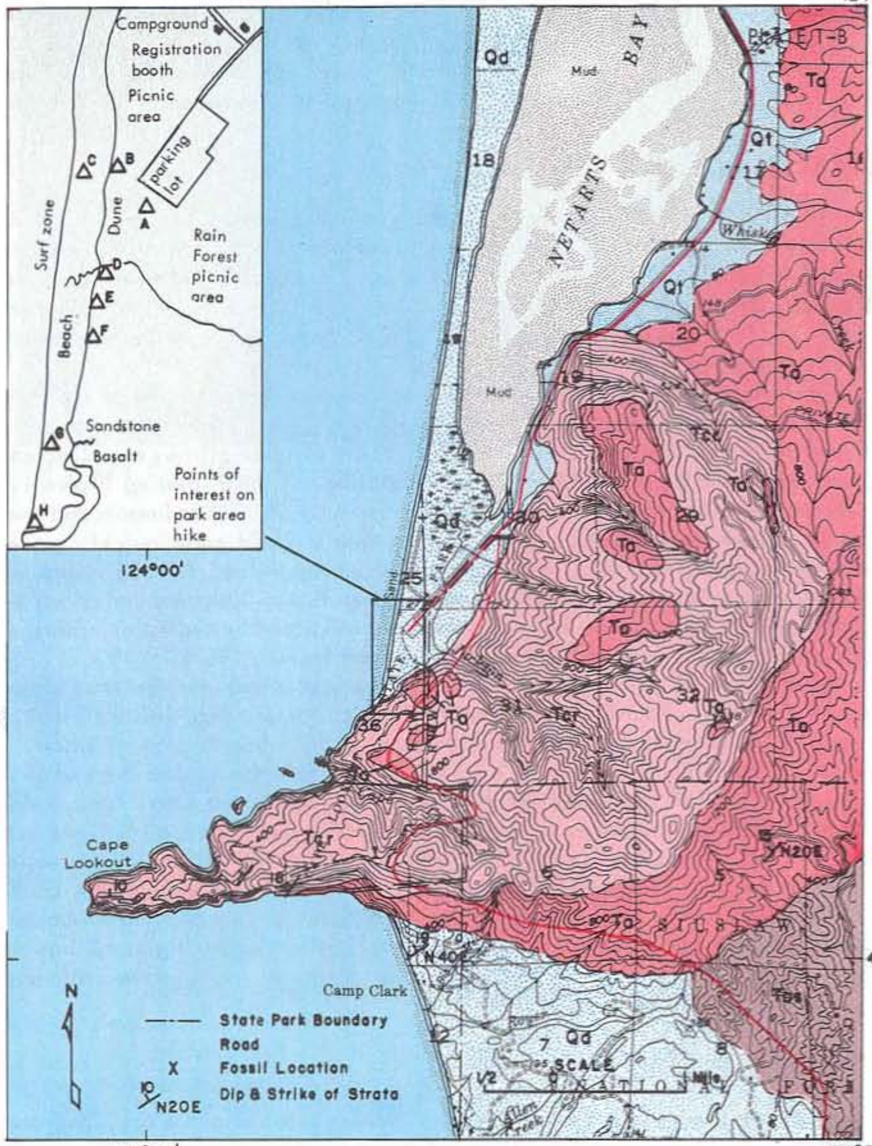
Scale 0 1 2 3 4 5 Miles

Map prepared by STATE OF OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

GENERALIZED CROSS SECTION



GEOLOGIC MAP OF CAPE LOOKOUT AND VICINITY



sediments accumulated above them.

G. At this location a contact between sandstone and basalt is exposed. The lower portion of the sandstone contains blocks of vesicular basalt as large as one foot in diameter. They probably broke off the sea cliff eons ago and were buried when the sediments were accumulating.

H. At the base of Cape Lookout there are some good exposures of pillow lava (see figure 11). Origin of pillows in lava is discussed in more detail under Trip No. 2.

2. Cape drive and hike

There is a new road over the cape and a trail that goes out to the end of the promontory (see figure 2). It is best reached from the park by driving back to the Jackson Creek spur road and turning right just outside the park entrance (see plate 1-B). On the way to the top of the cape there is a viewpoint for looking north toward Cape Meares. The lack of trees on the surrounding hills is due to recent logging by the clearcut method.

Road cuts expose Columbia River Basalt and interbedded siltstones of the Astoria Formation. Immediately beyond the huge fill crossing Cape Creek, there are "pillow" structures in lava on the left side of the road. Many of these pillows are elongate, with iron oxide and glassy rims and internal radiating columnar jointing (figure 12). They formed when hot lavas were extruded into sea water or wet sediments and congealed in pillow-shaped bodies. Lava flowing into a liquid cools quickly on the outside, forming a glassy skin, and more slowly on the inside, forming radiating shrinkage cracks. Some forms are more rounded than those illustrated and do not have the radiating joint structures. Pillows are usually separated by sediments, chert, or angular basalt fragments called breccia (Snyder and Frazer, 1963).

Good exposures of columnar jointing may be seen where the new road crosses the top of the cape. Rounded cobbles at the base of the columnar-jointed basalt in the road cut indicate possible beach erosion prior to the subaerial flow of basalt.

At the top of the cape there is a parking area where the trail to the end of the cape begins. The trail winds through the Sitka spruce rain forest where ferns, salal, and other vegetation provide a dense understory. In places the trail follows the edge of a sheer, 800-foot cliff and hikers should proceed with caution. From various points along the trail there are excellent views of the coastline south of the cape.

During World War II, a bomber crashed on the top of the cape and evidence of the wrecked plane may be seen stewn about. A memorial plaque (figure 13) has been erected a short distance from the start of the trail to honor the nine men who lost their lives and the one who survived.

3. Netarts Bay and Sand Spit drive

By driving north along Netarts Bay and keeping left along the bay, one can get a good view of both the bay and the spit.

Netarts Bay: Netarts Bay is very shallow (figure 14) and occupies a re-entrant in the coastline. Differential rates of erosion between the basalt headlands of Cape Lookout and Cape Meares and the softer sedimentary rocks of the Astoria Formation have formed the depression occupied by Netarts Bay. At one time, the bay may have been a fresh-water lake either with an outlet to the south or with no permanent outlet. According to Cooper (1958), the dunes at the northern part of the spit were

Figure 11. Pillow lavas at base of Cape Lookout at southern end of beach area.

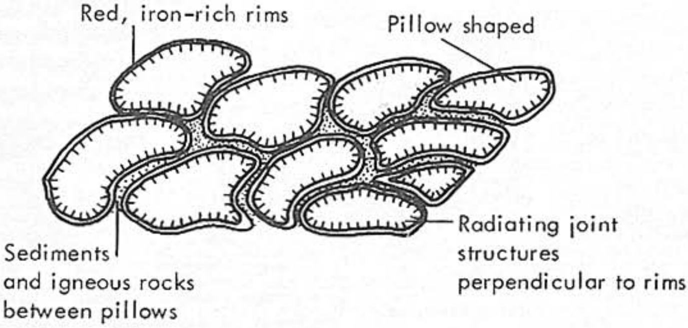


Figure 12. Sketch of pillow lava that has flowed into wet sediment.

Figure 13. Memorial plaque on Cape Lookout trail.

connected to those at Netarts until they were cut through by storm waves. Once an outlet at the northern end became well established, tidal currents and stream flows maintained it. Tree stumps exposed at low tide represent former forests inundated by a rising sea level. The bay is shallow, and at low water as much as 70 per cent of the bottom is exposed. Figure 14 shows the tidal channel at the northern end of Netarts Bay and the view looking in a northerly direction towards the Three Arch Rocks and Cape Meares.

Netarts has a public boat landing where boats can be rented for use in the bay. Since the bar at the mouth of Netarts Bay is very rough, few boats can cross it safely. The bay is a good place to get blue, cockle, quahog, littleneck, and soft-shell clams. Few razor clams live in the bay. Crabs are found in all the channels south to Whiskey Creek.

Many shore birds can be seen in the Netarts Bay area including herons, pelicans, gulls, and murres, handsome black and white birds.

Netarts Sand Spit: Netarts Spit is approximately six miles long, and can be divided into three sections. The northern part has dunes and blowouts and is only sparsely vegetated with dune grasses. Some of the plants growing on the dunes are Indian paint brush, dune strawberry, dune lupine, and tansy. The middle section is densely covered with conifers and brush. Some of the plants of the middle section are salal, Sitka spruce, beach pine, bracken, and thimbleberry. On the bay side there is a marsh area with tall marsh grasses, sedges, and salt rushes. Drift logs attest to periodic invasion by the sea during high tide and severe storms. The southern part of the sand spit next to the mainland resembles the northern part, but it is narrower and has no large dune. The southern end was cut completely through during two storms in 1939, leaving only a barrier beach between the bay and the ocean.

The prehistoric Tillamook Indians lived in several of the enclosed meadows on Netarts Spit. Newman (1959), who did a study on the Indian tribes in the Tillamook

Figure 14. Aerial view of Netarts Bay and Sand Spit, looking north toward Cape Meares.

area, located and dated by carbon-14 method three levels at which people had lived (1400, 1670, and 1850 A.D.) on the spit. The 1400 A.D. level is the earliest evidence of a Northwest Coast culture in Oregon.

The Northwest Coast Indians were the only North American Indians that learned to build good wooden houses. They emphasized water travel; their favorite pastime was gambling; and their greatest art was basket weaving. Many of the apparent disadvantages of the wet and rugged coastal strip were exploited and used advantageously. That they made good use of the local clams for food is evidenced by layers of shells buried by the dunes on Netarts spit (figure 15).

4. Cape Meares Loop Road trip

The 25-mile drive from Cape Lookout and around Cape Meares is a must in anyone's itinerary.

Oceanside: From Cape Lookout, drive along Netarts Bay and through Netarts to Oceanside, a total distance of about 7 miles. At Oceanside there is a good access to the beach. Oceanside, sheltered from northwest winds by Maxwell Point, has one of the best bathing beaches along the Oregon coast, as well as excellent rock and surf fishing, beautiful scenery, and agate hunting.

Maxwell Point is part of the large Cape Meares headland composed mainly of Columbia River Basalt. A tunnel through Maxwell Point provides access to the rest of the beach at high tide. Note the "pillow" structures and the fault beside the tunnel. Lost Boy Cave is between Oceanside and Short Beach. Legend has it that a boy became lost in the cave and was never found. The boy returned home, but the story of his safety never caught up with that of his loss.

Off shore from Oceanside are the Three Arch Rocks which Captain Meares called the Three Brothers. This nationally famous refuge is the nesting place for countless murres and the permanent home of a large herd of northern sea lions. Sea-lion pups are born in May and June and can be seen playing along the beach at many times during the year.

The Three Arch Rocks are good examples of sea stacks, which are portions of the resistant headland that have been detached from the shoreline. They formed when waves cut in on two sides of a promontory and then cut behind it. An island is left removed from the mainland. Other sea stacks at Oceanside are pictured in figure 16.

Cape Meares: About two miles beyond Oceanside there is a sign indicating a left turn into Cape Meares State Park. Cape Meares is a basalt headland with much rock and debris fall along wave-cut cliffs (figure 17).

The two main features are the lighthouse (not in use) and the octopus tree. There is also a picturesque picnic area with excellent views of the rugged sea cliffs and the Three Arch Rocks.

From the small parking lot a path leads down to the lighthouse (figure 18). According to Don Benskin in a Tillamook Chamber of Commerce brochure, the lighthouse was leased to Tillamook County in 1964 by the U.S. Coast Guard so it could be preserved as a historical site. It was built in 1890 from sheet iron and lined with bricks that were formed and baked on location. The beam of light could be seen from 21 miles at sea and it sent out an alternating red and white beam from sunset to sunrise, regardless of the weather. The unusual lens has eight sides. Four sides are covered with deep red panes of glass that produced a red beam of 160,000 candle power and four clear white sides which produced 180,000 candle power.

Figure 15. Shell mounds buried by dune sand on Netarts Spit.

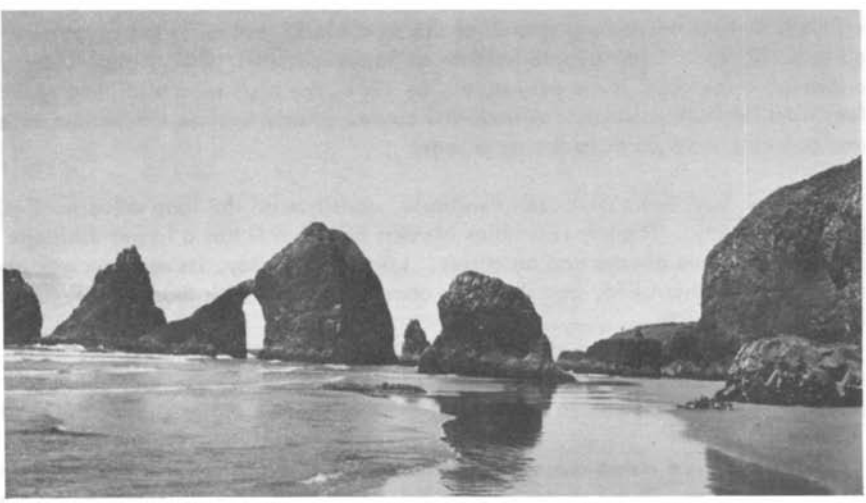


Figure 16. Sea stacks and arches at Oceanside.

Only one other eight-sided light of this type was ever constructed, and it is still operating in the Hawaiian Islands. The giant lens of the Cape Meares light was hand ground by Henry Lepaute in Paris, France, in 1887 and weighs more than a ton. It was carried around Cape Horn and hoisted up and over the 200-foot cliff. The first illumination was by a five-wick kerosene lamp, which was replaced by an incandescent oil-vapor lamp used until 1934, when the structure was electrified.

The lighthouse was designed to be built at Cape Lookout. Through an error, an ox-team trail was made to the summit of Cape Meares. The mistake was not learned until the lighthouse was finished in 1890.

The giant "octopus tree" was featured in Ripley's Believe It or Not as "seven trees in one." It is a huge Sitka spruce tree that has grown candelabrum-shaped in response to the strong winds. It may be reached by taking the trail from the parking lot and through the picnic area.

Cape Meares -- Bayocean Peninsula: After leaving Cape Meares State Park, drive north about 2 miles and turn left at the junction to visit the town and beach of Cape Meares, or turn right to continue the loop drive. When the jetty was built on the north side of Tillamook Bay, the sand transport equilibrium was upset and rapid erosion occurred at the town of Cape Meares. The terrace on which the town is situated has been receding at about 30 feet per year and it retreated 75 feet in 1960-61, taking part of the streets of Cape Meares with it (North and Byrne, 1965) (figure 19).

Significant changes have also taken place along the Bayocean Peninsula north of Cape Meares, probably accelerated by the building of the Tillamook Jetty. It is hard to believe that this uninhabited, dune-covered sand spit was once the site of a resort town. Beginning in 1907, Bayocean became a realtor's dream and was advertised widely as "the Queen of Oregon Resorts." Although it never achieved that status, nearly 2000 lots were sold, houses were built -- some quite costly -- and a few streets were paved; there was a natatorium and the beginnings of an elegant hotel. A ferry service operated from Garibaldi. By World War I time, the resort dream had died under insolvency and litigation, but some of the year-round residents continued to live there. According to newspaper accounts, there was a school with 16 pupils as late as 1932. In 1939, two winter storms in January and February cut through the road and undermined a long stretch of the sand bluff, including the natatorium and other buildings. A few people held on at Bayocean until 1948, when winter seas broke through three gaps in the peninsula. By 1961, the high sand bluff had receded 500 feet from its 1939 position. A rock-fill causeway now bridges the southernmost gap and one can drive north to the dune area.

Tillamook Bay: From Bayocean Peninsula, continue on the loop drive for 7 miles along Tillamook Bay. The bay resembles Netarts Bay, but it has a larger drainage area and so must have always had an outlet. Like Netarts Bay, its opening was also probably at the southern end, and its dunes once connected with those across the bay to the north.

There is a good fossil locality in an outcrop of the Astoria Formation across the road from the oyster-processing plant. It is interesting to note that there is a difference of 20 million years in the ages of the mollusks on either side of the road.

Five rivers: Five rivers drain into Tillamook Bay: the Miami, Kilchis, Wilson, Trask, and Tillamook. These rivers and the bay are "drowned"; that is, gradual rise in the sea level because of melting of ice-age glaciers has caused the ocean waters to invade low areas and back up into the rivers.

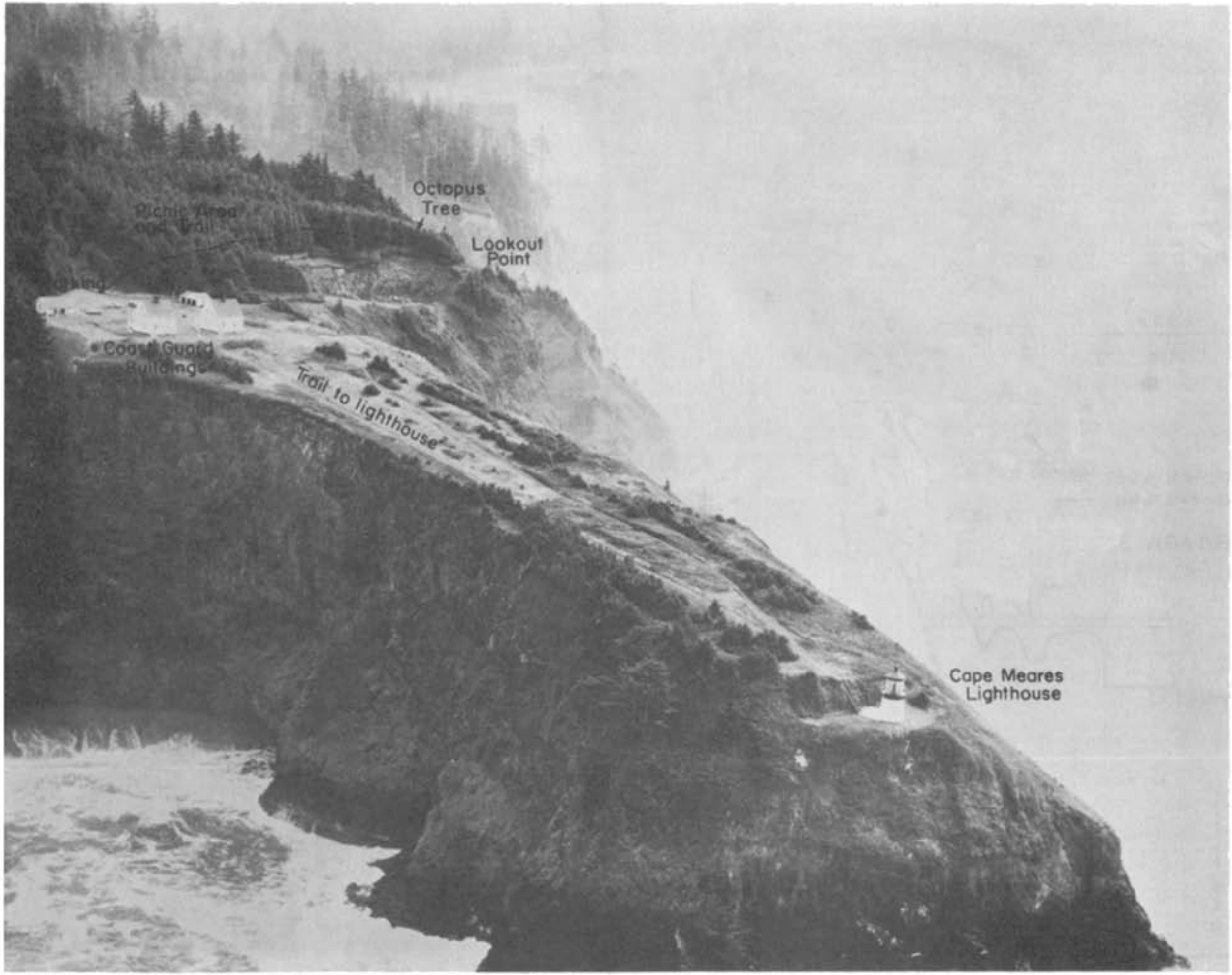


Figure 17. Aerial view of Cape Meares wim fog rolling in from southwest.

Figure 18. Lighthouse at Cape Meares.

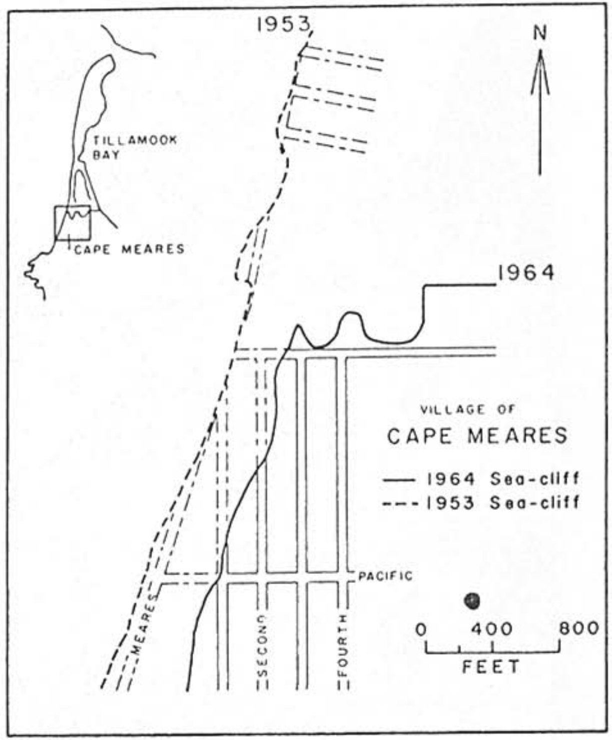


Figure 19. Sketch map showing coastal retreat at town of Cape Meares, 1953-64. (From North and Byrne, 1965)

All of these rivers have scenic drives and attractive picnic parks or campsites. The influence of the tides on the rivers is very noticeable in the alluvial valley surrounding Tillamook. At high tide the rivers are levee-bank full, but during low tide one can see logs that are being floated down stream lodged in the river-bottom sediments.

At the intersection, turn left for Tillamook or right to return to Cape Lookout State Park.

Acknowledgments

Acknowledgments are extended to Margaret Steere, Hollis Dole, and Raymond Corcoran of the State of Oregon Department of Geology and Mineral Industries for invaluable aid in preparing this report. Considerable help in the field was obtained from Irene and Edgar Schroeder, Jim Gettle, and Dick Windsor, personnel of Cape Lookout State Park. Unpublished field data and aerial photographs were made available by Parke D. Snavely of the U.S. Geological Survey, and fossils were identified by W. D. Addicott, also of the Survey.

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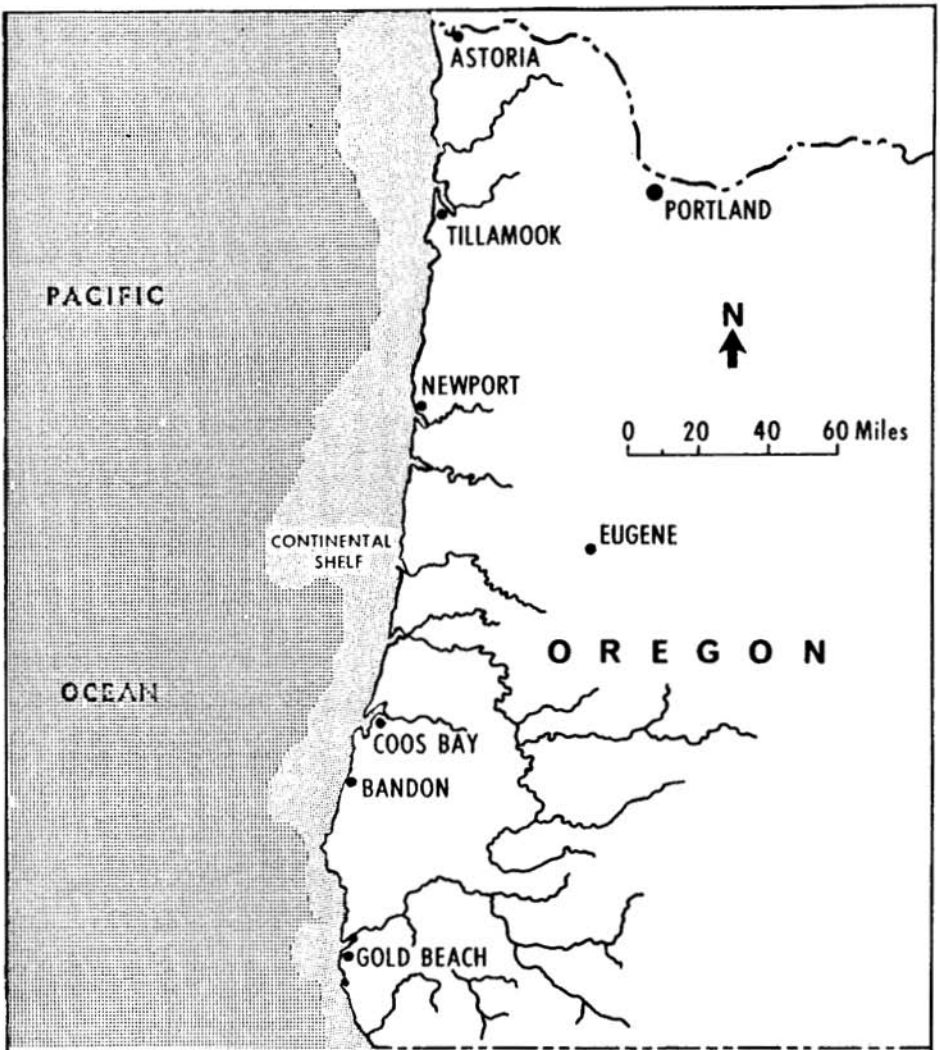

SEARCH FOR HEAVY METALS OFF OREGON Scientists of the U.S. Geological Survey, Department of the Interior, and Oregon State University, will team up in a search for heavy metals —such as gold, silver, mercury, and platinum— along the coast of Oregon and adjacent sea bottom.

Photo Credit/U.S. Department of the Interior, GEOLOGICAL SURVEY

CONTINENTAL SHELF MAY DISCLOSE HEAVY METALS

Announcement of a $77,500 research contract to the University for marine geologic investigations on the continental shelf off Oregon was made by Dr. William T. Pecora, Survey Director, who said that "the project is part of our stepped-up nationwide search for heavy metals -- such as gold, silver, mercury, and platinum -- which are in short domestic supply."

Parke D. Snavely, Jr., Chief of the Survey's Office of Marine Geology and Hydrology at Menlo Park, Cal., noted that "although the shelf area off Oregon has been a major target for oil prospecting in recent years, it has not yet been 'probed' for mineral deposits."

"Preliminary reconnaissance geologic studies of the narrow (8 to 10 miles wide) continental shelf off southern Oregon made last summer, however, indicate considerable potential for mineral resources," he said. "Through the research contract with Oregon State, detailed geologic studies will be possible within the area broadly outlined by this preliminary work."

Snavely said that sediments on the target area originated in the Klamath Mountains and the Southern Oregon Coast Ranges, long known as a source of such valuable minerals as gold, platinum, chromite, zircon, and magnetite. "These minerals, because of their high density, are concentrated by wave and current action into 'placer' deposits commonly referred to as 'black sands' because of the preponderance of dark-colored minerals within them," he said.

The Survey's marine geologist noted that gold and platinum were discovered in black sand on Oregon beaches in the 1850's and were extensively prospected during the gold-rush days. "It is probable," he said, "that similar black-sand deposits occur beneath the sea on the continental shelf."

Scientists of both organizations will be aided in their studies by a number of modern, sophisticated instruments and techniques, including the use of two research vessels of Oregon State University -- the 180-foot YAQUINA, and the 33-foot PAIUTE.

Geophysical techniques will be used to probe the sediment and the bedrock on the ocean floor, providing basic data on the sub-sea topography, structure, and distribution of rocks and sediment. Magnetometer surveys will help to outline any black-sand deposits beneath the sea. Samples of rock and sediment taken from the sea bottom will be analyzed in USGS and Oregon State University laboratories. Also, bottom photography and closed-circuit television will be employed to monitor processes that concentrate "black sands." In later stages of the contract, direct observations are planned from deep-sea research craft.

Named as principal investigators for the coast and shelf study are Dr. John V. Byrne and Dr. L. D. Kulm of Oregon State University and Dr. H. Edward Clifton, U.S. Geological Survey.

* * * * *

POWER SITES ON ALSEA OUTLINED

The U.S. Geological Survey has issued "Waterpower Resources and Reconnaissance Geology of Sites in the Alsea River Basin, Oregon," as Water-Supply Paper 1610-D. Authors are L. L. Young, D. W. Neal, and D. L. Gaskill. The Alsea River drains westward from the central part of the Coast Range and enters the ocean at Waldport. Preliminary geologic examinations were made at the two most likely dam sites --one near Scott Mountain and the other near Tidewater. Also investigated were two sites for possible diversion of Alsea River water to the Willamette River basin. Water-Supply Paper 1610-D is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 70 cents.

* * * * *

MINING-CLAIM RECORDING REQUESTED

Senator Henry Jackson (Wash.) has introduced in the U. S. Senate, at the request of the Administration, a measure (S. 1651) that would require persons now holding unpatented mining claims to record their claims with the Bureau of Land Management within two years following enactment of the Act, and would require similar recordation of claims filed in the future before any such claim could be deemed valid.

In requesting the legislation, the Department of the Interior stated that clearing title to public lands is often expensive and time consuming. The problem of old mining claims has arisen in connection with the Department's proposal for oil-shale development. Secretary of the Interior Udall told Congress that a recordation statute would not only be of benefit for the oil-shale program but also for orderly administration in general.

* * * * *

BANTA REAPPOINTED TO DEPARTMENT BOARD

Governor Tom McCall has announced the reappointment of Mr. Harold Banta to the Department's Governing Board for another four-year term, which began March 15, 1967, and ends March 15, 1971. Mr. Banta has been a member of the board since his original appointment by Governor Hatfield on March 13, 1959, and this will be his third consecutive term. Banta, who is senior member of the law firm Banta, Silven, and Young in Baker, is also a member of the Oregon State Bar Committee on Mineral Law and a member of the Legal Committee of the Interstate Oil Compact Commission.

Other members of the Department's Governing Board are Mr. Frank C. McColloch, Chairman, of Portland and Mr. Fayette I. Bristol of Grants Pass.

* * * * *

CONDON LECTURE PUBLISHED

"Moon Craters and Oregon Volcanoes," by Aaron C. Waters, has been published by the Oregon State System of Higher Education as one of the Condon Lectures. Dr. Waters, Professor of Geology at the University of California at Santa Barbara, delivered the Condon Lectures under the above title in February 1966. The lectures have been adapted for publication and may be obtained from University of Oregon Books, Eugene, Oregon 97403, for $2.00. Included in the 70-page booklet is a map of the moon prepared by Space Sciences Laboratory.

* * * * *

OXBOW GEOLOGY DESCRIBED

"Geology of the Oxbow on Snake River near Homestead, Oregon" is the title of Pamphlet 136 recently issued by the Idaho Bureau of Mines and Geology, Moscow, Idaho. Authors are Harold T. Stearns and Alfred L. Anderson. Price is 75 cents.

At the Oxbow, the site of a recently completed dam and powerplant, the Snake River canyon exposes Permian Seven Devils Volcanics overlain unconformably by Columbia River Basalt.

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DISTINCTIVE CONGLOMERATE LAYER NEAR LIME, BAKER COUNTY, OREGON*

By Howard C. Brooks**

Introduction

Near Lime in southeastern Baker County a distinctive bed of red and green conglomerate about 360 feet thick marks the boundary between Triassic and Jurassic rock sequences.

The conglomerate, as shown on the accompanying map, is traceable for more than 20 miles extending in a southwesterly direction from Iron Mountain, east of Mineral, Idaho, to Limestone Butte west of Huntington, Oregon. It crosses parts of the Mineral, Olds Ferry, and Huntington 15-minute quadrangles. Because of its stratigraphic position and distinctive lithology, the conglomerate forms a horizon marker that should prove very helpful in deciphering the Mesozoic stratigraphy and tectonic history of the southeastern Blue Mountains.

This is a progress report based largely on about 30 days field work in the vicinity of Lime during 1966 and cursory knowledge of the area acquired over a period of several years. N. S. Wagner, geologist at the Department's Baker office, has long recognized the conglomerate as a distinctive unit of wide distribution and has, therefore, aided and encouraged this study. The aid of Dr. George Williams of the University of Idaho, who is presently mapping the Idaho portions of the Mineral and Olds Ferry quadrangles is also gratefully acknowledged.

Previous work in the vicinity of the conglomerate includes two mining district reports: one by Livingston (1925) on the Mineral and Bay Horse areas, the other by Mackin (1953) on the Iron Mountain area. University of Oregon master's theses maps were prepared for the Oregon part of the Olds Ferry quadrangle by Spiller (1958) and for the Huntington quadrangle by Berry (1956) [NE quarter]; Kennedy (1956) [NW quarter]; and Beeson (1955) [south half]. The students described the red and green conglomerate, but

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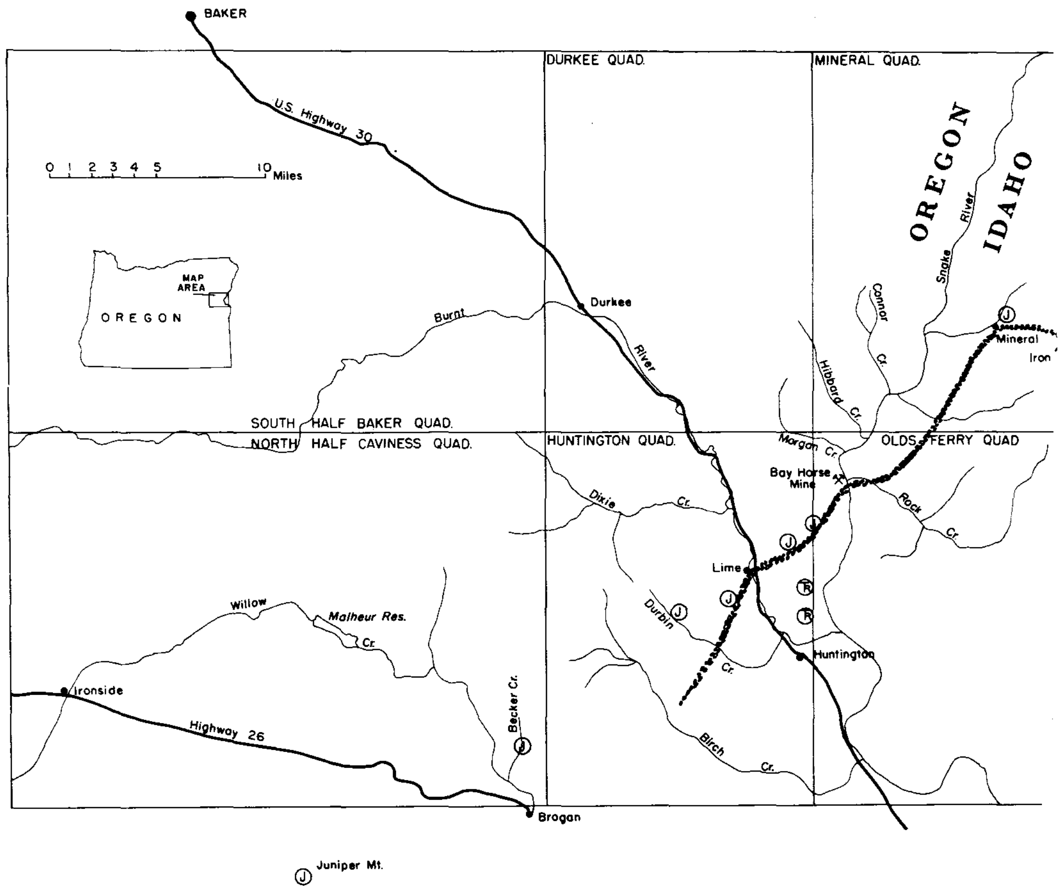
* Paper presented at Oregon Academy of Science meeting at Willamette University, Salem, Oregon, February 25, 1967.

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



Index map showing approximate surface trend of the red and green conglomerate layer (pebble pattern) and location of Jurassic (J) and Triassic (TR) fossils.

did not map it as a separate unit. As part of his doctoral requirements at the University of Oregon, Wolff (1965) mapped the north half of the 30-minute Caviness quadrangle which adjoins the Huntington quadrangle on the west.

In all of the quadrangle areas shown on the map, pre-Tertiary rocks of probable Mesozoic age are abundantly exposed. Accurate dating of these rocks, however, has been hampered by the extreme scarcity of fossil evidence.

Description of the Red and Green Conglomerate

The conglomerate, which is well exposed on the Snake River divide about four miles east of Lime, shows a remarkable consistency in composition and physical characteristics throughout its 20-mile extent. Probably its most distinctive macroscopic characteristic is its peculiar mottled color. Reds and purples predominate, but greens are also present in nearly every outcrop and hand specimen, and, locally, green is the salient color. On close observation, it is seen that many individual rock fragments are white to dark gray. Thin sections show numerous fine specks of magnetite, some of which may have altered to hematite and chlorite, giving the rock its red and green colors.

The conglomerate consists largely of clastic debris from andesitic and dacitic volcanic rocks which are commonly porphyritic. Quartz, limestone, sandstone, and chert clasts are numerous. The conglomerate is for the most part poorly sorted. The pebbles are subrounded and sphericity is poorly developed. In hand specimens from most outcrops typical particle sizes range from fine sand to cobbles as much as 2 inches long (figure 1). Occasionally boulders 10 inches across are found. Mackin (1953) mentions that in the Iron Mountain area the conglomerate contains limestone boulders as much as 10 feet in diameter.

Where bedding can be seen in the conglomerate, it is usually defined by thin, sandy layers intercalated in the coarser material and by variations in fragments size. In places, the pebbles lie with their longest dimensions parallel to the plane of bedding. Graded beds are found in most outcrops.

The thickness of the red and green conglomerate has been measured only on the Snake River Divide east of Lime. Here it is about 360 feet thick; elsewhere, thicknesses appear to be comparable. The layer has an over-all surface trend of roughly N. 40° E. and an average dip of about 30° NW.

The conglomerate has been sheared and mildly metamorphosed. In places fracture surfaces exhibit a phyllitic sheen, owing to the development of chlorite and sericite.

Figures 2, 3, and 4 show typical outcrops of the conglomerate in the Lime-Snake River area.

Stratigraphic Relationships near Lime

Triassic rocks

Between Lime and the Bay Horse mine on the west bank of the Snake River, the conglomerate rests discordantly upon a northwesterly tilted sequence of massive greenstones and associated sedimentary beds. These rocks

Figure 1. Conglomerate boulder illustrates typical fragment size range. Pencil gives scale. Note graded bedding and tendency of pebbles to lie flat in plane of bedding.

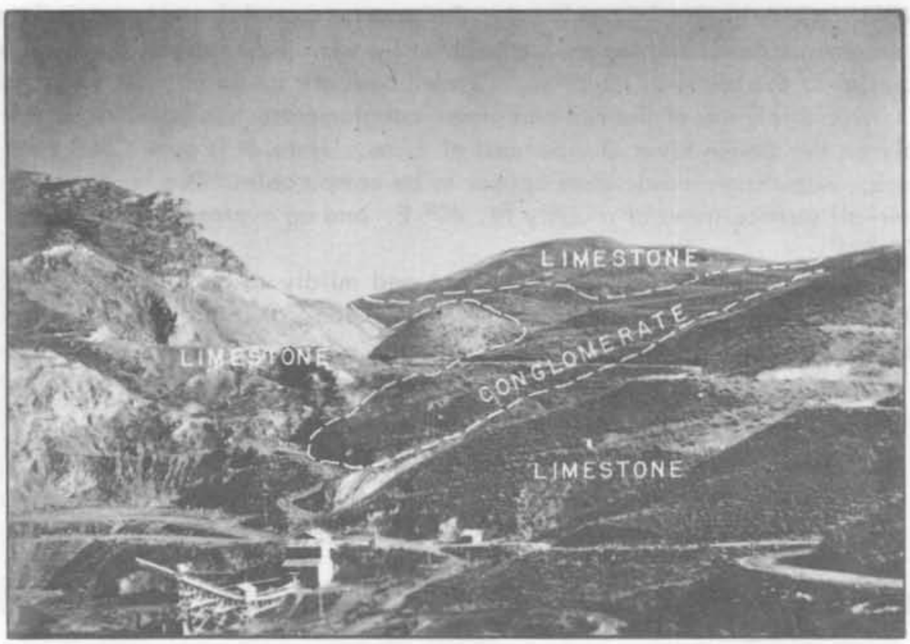


Figure 2. View eastward up Marble Canyon. Oregon Portland Cement Co. limestone quarry on left. The conglomerate rests on uneven erosion surface developed on the massive Upper Triassic (?) limestone.

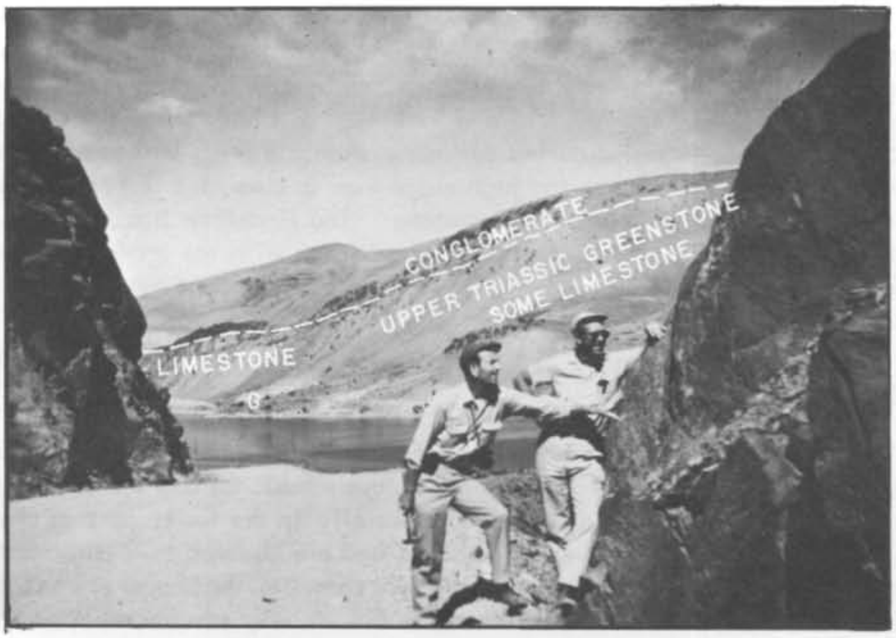


Figure 3. View northeast across Snake River from point near Bay Horse mine. Conglomerate caps ridge in middle distance and overlies Upper Triassic greenstone and limestone. Gypsum has been mined from cuts labeled (G) just above river's edge. Rocks in road cut in foreground are also Upper Triassic greenstones.

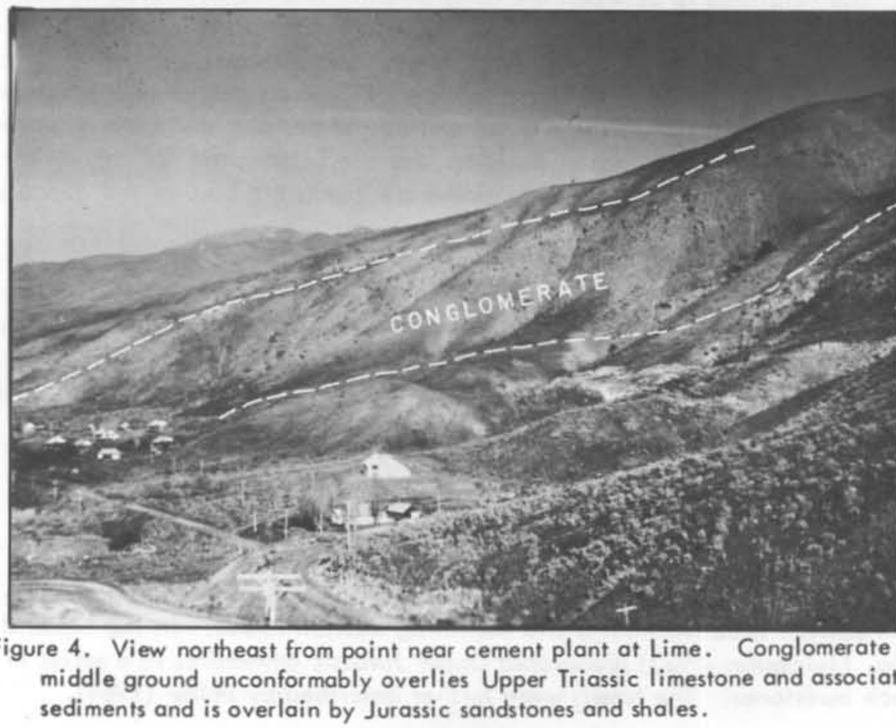


Figure 4. View northeast from point near cement plant at Lime. Conglomerate in middle ground unconformably overlies Upper Triassic limestone and associated sediments and is overlain by Jurassic sandstones and shales.

are well displayed along the Snake River road from Bay Horse south to Huntington and from Huntington north along Burnt River (U.S. Highway 30) to Lime. Fossils collected from sedimentary interbeds in this sequence were identified by J. B. Reeside, Jr., and S. Muller as Upper Triassic (Beeson, 1955), and by T. Susuki (written communication, 1964). East of Lime in Marble Canyon, and also on the high ridge west of Lime, the red and green conglomerate rests upon massive limestone. The limestone has not been dated by fossil evidence, and its contact relations with the greenstones to the south are obscured by landsliding. It is probably part of the upper Triassic sequence.

Jurassic rocks

In the Lime area the red and green conglomerate unit is overlain by a sequence of khaki- to buff-colored tuffaceous sandstones and shales. Small limestone lenses are present locally, especially in the lower part of the sequence. The rocks are well compacted and are sheared to a moderate degree. The sandstones contain sericite and chlorite; the shales are mildly phyllitic. Fossils have been collected in the vicinity of Lime from three sites over a distance of 6 miles. Each occurs near the base of the sequence. After studying the collections, Dr. Ralph Imlay tentatively concluded the fossils are probably representative of upper Lower Jurassic (written communication, 1966).

The relationship between the conglomerate and the overlying Jurassic sandstone and shale sequence in the Lime area has not been confidently established. In places the change from conglomerate to sandstone appears to be gradational through several tens of feet. Elsewhere the change is abrupt. There is sufficient consistency in the attitude of bedding and other structural features to suggest that deposition was not interrupted for any great amount of time, and that the conglomerate marks the base of the Jurassic section in this region.

The thickness of the Jurassic sequence has not been determined. To the north, the khaki- to buff-colored sandstones and shales are in contact with a thick, tightly folded series of grayish to black phyllites and slaty rocks of unestablished age. The phyllites and slates are well exposed along Burnt River in the vicinity of Dixie Creek and along Morgan, Hibbard, and Connor Creeks, which flow eastward into the Snake River.

Regional Correlations

Fossiliferous Jurassic strata are reported from relatively few places in southeastern Blue Mountains and adjoining western Idaho. In the Mineral area, Livingston (1925) discovered Upper Jurassic ammonites in a series of black mudstones. The fossils were further described by Imlay (1964).

Williams (in preparation) shows that Jurassic rocks rest on the red and green conglomerate which, in turn, overlies greenstones believed to be correlative with the Triassic rocks in the Lime area.

Southeast of Brogan in the Juniper Mountain area, Wagner, Brooks, and Imlay (1963) found Middle Jurassic ammonites in dark-colored shales and sandstones. Here, the Jurassic rocks are separated from undated greenstones and limestone by a thin layer of reddish sandstone and shale which may represent a southwesterly extension of the red and green conglomerate.

In the Huntington quadrangle, Wagner and Brooks collected Jurassic fossils from a small locality on Durbin Creek in 1964. The site was later collected by Dr. Imlay. No formal report of this discovery has been made.

In the Caviness quadrangle, a solitary ammonite fragment found by Wolff (1965) in the Becker Creek area was regarded by Imlay as probably Jurassic in age.

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REGIONAL GRAVITY OF OREGON

By Joseph W. Berg, Jr. and John V. Thiruvathukal
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> The following text describes two maps in a series of three entitled "Gravity Maps of Oregon (Onshore and Offshore)" published by the State of Oregon Department of Geology and Mineral Industries as No. 4 in its Geologic Map Series. The two maps here described are: Map GMS 4-a, "Free-Air Gravity Anomaly Map of Oregon", and Map GMS 4-b, "Complete Bouguer Gravity Anomaly Map of Oregon." They were prepared by the above authors. The third map (offshore), designated as Map GMS 4-c, "Free-Air Gravity Anomaly Map West of Oregon," was prepared by P. Dehlinger, R. W. Rinehart, R. W. Couch, and M. Gemperle, Department of Oceanography at Oregon State University.
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> The three maps are printed on 43- by 54-inch transparent sheets at a scale of 1:500,000. They are sold in an unbroken series for $2.00 in flat form, $2.25 folded in envelope, and $2.50 rolled in map tube, and can be purchased from the Department's Portland office.
>
> Also available from the Department is the Geologic Map of Western Oregon, published in 1961; it is printed at the same scale as the gravity maps and sells for $2.00, with the gravity maps.

Introduction

From 1962 to 1966, a research program to establish gravity base station control and compile data for more than 8000 gravity measurements made in Oregon was conducted at Oregon State University. The purpose of this work was to construct gravity maps for the State of Oregon that had enough detail to be useful for regional geologic studies.

Woollard and Rose (1963) established 10 base stations in Oregon as part of the international gravity network. Berg and Thiruvathukal (1965) refined the values of gravity for the 10 base stations and established 22 additional bases. The Oregon base network was tied directly to the gravity station at the Carnegie Institution of Washington, D. C., which was measured relative to Potsdam, Germany. The accuracy of the base station control relative to Washington, D. C. is estimated to be better than ± 0.3 mgal. All gravity data used in this paper are relative to the gravity values of the Oregon base network.

Woollard and Rose (1963) presented a simple Bouguer gravity anomaly map of Oregon contoured on a 20-mgal interval. Bromery and Snavely (1964) published a simple Bouguer gravity anomaly map of northwestern Oregon contoured at 5 mgal. Blank (1966) published a Bouguer gravity anomaly map of southwestern Oregon using a contour interval of 10 mgals. The U.S. Geological Survey (Woollard and Joesting, 1964) published a simple Bouguer gravity anomaly map of the United States (including Oregon) which was contoured on a 10-mgal interval. All of the gravity data for Oregon that were used in the above works were used in this research. In addition, data for about 2500 and 1100 gravity stations in the state were obtained from the Standard Oil Co. of California and the Humble Oil & Refining Co., respectively. Additional gravity measurements for 2500 stations in southwestern Oregon were made available by the U.S. Geological Survey. Measurements at 500 selected stations were made by members of the Geophysical Research Group, Oregon State University, to fill gaps in the station coverage of the state.

Four thousand stations out of more than 8000 available were chosen for the purpose of constructing the gravity maps of Oregon. Consideration of the deleted stations would not change the contours of the map. The average station coverage for west of about 119° W. longitude is about one station every 25 square miles. East of that longitude, it is about one station every 100 square miles. However, there are exceptions to these coverages. For example, in areas of easy access by highways the station coverage may be very large, whereas in southeastern Oregon the coverage is sparse because of difficult access.

Corrections to Data

Data from all organizations were corrected to read observed gravity relative to the base station at Corvallis, Oregon (OSU-1). Standard corrections that were made to the data consist of corrections for instrumental drift and elevation (free air + Bouguer correction, $\rho = 2.67$ gm/cc). The datum for the reductions was mean sea level.

Many different gravity meters were used during the process of data accumulation. Most instruments used by other organizations were of the Worden type. Measurements were made by our group using both Worden (master) and La Coste-Romberg gravity meters having sensitivities of about 0.1000 mgal and 1.000 mgal per dial division, respectively.

Elevation control along highways was by bench marks and road intersections as given by USGS topographic maps. The accuracy of these elevations is within one foot. However, a considerable number of elevations for stations was determined by altimetry. Elevations determined by altimeters are believed to be accurate to within 10 feet. A few stations in areas of high relief may have uncertainties greater than 10 feet.

Terrain corrections were calculated for 460* gravity stations distributed equally over the entire state. The corrections were made using Hammer's terrain correction chart (Hammer, 1939) for zones D (175 to 558 ft.) through M (48, 365 to 71, 996 ft.). The terrain corrections for these selected stations were plotted on a map of the state and contoured, and terrain corrections for the remaining stations were interpolated from the contours.

Complete Bouguer gravity: The elevation and terrain corrections were added to the observed gravity to obtain the corrected gravity. Values of theoretical gravity computed by using the International Gravity Formula of 1930 were subtracted from the corrected gravity for each station to obtain the complete Bouguer anomaly values.

Free air gravity: The free air and terrain corrections were added to the observed gravity to obtain the corrected gravity. The terrain-corrected free air anomaly values were obtained by using the International Gravity Formula of 1930 as described above.

Precision of Data

Since many organizations participated in obtaining the data for this research, a check was made on the precision of observed gravity values at 100 stations throughout the state that were occupied by more than one group. The mean deviation was 0.04 mgal and the maximum deviation was 3.76 mgal. The standard deviation was 1.10 mgal. All data used for this comparison were corrected to read relative to the gravity base value at Corvallis, Oregon.

To check the precision of the interpolated terrain corrections, 38 stations were randomly selected and terrain corrections were computed. The average of the differences between the computed and the interpolated terrain corrections was 0.12 mgal and the maximum deviation was 5.39 mgal. The standard deviation was 1.61 mgal.

In view of the above results, the majority of the data used to construct the gravity maps is considered by the authors to be precise to within 2 mgal for the computations that have been made. However, extreme deviations (5 mgal or more) in a few areas of great relief have been incorporated into the maps.

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* Included in this number are some station corrections made by Blank (1965) of the U.S. Geological Survey, who corrected each station in southwestern Oregon for terrain.

Gravity Maps of Oregon

Complete Bouguer Anomaly Map: The contour interval for the map is 10 mgal. Some contours in eastern Oregon are dashed because additional data may alter them slightly. The distinctive features of the map are listed below.

1. The gravity field decreases from + 60 mgal in northwestern Oregon to -190 mgal in southeastern Oregon, a difference of 250 mgal. The general trend of the decreasing field to the southeast reflects variations in regional geology, which include variations in crustal thickness and changes in density of the crust and the upper mantle. Seismic refraction studies based on a quarry blast indicate an apparent crustal thickness of 16 kilometers for the region of the northwestern Oregon Coast Range (Berg and others, 1966). These results are tentative and more information is needed to determine more precisely the anomalous condition that exists in the vicinity of the gravity highs of + 50 mgal in the northwestern portion of the state. These results may indicate a deep-seated anomalous distribution of mass beneath the Coast Range.

Deep electrical resistivity work (Cantwell and others, 1965, and Cantwell and Orange, 1965) has shown a distinct difference between the electrical properties of the deep crust in northern and southern Oregon east of the Cascade Mountains. Northern Oregon was characterized by low resistivity values and no resistive basement was found, whereas the data in southern Oregon indicated the existence of a resistive basement. The above authors suggest the possibility that the difference could be associated with a basaltic oceanic crust in northern Oregon and a granitic continental crust in southern Oregon.

Pakiser (1963) gives a crustal thickness of about 47 km near Boise, Idaho. However, extrapolation of crustal sections into Oregon from the crustal section near Boise, Idaho, should be done with reservations, since the possibility of lateral variations in crustal and mantle densities cannot be discounted. Southeastern Oregon is at the northern edge of the Basin and Range system (Eardley, 1962) and the upper mantle of this system, in general, has been found to have low density and seismic velocity (Pakiser, 1963).

2. Three regular gravity features are evident on the complete Bouguer gravity anomaly map. The first is along the eastern margin of the Oregon Coast Range. The steep east-west gradient (5 mgal/mile) between Corvallis and the Columbia River indicates a major structural feature such as faulting, which is in agreement with Bromery and Snavely (1964), and faulting could extend south into the Roseburg area along a continuation of the gradient. A few earthquakes have been reported around Roseburg (Berg and Baker, 1963), but the area does not seem to be very active seismically.

The second regular gravity feature is the gradient (about 2 mgal/mile) along the western margin of the Cascade Range. The gravity contours, although serpentine in form, are continuous from the northern section of the Oregon Cascades to the eastern boundary of the Klamath Mountains. This feature shows that gravity decreases towards the Cascade Range and results, in part, from thickening of the crust towards the east. It is not known if faulting is associated with this gravity trend, but seismic activity has been slight.

The third regular gravity feature is the regularity of the gravity contours in the region of the Blue Mountain front (defined by Taubeneck, 1966, as the boundary between the Blue Mountains and the Columbia Basin). There has been some seismic activity along this gravity trend, but the activity has not been great. This region may be a transition zone with a former oceanic type crust characteristic of the Columbia Basin and a crust of more nearly a continental type to the south (Cantwell and Orange, 1965; Skehan, 1965; and Taubeneck, 1967).

3. The Cascade Range trends north-south along the eastern margin of the regular gravity gradient east of the Coast Range. The gravity contours are affected by the volcanic mountain range such as to make gravity less than would be the case if the mountains were not there. This would indicate that the crust is less dense in this region and/or the mountains rest on a low-density mantle (roots). Individual mountains do not have large negative anomalies associated with them, indicating that the greater part of any isostatic compensation would be regional.

4. There is a system of closed gravity highs and lows in the general region of the Blue Mountains (immediately south of the Blue Mountain front and in the region of Baker, Oregon). Some of these gravity anomalies are associated with intrusions, and others have no surface geologic expression. A similar type pattern of gravity anomalies exists in the region of the Klamath Mountains. The geologic implications of these gravity features are unknown at the present time.

5. South of 44° N. longitude and along the Oregon-Idaho border (Owyhee Upland), several closed gravity highs that extend along the border are apparent. These anomalies are probably associated with intrusions. Outcrops of pre-Tertiary intrusions are known to exist in the vicinity of the most southerly high.

6. The northern limit of the Basin and Range Province extends into southern (central and eastern) Oregon. The northern limit of the province cannot be determined from the gravity map. The well-defined closed gravity highs over the mountains and lows over the basins, both in a general north-south trend (characteristic of other parts of the province, according to Cook and Berg, 1961), are not apparent. More detailed gravity data may show some of these features. However, this region may be a younger Basin and Range development (Walter Youngquist, personal communications) and/or transitional Basin and Range type structure (affected by transition into a highly volcanic region), and gravitational measurements may not reflect variations in structure as strongly here as elsewhere.

7. There are many localized gravity anomalies shown in the complete Bouguer gravity anomaly map. Some of these anomalies are associated with surface geological expressions (cones, intrusions, and so forth), but some cannot be correlated with the surface geology. The latter anomalies are real and should be more thoroughly investigated, using the gravitational as well as other methods.

Free Air Gravity Anomaly Map: The free air anomaly map is contoured on a 10-mgal interval. The observed gravity values used to contruct this map were corrected for terrain and altitude effects. One can imagine this map as a sea-level surface on which all of the mass above sea level has been concentrated. Thus, the variation in height of different stations is removed from the gravity measurements. Anomalies exhibited on this map reflect variations in mass beneath different areas. However, some variations of subsurface horizons do affect the gravity in nearby areas. This effect would not be as pronounced as that from surface terrain.

There is a considerable variation in gravity anomalies in this map (+140 to -80 mgal). However, most of the anomalies are small in areal extent. Excesses or deficits of mass from a standard (zero anomaly) geologic column would appear to be localized, mainly. Thus, extreme deviations from hydrostatic equilibrium would appear to be limited to small areas.

Additional analysis of the data presented in these maps is currently in progress and will be presented for a doctoral dissertation by John V. Thiruvathukal at Oregon State University.

All the gravity data for the state are on file with the State of Oregon Department of Geology and Mineral Industries.

Acknowledgments

Hollis M. Dole, State Geologist of Oregon, originally suggested that a gravity map of the State of Oregon could be constructed mainly by using existing data. We wish to thank Mr. Dole and the staff of the State of Oregon Department of Geology and Mineral Industries for their help and encouragement during the course of this project.

Gravity data were provided by Standard Oil Co. of California, Humble Oil Co., U.S. Geological Survey, University of Wisconsin, University of Oregon, Naval Oceanographic Office, Southern Methodist University, and the State of Oregon Department of Geology and Mineral Industries.

Delmar L. Evans, Robert Gaskell, Orin W. Knee, John H. Livingston, Philip R. Laun, William R. McKnight, Mark E. Odegard, Wilbur A. Rinehart, Suryya K. Sarmah, and Lynn D. Trembly made gravity measurements during the course of the project.

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B.L.M. ADMINISTRATION TOLD

The U.S. Bureau of Land Management has published "BLM Facts," a booklet containing tabulated information on the activities of the bureau. Of particular interest to the claim holder is the following table which summarizes the bureau's activities with respect to mineral patents, permits, and Public Law 167 claim determinations during fiscal years 1965 and 1966. Figures for the State of Washington are also included.

Minerals

Item	Oregon FY 1965	Oregon FY 1966	Washington FY 1965	Washington FY 1966
Mineral Patents Issued----	2	1	3	--
Mineral Permits & Licenses	--	2	2	1
Mineral Leases------------	8	39	2	4
P.L. 167 Determinations Completed, acres--------	540,201	125,077	--	--
Cumulative Determinations, acres------------------	1,409,451	1,534,528	143,414	143,414
Claims Retaining Surface Rights, number---------	95	95	6	6
acres----------	1,900	1,900	120	120
Percent of Mineralized Area on which P.L.167 Action is completed-----	40	45	95	95

Land Patents Issued

Kind of Patent	FY 1965 No.	FY 1965 Acres	FY 1966 No.	FY 1966 Acres
Oregon				
Homestead---------------	2	60	1	40
Desert Land-------------	2	200	2	156
Public Sale-------------	14	2,977	6	560
Exchange----------------	35	20,798	34	25,961
Small Tract-------------	1	5	1	6
Recreation Sale---------	4	95	6	3,104
Reclamation Sale--------	5	550	1	120
Other-------------------	4	315	--	--
Total-----------------	67	25,000	51	29,947
Washington				
Homestead---------------	1	160	--	--
Desert Land-------------	--	--	--	--
Public Sale-------------	5	255	1	120
Small Tract-------------	--	--	--	--
Recreation--------------	2	11	--	--
Exchange----------------	2	5,478	2	5,894
Mineral Patent----------	--	--	--	--
Reclamation Sale--------	--	--	--	--
Other-------------------	6	1,655	4	3,019
Total-----------------	16	7,559	7	9,033

The bureau administers only 275,000 acres in Washington in contrast to 16,017,000 acres in Oregon; 25 percent of Oregon is BLM land, but only one percent is administered in the State of Washington.

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PARKERVILLE PLACER MINE CONVERTS

The Parkerville placer mine in the Greenhorns, Grant County, is being converted from a hydraulic operation to a washing plant by A. W. Brandenthaler. The new plant will have a capacity of about 1000 yards per day. Presently the crew of 10 men is constructing a series of settling ponds to clarify the plant effluent before it is returned to the North Fork of Burnt River.

* * * * *

BRETZ QUICKSILVER MINE SOLD

The Bretz mine in southwestern Malheur County has been sold to New Idria Mining & Chemical Co., Idria, Cal. The Bretz was owned by Minerals & Chemicals Philipp Corp. of New York and had been operated by Sam Arentz until last fall. The mine was discovered in 1917, and during the half century since has produced more than 15,000 flasks of mercury. During the past 10 years most of the ore has been obtained from surface pits. The ore was concentrated in a flotation plant before retorting.

* * * * *

BRANDENTHALER OPERATING BUFFALO MINE

A. W. Brandenthaler of Baker has reopened the Buffalo mine in the Granite district of eastern Grant County. Brandenthaler is operating the Buffalo under a lease-purchase option from the Union Pacific Railroad. Jim Jackson, who operated the mine for 15 years prior to the Union Pacific period of ownership, will be in charge of the mining and milling. The mine crew will extend the drift on the No. 5 level along the vein cut by UP last year. Milling will begin when the new drift is complete.

The Buffalo mine has a history extending back to the beginning of the century. Records indicate that nearly $1,000,000 in gold, silver, copper, lead, and zinc has been produced from the property.

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BOURNE MINES DEVELOPED BY OMEGA MINES, LTD.

Omega Mines, Ltd., under the supervision of Henry Bowyer, has continued to develop the complex of veins in the old mines at Bourne in the Cracker Creek district of Baker County. A nine-man crew has been driving a tunnel on the Excelsior No. 1 level for the past season and work is expected to continue for at least another year. Adjacent properties which will benefit from the development program include the Columbia, North Pole, and the E and E.

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Structure and Orogenic History of the Southwestern Part of the John Day Uplift, Oregon

By H. J. Buddenhagen*

Predominantly marine sediments ranging in age from Devonian to Cretaceous, unmetamorphosed, and not intruded by large igneous bodies, are exposed in the John Day Uplift** of central Oregon (figure 1). Detailed mapping of these beds and their structural features in the southwestern part of the uplift has provided important clues to the pre-Tertiary geological history of the vast lava-covered plateau region east of the Cascade Mountains. It is expected that the results of this work will be published as a bulletin of the State of Oregon Department of Geology and Mineral Industries within the next 12 to 18 months. In the meantime, the following is offered as a brief preview and summary of the more important findings and implications.

The distribution and structural relationships of the major stratigraphic units are shown on the accompanying generalized maps (figures 1 and 2). These units are listed and briefly described in the following paragraphs. For more detailed description of the stratigraphy of this area, reference may be had to the reports listed at the end of this paper.

Stratigraphy

Paleozoic

Devonian: fossiliferous limestone with a little gray shale; depositional relationships to older and younger formations unknown.

Mississippian: fossiliferous limestone, marl, and sandstone.

Pennsylvanian: clastic sediments, mostly of non-marine origin, consisting of greenish mud-siltstones containing sparse fossil plants; feldspathic sandstones with occasional laminae and lenses of magnetite grains; and coarse, rounded porphyry boulder conglomerates.

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* Consulting geologist, Grants Pass, Oregon.

** The term "John Day Uplift," as used herein, refers to the inlier of pre-Tertiary formations which are exposed largely within the triangle formed by lines joining the settlements of Burns, John Day, and Paulina in east-central Oregon. The uplift is bordered on the north by the John Day River and it is drained principally by tributaries of this river. The town of John Day is located on the north edge of the uplift 12 miles west of its northeast corner.

Permian (early): limestones containing fusulinids and other fossils with interbedded green and maroon cherts, siltstones, and sandstones. Trilobite fragments were found in an isolated fault block of Permian limestone--the only known trilobite occurrence in Oregon*.

Mesozoic-Paleozoic?

Birdsong beds: interbedded fine-grained sandstones, siltstones, chert fragment grits and conglomerates, bedded chert and massive, chert-like, felsitic andesite; unfossiliferous; stratigraphic position and age uncertain. The principal occurrence is in the hills $1\frac{1}{2}$ to 3 miles west of the Weberg and H. Robertson ranch buildings.

Mesozoic

Triassic: an unfossiliferous lower section several thousand feet thick, consisting of chert fragment and volcanic wacke grits and sandstones with lenticular conglomerates, overlain unconformably by a section of marine origin containing fossils of Late Triassic age**. The latter has a limestone boulder conglomerate at the base which is overlain by thinly interbedded black organic shale, siltstone, fine-grained graded sandstone, sandy limestone, and calcareous sandstone with occasional zones of rubbly limestone and thin, agate-pebble conglomerates.

Jurassic: many thousand feet thick, predominantly thinly interbedded, sparsely fossiliferous (ammonites) tuffaceous siltstone, black shales, and volcaniclastic sandstones with a relatively thin (200- to 300-foot) basal section composed of highly fossiliferous sandy limestone and calcareous sandstone with interbedded organic black shales. The fauna of the basal beds, except the Hettangian, referred to later, includes the unique Plicatostylus and abundant pelecypods and brachiopods, as well as distinctive ammonites.

Upper Cretaceous: fossiliferous sandstone with minor interbedded siltstone and conglomerate.

Tertiary

Miocene and Pliocene: Tertiary lavas surround the uplift. In the southwest part, with which this article is concerned, these are mostly basalts, and mostly post-Columbia River Group in age. Younger ridge-capping pumiceous tuffs and rhyolitic lavas occur both within and outside the inlier in the same area. Underlying both, although not everywhere present, is a thin, widespread zone of bentonitic clay and tuffaceous sand associated with uncemented conglomerate composed of well-rounded quartzite pebbles and boulders. This zone probably correlates with the Mascall Formation of the John Day Valley. Pre-Miocene Tertiary volcanic rocks and sediments have not been recognized in the area under discussion.

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* Identification by D. A. Bostwick.

** Fossil determinations and correlation by N. J. Silberling.

Structure and Tectonic History

Because of the complex structure, the apparent discontinuity of the beds, and scarcity of outcroppings, the geology of the Paleozoic area is very obscure. It is known from fossil evidence that formations of Devonian to Permian age are present, but it has not been possible to establish a proper lithologic-stratigraphic column for the Paleozoic section based on observed superposition of beds; and the basement on which the oldest Paleozoic sediments were deposited is unknown. Consequently, deciphering the geology of the Paleozoic area is akin to working a jigsaw puzzle with many of the pieces missing. It is clearly evident, however, that these beds have been extremely compressed and much faulted.

Paleozoic-Triassic episodes

Although specific unconformities in the Paleozoic section, indicative of diastrophic episodes, cannot be detected with assurance because of the complex and obscure structure, it cannot be doubted that tectonic activity has occurred during the late Paleozoic-Early Triassic interval, perhaps repeatedly.

The non-marine origin of much of the Pennsylvanian section, with its coarse conglomerates, in contrast with the fossiliferous limestones and sandstones of the Mississippian, indicates an intervening period of uplift and diastrophism.

The absence of Late Permian deposits suggests that the area was either above sea level during this time interval, with consequent non-deposition, or that sediments which may have been deposited during this period were uplifted and eroded during Early or Middle Triassic time. The latter possibility is supported by the reported occurrence of a Late Permian fusulinid in a limestone boulder from an Upper Triassic conglomerate (Bostwick and Nestell, 1965).

Additional evidence of diastrophism in the Late Permian-Early to Middle Triassic interval is present in the area between Williams Reservoir and Grindstone Creek (to the north), where there is a strong angular unconformity between Early Permian beds and overlying limestone boulder-bearing conglomerates of probable Upper Triassic age.

Within the Triassic itself, Paleozoic limestone boulder conglomerate at the base of the fossiliferous marine section suggests the presence of a land mass rising at that time and exposing Paleozoic limestones to erosion near a subsiding basin; but the fine-grained character of most of the subsequent Upper Triassic sediments indicates that the deformation was probably not great.

Lower Jurassic episode

The major mountain-building episode in the entire post-Devonian geologic history of the area appears to have occurred following the deposition of the lowermost Jurassic (Hettangian)* beds which are now found cropping out in this area only on the north side of Twelvemile Creek at the east end of Williams Reservoir. During this period several thousand feet of Triassic sediments, together with the basal Jurassic, were compressed into predominantly north-south trending, nearly isoclinal folds over a wide area (see cross section, page 134). As the east-west compressional forces

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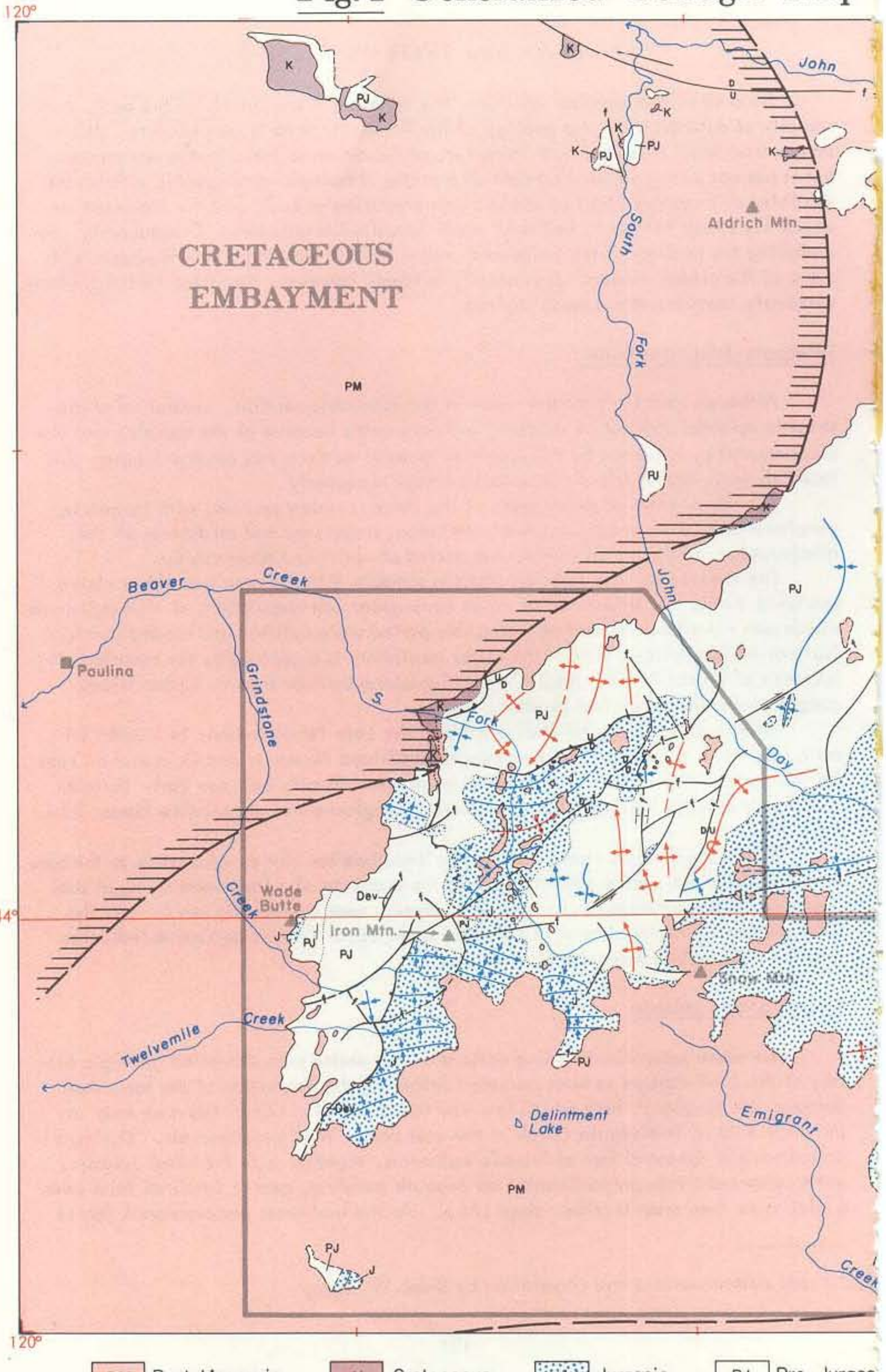
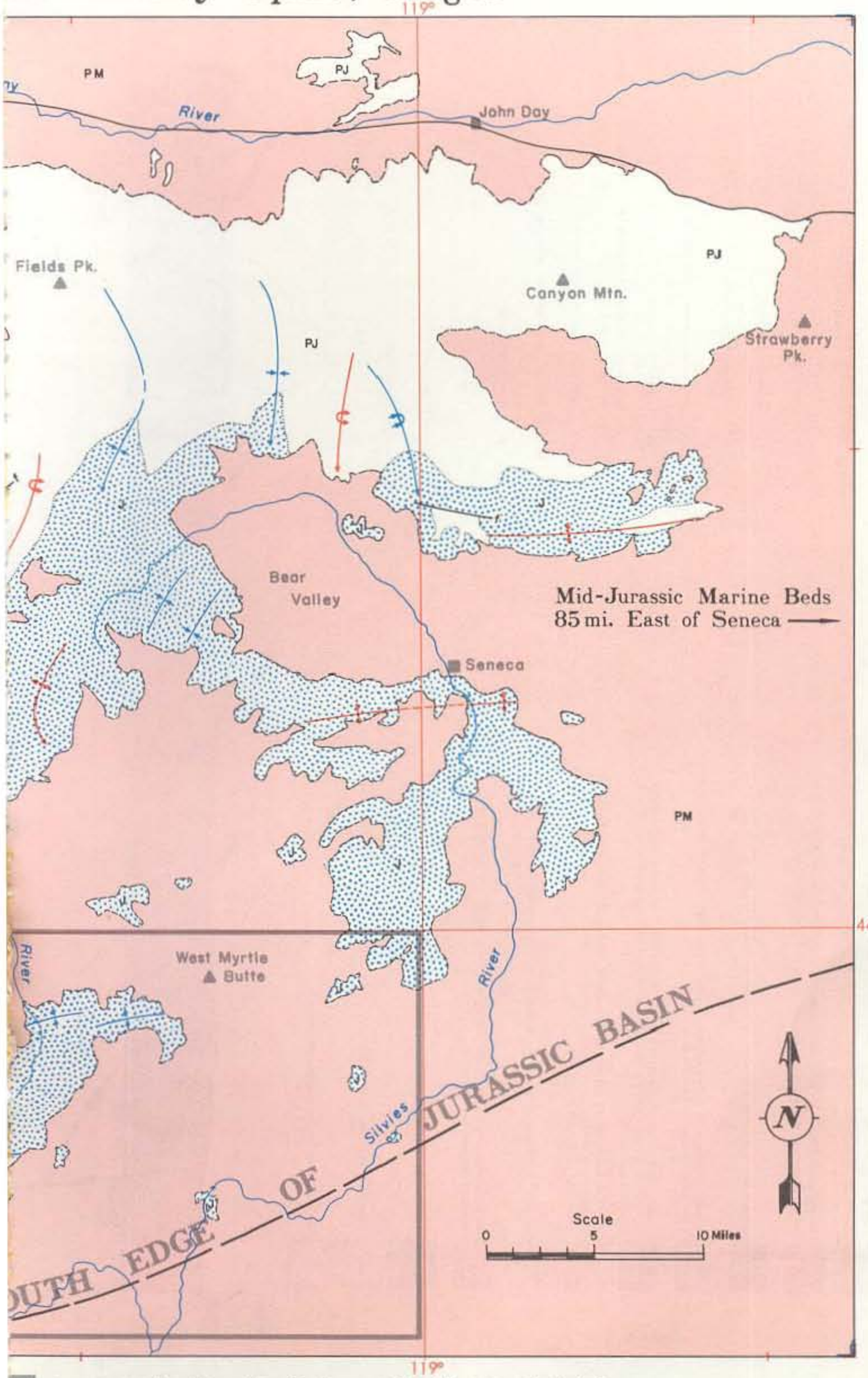
* Fossil determinations and correlation by Ralph W. Imlay.

Fig. 1 Generalized Geologic Map



e John Day Uplift, Oregon

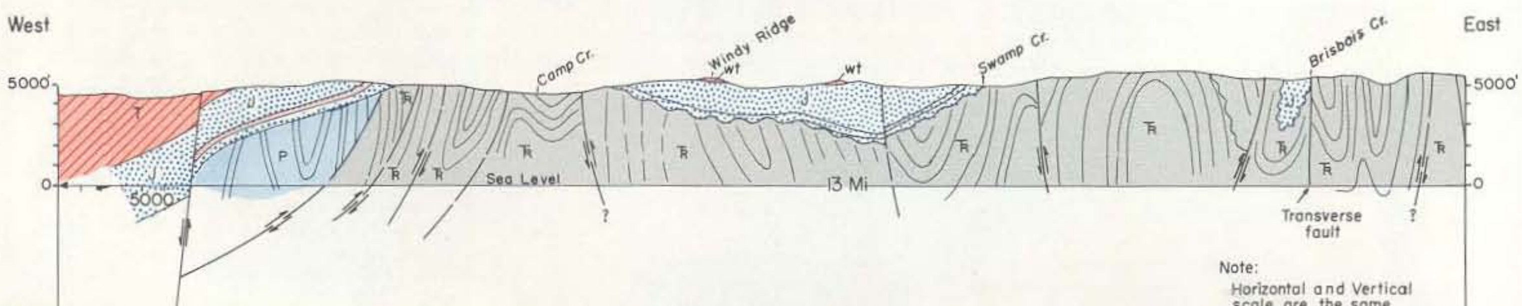


Area mapped by the author. Geology outside this area adapted from maps by C.E. Brown–T.P. Thayer & W.R. Dickinson – L.W. Vigrass

Explanation

- wt — Youngest volcanic rocks, mainly welded tuff; probably correlates with Rattlesnake and Danforth. Not mapped on south side of uplift.
- T — Tertiary undifferentiated. Predominantly basalt, mostly post-Columbia River, but includes thin, widespread quartzite boulder conglomerate and bentonitic clays.
- K — Upper Cretaceous marine sandstone, conglomerate, and shale, interbedded.
- J — Jurassic undifferentiated, predominantly marine volcaniclastic and tuffaceous sediments; porphyritic andesite and basalt in lower part.
- ℞u? / ℞ — Triassic undifferentiated, predominantly clastic sediments with marine fossils in upper shales and limestone; ℞u? in Paleozoic area beds containing coarse limestone and sandstone boulders.
- bs / a / c — Age ? Probably Triassic and Permian. No fossils. bs: predominantly fine-grained sandstone to grit with chert fragments; a: andesite and dacite, massive, felsitic, chert-like, buff; c: bedded cherts.
- P — Permian: fossiliferous limestone and associated maroon and green cherts.
- ?
- IP — Pennsylvanian: clastic, mostly non-marine sediments ranging from fine-grained sandstone to coarse boulder beds.
- M — Mississippian. Marine limestone and sandstone.
- Dev — Devonian. Fossiliferous limestone.
- ? — No information on, or uncertain correlation.

- Unconformity.
- Fault, concealed where dotted.
- Fault interpreted to be thrust or reverse type; tooth on over-thrust block.
- Depositional contact.
- Strike and dip of bedding
- Vertical or near vertical bedding (shown only in Paleozoic area).
- Overturned bedding
- Direction of gentle (2°-5°) dip in Tertiary formations; determined by photogeology.
- Axes of folding: syncline, anticline.
- Axes of overturned folds: anticline, syncline
- Invertebrate fossil
- Plant fossil
- Main roads.
- Other roads



East-West Cross Section

continued to be active, low-angle, westerly-dipping thrust faults developed on which Paleozoic and Birdsong beds overrode the Triassic to the east. The large limestone blocks at the northeast end of the Paleozoic area and the steeply dipping bedded chert capping the three hills directly south of the Williams Reservoir are considered to owe their position to this faulting. They now remain as outliers, or klippe, as a result of subsequent erosion of the surrounding area (figure 2).

The irregular lobate contact between Paleozoic-Triassic rocks on the west and the Triassic-Jurassic beds on the east, which bears about N. 20° E. from the vicinity of the Burger Ranch in the southwest corner of the map to near the north edge of the map (figure 2) marks the outcrop area of this thrust-fault zone. The overthrust mass appears to have broken into several blocks, probably separated by nearly vertical transverse faults, which have moved eastward differentially, some moving farther than others, and at different times.

Upper Jurassic-Lower Cretaceous episode

Relatively soon after this mountain-building episode, a major easterly-trending trough, as much as 30 miles wide and more than 100 miles long, developed, in which thousands of feet of marine Jurassic sediments accumulated. There is no record of uppermost Jurassic or Lower Cretaceous sedimentation in this trough, so it is concluded that the sea had withdrawn prior to this time, probably because of regional uplift. It was during this depositional hiatus that north-south compressional forces became dominant, resulting in folds in the Jurassic with generally easterly-westerly trends, as shown on the accompanying maps. The thrust-fault contact between the Triassic and Jurassic, extending easterly from near the Colpitts Ranch, and between the Jurassic and older formations in the Burger Ranch-Iron Mountain area, also probably occurred during this period of tectonic activity.

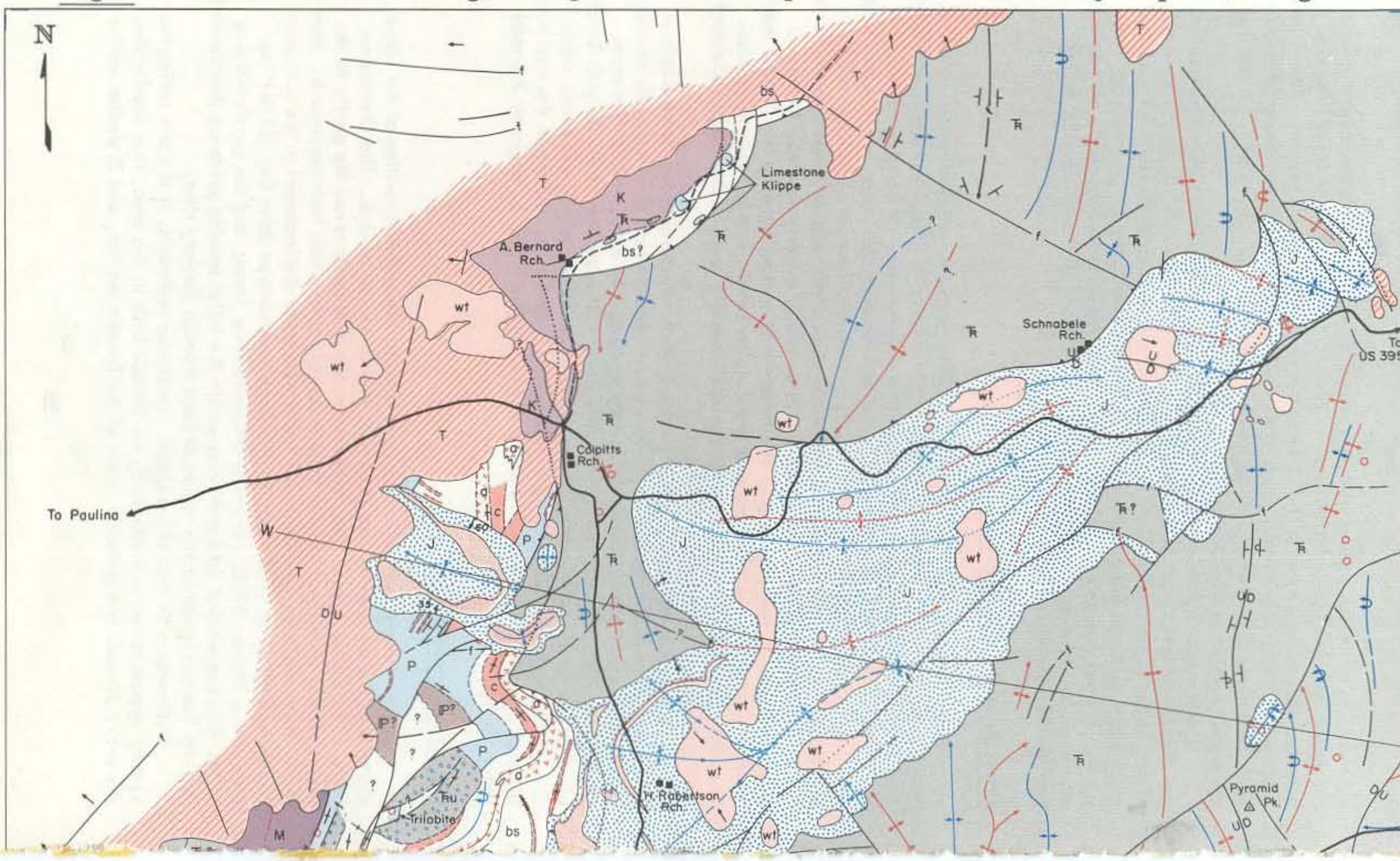
The pre-Jurassic rocks, with their north-south structural grain, were affected by this north-south compression in various ways: development of 1) markedly sinuous trends of structural axes and vertically dipping beds; 2) deep, saddle-like cross folding, for example, the one about a mile and a half southwest of the Colpitts Ranch, which preserves Jurassic beds in a west-plunging syncline; and 3) extremely steep anticlinal plunge dips terminating in thrust-type cross-faults, present on the west side of lower Brisbois Creek south of the east end of the Paulina-U.S. Highway 395 road shown on figure 2.

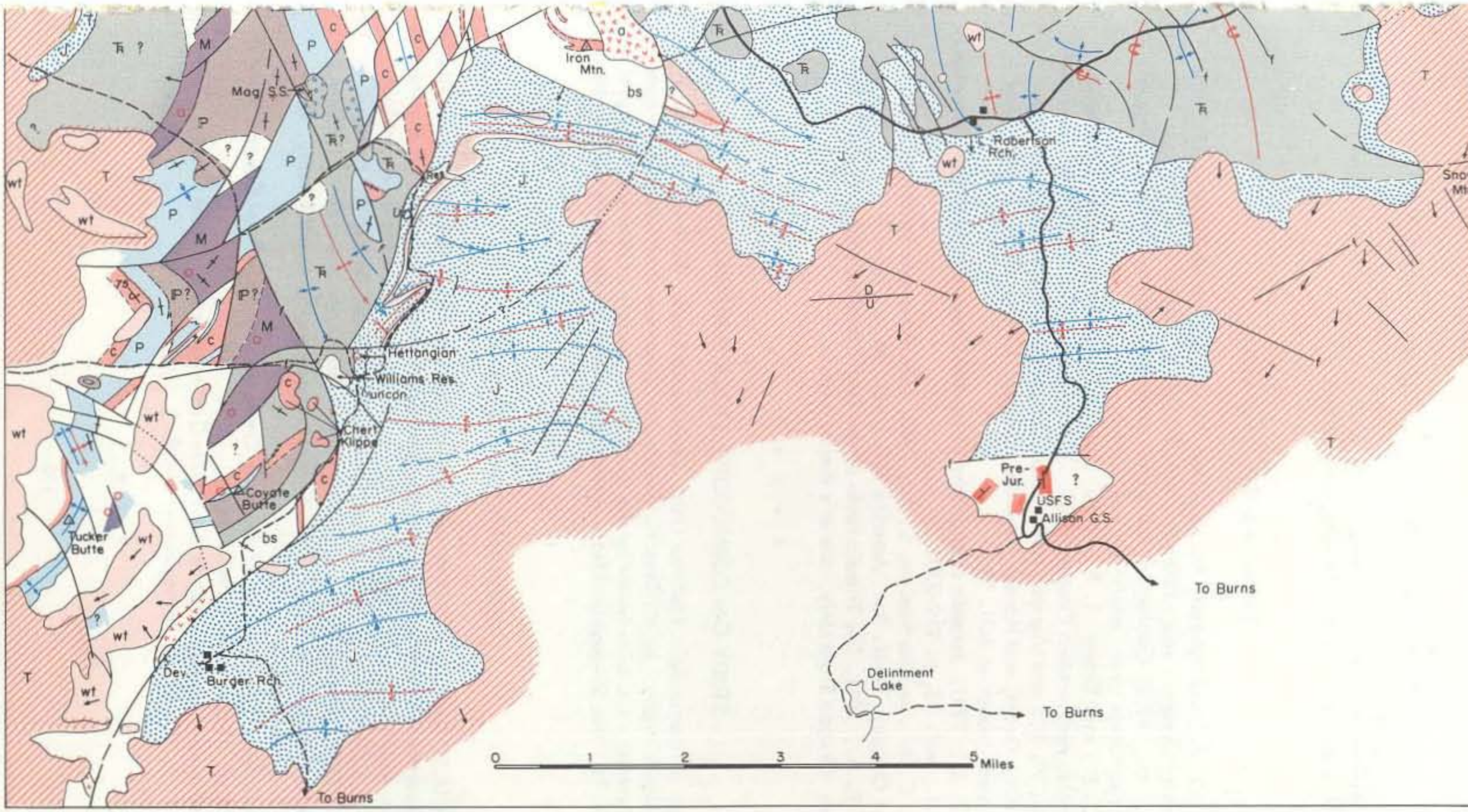
Post-Cretaceous activity

Except for regional uplift, tectonic activity since the deposition of the Upper Cretaceous has been minor compared with that of earlier periods. The Cretaceous beds, cropping out only in the northwest corner of the map area, dip gently to the northwest and appear not to have been involved in important fault movements. However, the prevalence of normal type faults with small displacement in the surrounding upper Tertiary volcanic terrain, the large reverse-type John Day (River) fault (Brown and Thayer, 1966) involving Columbia River lavas; and the gentle warping of the Pliocene welded tuffs and lavas within the inlier provide evidence that tectonic activity has continued in this region at least through Tertiary time.

With respect to the marine Upper Cretaceous sediments, it is worth noting that: 1) they appear to rest unconformably on Triassic beds in this area, thus overlapping the entire Jurassic and probably much of the Triassic section, and 2) similar marine

Fig. 2 Generalized Geologic Map of the S.W. part of the John Day Uplift, Oregon





Iron Mtn.
bs
Mag. S.S.
Hettangian
Williams Res.
Toarcian
Chert Klippe
Coyote Butte
Tucker Butte
Dev.
Burger Rch.
To Burns
Robertson Rch.
Snow Mtn.
Pre-Jur.
USFS
Allison G.S.
To Burns
Delintment Lake
To Burns
0 1 2 3 4 5 Miles

Upper Cretaceous deposits occur in north-central and northwestern Washington and in southwestern Oregon. The implication is that much of the terra incognita below the Tertiary lavas westerly from this area is underlain by unmetamorphosed Cretaceous, and probably also Jurassic and Triassic, marine beds.

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STUDY ON CORNUCOPIA STOCK PUBLISHED

"Petrology of Cornucopia Tonalite Unit, Cornucopia Stock, Wallowa Mountains, Northeastern Oregon," by William H. Taubeneck, Department of Geology, Oregon State University, has been issued by the Geological Society of America as Special Paper No. 91. The 56-page booklet is a study of the nature and origin of the tonalite.

* * * * *

USGS MAPS ON OPEN FILE

The three U.S. Geological Survey maps listed below have been placed on open file in the Department's Portland office, where they are available for consultation. Material from which copies of these maps may be made at private expense is available from the U.S Geol. Survey, 830 N.E. Holladay St., (P.O. Box 3202) Portland, Oregon. 97208. Maps are accompanied by explanation, and the scale is 1:62500.

Preliminary geologic map of the Courtrock quadrangle, Grant County, Oregon, by T. P. Thayer and C. Ervin Brown.

Preliminary geologic map of the Long Creek quadrangle, Grant County, Oregon, by T. P. Thayer and C. Ervin Brown.

Preliminary geologic map of the Prairie City quadrangle, Grant County, Oregon, by T. P. Thayer, C. Ervin Brown, and R. L. Hay.

* * * * *

THE OUTLOOK CONCERNING A RISE IN THE PRICE OF GOLD

Broadcast talk by Dr. J. E. Holloway
South African Broadcasting Co., May 18, 1967

On April 21, 1967, the Northwest Metals and Minerals Conference presented an all-day session discussing the problems and relations of gold and money. This was the third Gold and Money Session to be held in Portland since 1960. As usual, the speakers were authorities in the fields of mining, economics, and banking. The titles of the papers and their authors were as follows:

(1) Have 6,000 years of gold mining exhausted the world's gold reserves? Dr. Paul M. Kavanagh (Vice President - Exploration, Kerr Addison Mines, Ltd., Toronto, Ontario, Canada).
(2) Gold or authoritarian money - Dr. John E. Holloway (Director, Barclays Bank, Johannesburg, South Africa).
(3) Is gold as good as the dollar? - Dr. Lorie Tarshis (Professor of Economics, Stanford University, Stanford, Cal.).
(4) Gold as an economic fever thermometer - C. Austin Barker (Partner-Economist, Hornblower & Weeks - Hemphill Noyes, New York City).

A panel discussion was held during the afternoon of the session, at which time the above-noted authors of papers discussed differences of opinions on gold and money. Dr. Donald H. McLaughlin (Chairman of the Board, Homestake Mining Co., San Francisco, Cal.) and Mr. Angus C. Collie (Secretary-General, Gold Study Committee, Chamber of Mines of South Africa, Johannesburg, S.A.) moderated and participated in the discussion.

The papers presented at the session, the verbatim transcript of the testimony, papers by Dr. McLaughlin and Mr. Pierre R. Hines (Co-Chairman of the session), and the June, 1967 statement of the Hon. Joseph W. Barr, Undersecretary of the Treasury, before the House Internal and Insular Affairs Committee, will be available through the State of Oregon Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Oregon 97201. Publication of the "Proceedings of the Third Gold and Money Session" will be completed by August 1, 1967.

Following his return to South Africa, Dr. John E. Holloway was interviewed by the South African Broadcasting Co. The text of the interview is given below. Dr. Holloway is one of South Africa's most distinguished citizens. A few of his many positions in his long career include: Professor of Economics, Pretoria 1922-1925; Director of the Office of Census and Statistics 1925-1933; Secretary for Finance 1937-1950; Ambassador of South Africa to the United States 1954-1956; High Commissioner for the Union of South Africa in London 1956-1958. He is the author of a number of publications including "The International Monetary Fund" and "The Debacle of Money."

Q. I imagine I am not far from the point if I guess that in your recent overseas trip you gave some attention to the price of gold.

A. You guess right. Since Mr. Havenga initiated the discussion on the revaluation of gold in 1949, I have kept a close watch on all the operative forces which could affect the price of gold. I am, therefore, sensitive to changes in the climate.

Q. Did you notice any changes abroad in the sentiment about the price of gold?
A. I will have to divide my answer to that question into three parts:

Firstly, there is no change in the attitude of the American Government. They say the price is S35 an ounce, and there it shall remain. This is, however, not of any importance. Even if they decided to change their policy, it would be extremely foolish to say anything about it until they could act.

Secondly, I noticed that an increasing number of Americans both in business and in academic circles now protest that America is selling her gold too cheaply.

Thirdly, and this is the most important because it is concerned with fundamental operative forces, the question arises how the stern realities are influencing the future of the price of gold.

Q. Would you enlarge on these points?
A. Yes, particularly about the last two.

Q. The second is whether America is selling her gold too cheaply.
A. Yes. The United States accumulated her large stocks of gold particularly in the years 1945 to 1949. Prices were then much lower than they are now. In other words, they gave more commodities in exchange for an ounce of gold than they now receive for it. When they bought their gold it was relatively dear. As a result of their policy of pegging the price of gold during a period when commodities were steadily becoming dearer, they now receive fewer commodities for gold. When they must pay with gold today their decision to keep gold cheap operates against them.

Q. That is clear enough. Don't they understand it?
A. Some of them certainly understand it and say that the U.S.A. should not sell its gold so cheaply. The American Treasury surely understands it too, because they are no fools. They, however, accept it because up to the present it has been their opinion that other considerations outweigh this disadvantage. To understand how the present position has arisen it is necessary to know its history. In the last 15 years the U.S.A. has lived in debt. In other words in every one of these years, except one, she has spent more abroad than she has earned abroad. She has, therefore, incurred a continuing deficit in her balance of payments. The difference has been partly settled in gold, but only partly. The rest has been settled with dollars which came partly from the printing press and partly from bank loans, that is to say, with money which for the time being costs them nothing.

In view of the fact, firstly that the United States is the richest country on earth, and secondly that the dollar is a so-called key currency, she could settle her deficits with created money, that is, with I.O.U.'s or promises to pay. As long as this process can continue the price of gold is not really important to her. As Jacques Rueff often says, if one falls from a fiftieth storey one cannot really be hurt as long as one keeps on falling. It is now becoming evident, however, that the process of paying with I.O.U.'s is running out. The reason why it paid America to keep gold cheap, namely, that she could pay with promises and not with gold, has lost such validity as it might have held. The American Treasury just does not seem to have found this out.

How large is the accumulated debt?

Every dollar outside the U.S.A., whether in circulation or in Central or other banks, is a debt of the U.S.A. The short-term liabilities of the U.S.A. to the rest of the world have accumulated to the vast sum of more than $26 billion, that is, $26 thousand million. In addition she owed $5 billion to international organisations. The debt has become so large partly because America has had to pay inflated prices. In the meantime she has pegged gold at the old price of $35. She has, therefore, not enough gold to cover the deficit at $35 per ounce. Against the $26 billion short-term liabilities she owns slightly more than $13 billion in gold.

Then, surely, it would be in the interests of the U.S.A. to increase the price of gold.

One would think so, especially as long as she still possesses a large gold stock and can benefit from the price increase. But this is not the view of the American Treasury.

If they continue with their present policy how can it affect the price of gold?

This brings us to the third and more fundamental aspect of the matter. As I have already said, America has for years had deficits in her balance of payments, that is to say she has accumulated debts to foreigners. It looks now as if the easy way of financing it is running out. Various possibilities emerge from this situation. The most far-reaching one depends on her persuading the rest of the world to create a new artificial international method of payment. This would defer the payment of her debt for an indefinite period. If this should happen, the question of the price of gold would fade into the background. If she does not succeed in this she must either:

(a) Reduce her foreign expenditure to the level of her foreign earnings, or
(b) Persuade foreign central banks to continue adding more dollars to their reserves, or
(c) Pay in gold.

What progress is there in the international conferences in this field?

One cannot really speak of progress in the direction which America desires. The discussions have been going on for about four years. In the middle of March the American Minister of Finance, Henry Fowler, warned that time is running out. On April 16th the Finance Ministers of the Common Market countries met in Munich. According to press reports, Germany and also some of the others moved nearer to the French standpoint, which wants to restore gold to the place of honour. Press reports described this as a serious setback for America. Early this month there was a joint meeting in Washington of the International Monetary Fund and the Group of Ten. According to press reports and to what I myself could ascertain in Washington, progress was confined to certain technical matters. The crucial issues of substance were not really tackled although they were discussed.

It rather looks as if the finding of a long-term solution has become a long-term problem?

It looks like that to me, and therefore we should confine our attention to the immediate problem.

Q. That is the question whether the United States can avoid a payments deficit this year. What is the expectation?

A. In America there is a terse answer. No. Rather is it anticipated that the deficit will increase, some say to as much as $2 billion.

Q. The question, therefore, arises how it is to be financed.

A. Yes. But it is becoming more and more difficult to secure acceptance of her promises to pay abroad. It looks as if everywhere there is a surfeit of dollars and holders would prefer to get rid of them. In 1965 France bluntly said that she did not want surplus dollars, and she has exchanged them for gold to the tune of between $1 and $2 billion. It is alleged that some Central Banks have clandestinely bought gold on the London Market, because they do not wish the U.S. to know that they are divesting themselves of dollars. Private buyers of gold take as much as they can lay their hands on, thus moving out of dollars. Last year all the newly-mined gold went into private ownership and, in addition, Central Banks had to pour in between eighty and one hundred million dollars worth of gold in order to keep the price down at $35. The East turns dollars derived from oil, from the clandestine trade in opium, and from American disbursements for the Viet Nam War into gold as fast as they can. It has become necessary for America to allow a large amount of gold to flow into View Nam to keep inflation in check.

Q. The U.S.A. is therefore faced with a real and massive problem of financing.

A. Yes. It is clear that she will use all her vast political influence to barricade her remaining gold reserves. But if she fails to get more short-term financing abroad, and again has a payments deficit, it is obvious that she will lose gold. She still has a vast store, more than $13 billion. But there is no sense in watching idly while her gold flows away. If the drain is not stopped in time it stands to reason that the price of gold will rise. But of what use will it be to her if the price rises when she has little of it left? Sooner or later she will have to call a halt by increasing the price on her own.

Q. When can this be regarded as practical politics?

A. Last year a large gold dealer told me that he thought this would happen if the stock approaches the $10 billion mark. This year I heard the same figure from quite another source. I recently read in a trade paper: "Washington is thought to regard $10 billion as the safety minimum." But if anyone wishes to speculate, he will have to make his own guess.

Q. According to press reports, the question of the relationship of the dollar to gold recently evoked lively discussions in America. Can you say anything about this?

A. Yes. It is certainly a remarkable incident. The two largest banks in America published astonishing statements in connection with the dwindling gold hoard of the U.S.A. The Chase Manhattan Bank mentioned the well-known fact that as the total liquid liabilities of U.S. banks to foreigners is more than two times the amount of the U.S. gold stock, a run on that stock could not possibly be satisfied. To that they added the following: "If it is made unmistakably clear that in the event of a crisis the U.S. would simply terminate the privilege now given to foreign central banks of buying gold freely, then the burden of decision regarding the defense of the dollar would be shifted even more than now from the U.S.

to the shoulders of European and other central banks." The words and the meaning are clear, but it is difficult to believe that an American bank could have seen fit to publish them.

Shortly afterwards the President of the Bank of America, the largest bank in the U.S.A., said the following: "In the event a cumulative gold drain becomes intolerable, we will have no choice but to react with more massive retaliatory measures. These measures, which will inevitably include the abandonment of our gold selling policy, it must be made clear, are the efforts of last resort, to be taken only when it is abundantly evident that other major countries are not prepared to function under the only feasible international monetary system--that is to say, the dollar standard."

The discussion in America about these two astounding declarations took the form of conjecturing whether they presaged a change in the American gold policy. It was even suggested that the American Treasury inspired these declarations to serve as a trial balloon to gauge public reaction to a possible change in the gold policy. Naturally, the Treasury denied this.

To me, the most remarkable aspect of the matter is that two obvious conclusions arising from the suggestion that America must refuse to sell gold were overlooked by all but a few commentators. These were the following:

(1) That the greatest capitalistic country and withal in the world is asked to declare that it will, under certain circumstances, repudiate its debts.

(2) That it is proposed that the dollar should become inconvertible.

Bankers never favour repudiation of debts by people who are able to pay. Making the dollar inconvertible is simply an acknowledgment that the authoritarian monetary system has totally failed. The words quoted have, however, been employed by the bankers not casually but in considered printed declarations. That any banker can say that it is a privilege to have one's debts paid, leaves me speechless. The only alternative to an authoritarian monetary system is a system of money of real value, that is, gold.

This incident, which shows the disarray in the ranks of the defenders of the authoritarian monetary system, has inspired in me much confidence in the future of gold as the only sound money.

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GROUND-WATER STUDY OF BAKER VALLEY PUBLISHED

"Ground water of Baker Valley, Baker County, Oregon," by D. J. Lystrom, W. L. Nees, and E. R. Hampton, has been issued as Hydrologic Investigations Atlas HA-242 by the U.S. Geological Survey. The atlas consists of one sheet measuring 27 by 45 inches, folded in an envelope. The information on it includes: 1) a generalized geologic map showing gravel distribution and altitude of ground water; 2) a second map showing degrees of salinity of the ground water and other pertinent data; and 3) a text describing the ground-water resources and their suitability for irrigation. Atlas HA-242 is for sale by the U.S. Geological Survey, Denver Center, Denver, Colo. 80225. Price is 75 cents.

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STATE FAIR INVITES ROCKHOUND DISPLAYS

For the first time in its history, the Oregon State Fair is establishing a display hall for exhibits from gem and mineral societies and individuals. According to an announcement by J. A. "Tony" Nunn, Superintendent of the Crafts, Hobbies, and Mineralogy Department, "This initial year will be devoted exclusively to those of you who bear the worthwhile distinction of 'Rockhound.' It is hoped that by so doing we will bring to the attention of the more than 350 thousand people who annually attend the State Fair, as well as all other Oregon residents, the importance, the satisfaction, and the service to our state that is performed by rockhounds and rockhounding."

The show will be noncompetitive and each entry will be awarded a special blue ribbon for excellence. In addition, demonstrations in cutting, lapping, and faceting are being requested by the State Fair Manager. Twenty-four-hour security will be maintained for the exhibitors and a limited number of display cases will be available.

All exhibits will be received at the Crafts, Hobbies, and Mineralogy Building on the State Fairgrounds on any of the following days: Saturday (August 19) 9 a.m. to 5 p.m.; Sunday (August 20) noon through 5 p.m.; Thursday (August 24) 1 p.m. through 9 p.m.; Friday (August 25) 9 a.m. through 9 p.m. All exhibits must be in place and ready for fair opening at 11 a.m., Saturday (August 26). Exhibits will be released after 9 p.m. on Monday (September 4).

Entry forms may be obtained by writing the Mineralogy Department, Oregon State Fair, Salem, Oregon 97310. A $1.00 handling fee must accompany each entry form submitted.

The Department of Geology and Mineral Industries urges rock hobbyists to display at the fair in order to call attention to the wide interest in rockhounding, and to show more people in our state how diversified and beautiful the Oregon rocks are.

The State Fair for this year runs from August 26 through September 4. Robert L. Stevens is the State Fair Manager.

* * * * *

GRANTS PASS FIELD OFFICE MOVES

The Department's field office in Grants Pass has moved to new quarters on 521 N.E. "E" Street. The move, which was made on July 1, puts the office only a few blocks from its former location on "H" Street, where it had been situated for 17 years. The new quarters provide much-needed space for office and laboratory equipment and for the eventual establishment of a mineral museum. The telephone number is the same --476-2496.

Operating the Grants Pass office are: Len Ramp, Resident Geologist, whose present field work is in the upper Chetco area; Norman Peterson, District Geologist, who is evaluating the geothermal possibilities of south-central Oregon; and Arline Jacques, who has been Secretary and Receptionist at the Grants Pass office for the past 16 years. Working out of the office this summer are Joseph Wise, graduate student at Idaho State University, and Gerald Shearer, student at Portland State College. Both are participating in the Department's geochemical stream-sampling program under Department Geologist Richard Bowen, Portland office.

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The ORE BIN
Vol. 29, No. 8
August 1967

THE SAMS VALLEY METEORITIC SHOWER

By Erwin F. Lange*

One of Oregon's important meteorites is the 15-pound Sams Valley iron found in 1894 by George P. Lindley of Medford. Recent investigations give evidence to the fact that the Sams Valley meteorite was not an individual fall as was commonly reported, but a shower of which five specimens were found. Three individuals can definitely be accounted for. Other specimens may yet be in the possession of residents of the Sams Valley and Medford areas. It is also quite likely that other meteorites will be found in the Sams Valley area.

The 15-pound and largest of the irons was found in the Sams Valley about 10 miles northwest of Medford (see accompanying map). It was discovered lying on rocky soil, but the exact location is not known. At the death of George P. Lindley, the meteorite became the property of his son, Nolo M. Lindley. It then became known to E. W. Liljegran, also a resident of Medford. Young Lindley and Liljegran arranged for the sale of the meteorite in October 1914 to the Foote Mineral Co. of Philadelphia, a firm that was very active in meteorite dealing at that time. The iron was first reported in the scientific literature by W. M. Foote, who mentioned that no other pieces were known to have been found.

Foote's description (Foote, 1915) suggests that the Sams Valley was an old fall, since the specimen was thinly oxidized on its outer surface and was lacking a fresh fusion coating. His published report on the meteorite carried three photographs in natural size -- two of external views and one of the polished and etched surface of a slice.

The mass measured about 6.75 by 4.75 by 3.5 inches. There were no piezoglyphs (thumbprints) or flow lines from atmospheric shaping. The specific gravity was 7.794. Chemical analysis indicated the composition to be: iron, 89.36%; nickel, 9.76%; and cobalt, 0.68%. There were traces of silicon, sulfur, and copper. Widmanstatten figures produced by etching a polished section were those of a medium octahedrite.

The 15-pound mass was sawed into slices by the Foote Mineral Co. and the pieces have become widely distributed, since they were sold to collectors and museums all over the earth. It is probably safe to say that the Sams

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* Professor of General Science, Portland State College.

Valley is Oregon's most widely distributed meteorite. Four large slices and other outer pieces were cut the long way so that each slice would have the greatest possible area. Recently the writer had the opportunity to examine one of these which is in the meteorite collection of the American Museum of Natural History in New York City. According to the museum's accession records, the slice which had been polished and etched was purchased from the Foote Mineral Co. for $585.00. This slice, weighing 2.4 pounds, is one of the largest known existing pieces of the Sams Valley meteorite. A two-pound slice is in the meteorite collection of Harvard University.

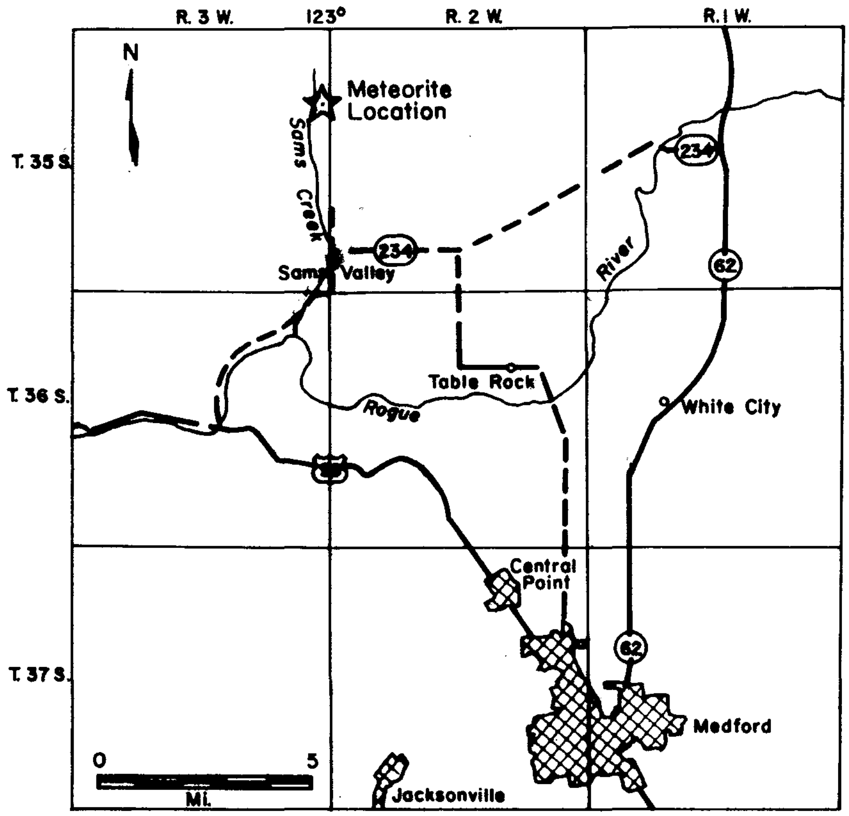
The second specimen in the Sams Valley shower became known in 1938, when J. Hugh Pruett, astronomer at the University of Oregon, attempted to obtain a piece of the iron from the American Museum of Natural History. The museum proposed to give the University of Oregon a pound specimen if the University would stand the cost of cutting it and then of having the cut surface polished and etched. When the specimen arrived, Pruett was much astonished, for he wrote: (Brogan, 1939)

> When the Sams Valley meteorite arrived it proved to be an entire individual and had not been cut from a larger piece. Catalog statements that it fell as one piece were apparently incorrect.

Later Pruett described the difficulty of cutting the very hard metal from space: (Pruett, 1949)

> C. A. Coulter of the Eugene High School faculty was engaged to remove the slab with his motor-driven "diamond" saw. He estimated it would require about one hour, so set his price at $1.50. He and his teen-age son, Donald, started about 10 a.m. on Saturday. Mr. Coulter soon telephoned the writer that the meteorite was so extremely hard that his saw would hardly make a dent in it.
>
> As a last resort the humble hand-driven hack saw was put into use. Then began the back-breaking operation. "From morn to noon" they sawed; "from noon to dewy eve," but the "summer's day" was not yet done for them. At 9 p.m. the final sawdust was extracted and the slab fell off with a thud. With heavy sighs the sawyers admitted they had never before attempted to cut anything so hard. On the work bench lay 18 completely ruined hack-saw blades. But no persuasion would induce the acceptance of more remuneration than called for in the original contract.

While visiting the American Museum, the writer investigated the second Sams Valley meteoritic specimen. According to the museum's accession records, this specimen, weighing about 2.7 pounds, was obtained from E. W. Liljegran of Medford by exchange. A note in the accession book stated that the specimen was found before 1918 about 6 miles from Sams



Index map of Sams Valley area near Medford, Oregon, showing meteorite location on Sams Creek.

Valley. The exact date and location of discovery are unknown. At the present time the American Museum has two pieces, the large slice and the half of the smaller one returned by Pruett. The museum also has two colored plaster casts of the original 15-pound meteorite.

The third specimen of the Sams Valley iron was made known in 1950 by Russell A. Morley, a geologist then living in Salem. During the summer of 1949, Morley and his mother visited the Jacksonville Museum in the hope of obtaining definite information regarding the exact location of the Sams Valley fall (Morley, 1950). While unsuccessful in this objective, they did find a two-pound meteorite in looking through a box of minerals. Morley had a local machinist remove a slice which, when polished and etched, produced Widmanstatten patterns characteristic of a medium octahedrite.

Morley then set out to determine the place of fall in the Sams Valley area. Most of the people he questioned were unfamiliar with any local

Two views of the 15-pound Sams Valley meteorite facsimile which is in the Museum of Natural History at the University of Oregon (photograph courtesy of J. Arnold Shotwell).

meteorites. After a long search, he was fortunate in locating Frank B. Payne, who owned property on Sams Creek (see map). Payne related to Morley how his father, W. M. Payne, had found three meteoritic specimens while panning in a small gulch on the property. The location is believed to be on the north bank of Sams Creek, about 10 feet above the stream in the NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 13, T. 35 S., R. 3 W. One of the specimens was given to a friend named Edward Cooper, whom Morley was unable to locate. The fate of the second specimen is unknown. The third one was the specimen in the Jacksonville Museum. These three meteorites found by the elder Payne in the late 1800's went unreported, because he thought they were of little importance.

Since the evidence is quite clear that the Sams Valley meteorite fell as a shower, it is likely that other specimens may yet be found in the general area. The writer is also hopeful that the other two specimens discovered by W. M. Payne may yet be in the hands of local residents and might be made known so they can be reported in the scientific literature.

Samples of the Sams Valley meteorite are exhibited in two places in Oregon. The Jacksonville Museum has its one piece prominently displayed amid a collection of rocks and minerals. The Museum of Natural History on the campus of the University of Oregon in Eugene has two pieces, the one obtained by Pruett from the American Museum of Natural History, and the other cut off the Jacksonville specimen by Morley. The properties of these two pieces are almost identical, indicating they came from the same fall. The Museum of Natural History at the University of Oregon also has a plaster facsimile of the Sams Valley 15-pound specimen in its meteorite collection. The accompanying photographs show two views of this facsimile at about half its actual size.

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* * * * *

DEPARTMENT DISPLAYS METEORITE SPECIMENS

Meteorites from the Ben Bones' mineral collection and from a collection on loan from Arizona State University are being displayed by the Department in several southern Oregon communities this summer. On exhibit are nine selected specimens that show the most common features of the four main types of meteorites. These include metallic irons, stony irons, chondrites, and achondrites.

Small community stores in broad valley areas have been selected for the first showings of the specimens. It is hoped that, during the short stay of the exhibit, local residents will become acquainted with what meteorites look like and will submit specimens to the Department for identification.

The meteorites have already been shown in the Table Rock store north of Central Point and in the Sams Valley store at Pruitts Junction, in the United States National Bank branch in White City, and at the Josephine County Fair. Between August 26 and September 4 they will be on display in the Crafts and Hobbies Building at the State Fair in Salem.

FIELD WORK BY STATE AND FEDERAL GEOLOGICAL AGENCIES
SUMMER 1967

By R. E. Corcoran*

The summary of field activities described in the following paragraphs illustrates the work that is being done this year by this Department and by the U.S. Geological Survey. Areas where work has recently been completed or is still in progress are outlined on the accompanying map.

Activities of the Department

1. Engineering geology of the northern Willamette Valley

H. G. Schlicker, engineering geologist with the Department, and R. J. Deacon, Portland consulting geologist, completed the first part of this long-range project by publication of a report on the Tualatin Valley (Department Bulletin No. 60) in the spring of 1967. Studies are planned for the Salem area in the future.

2. Geology of the upper Chetco River area, Curry County

Len Ramp, assisted by members of the Department and students from the universities, has been mapping in the Kalmiopsis Wilderness area. The Department is developing a better understanding of the mineral potential of the upper Chetco River drainage and is acquiring more information on the bedrock geology before this large region becomes closed to prospecting and mineral entry.

3. Geochemistry of stream samples, southwestern Oregon

R. G. Bowen, assisted by students from the universities, is completing a geochemical sampling program in southwestern Oregon which began in 1963. More than 7,000 samples of stream and bank sediments collected from the area will be analyzed in the laboratory for copper, zinc, molybdenum, and mercury. Information on analyses made thus far is available in the Portland office.

4. Geothermal investigation of the Klamath Falls area

N. V. Peterson, district geologist, and E. A. Groh, private geologist, spent part of the summer continuing their investigation of the geothermal zone located beneath Klamath Falls. Results of their work will be published in a forthcoming issue of The ORE BIN.

5. Geology of the pre-Tertiary rocks in the Snake River canyon

H. C. Brooks, district geologist, and T. Vallier, professor of geology at Indiana State University, have spent the past summer working in the Snake River gorge north of the Oxbow Dam, and also in the Huntington and Olds Ferry quadrangles to the south. This is the continuation of past work in the Baker quadrangle by Brooks and Vallier and will add to the geologic mapping of H. J. Prostka, formerly with the Department. This work, when completed, will be published in the Department's geologic map series as well as being incorporated in the geologic map of the Baker AMS quadrangle.

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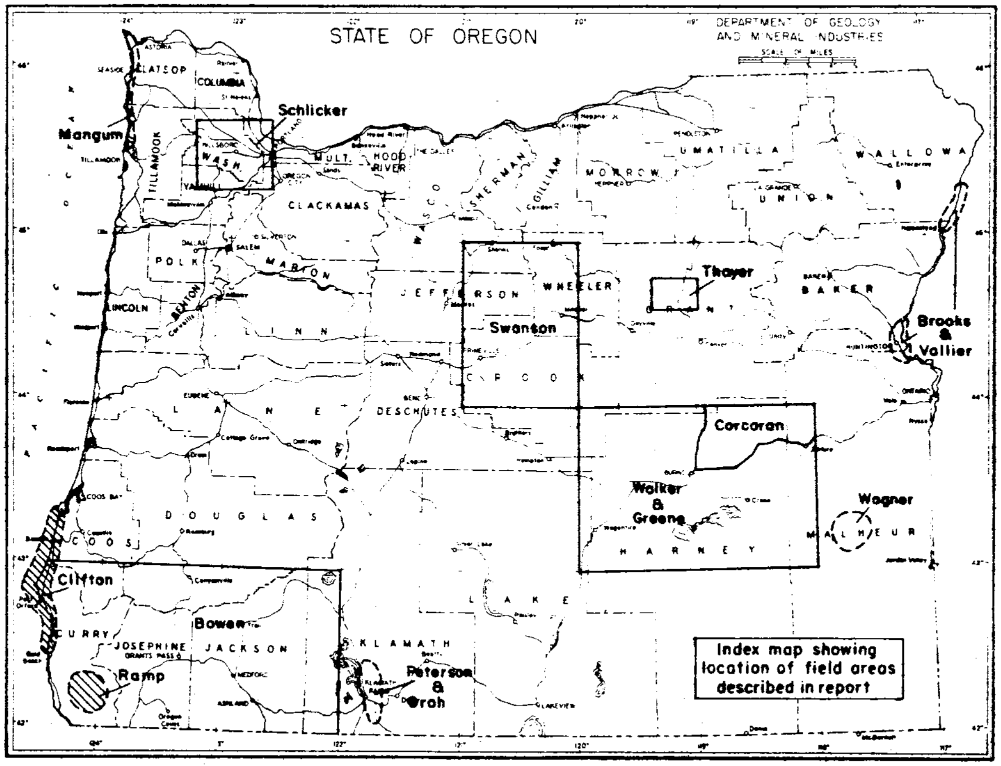
*Stratigrapher, State of Oregon Dept. Geology and Mineral Industries, Portland.



6. Geology of the northeast quarter of the Burns AMS quadrangle

R. E. Corcoran continued field work in the northern part of Harney County for the State Geologic Map project. Mapping was concentrated in the plateau area in the upper reaches of the middle fork of the Malheur River, tracing Miocene and Pliocene volcanics and continental sediments westward from the vicinity of Drewsey and Van guard station. The geology of this area will eventually be integrated with maps by Walker and Greene (U.S. Geological Survey) in the western and southern parts of the quadrangle.

7. Geology of Oregon State Parks

During the summer of 1966, the Department and the State Parks Division shared in an experimental program to produce geologic information of interest to the park visitor on some of the major state parks (see April and May 1967 issues of The ORE BIN). This summer Miss Doris Mangum is field mapping in several state parks between Tillamook and Astoria.

8. Lava tubes in Malheur County

N. S. Wagner visited several large lava tubes in southern Malheur County in company with staff members of the U.S. Bureau of Land Management. The tubes occur in lavas north of Rome on lands under the jurisdiction of the B.L.M., and a geologic inspection was requested in order to determine whether these tubes were safe enough to be opened to the general public. A report summarizing the findings and recommendations will be presented in the near future.

Activities of the U.S. Geological Survey

Probably the most significant new program started during the past year by the U.S. Geological Survey was the Oregon Black Sands Project. The Office of Marine Geology and Hydrology, headed by Parke D. Snavely, will investigate the origin, distribution, and economic potential of black-sand deposits on the continental margin off southern Oregon (see May 1967 ORE BIN).

R. E. Greene and G. W. Walker continued working in the Burns AMS quadrangle for the State Geologic Map project. D. A. Swanson is completing the east half of the Bend AMS quadrangle, T. P. Thayer is finishing the geologic maps of the 15-minute Court Rock and Long Creek quadrangles, and R. C. Coleman has been investigating the Colebrook Schist in southwestern Oregon.

In the spring of 1968 the U.S. Geological Survey, in cooperation with the Department, will publish a report on the mineral resources of Oregon. This report will describe the geology, geologic history, and geomorphic provinces and give a detailed description of more than 60 known occurrences of metallic and non-metallic mineral deposits in the state.

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WISCONSIN STUDENTS STUDY CURRY COUNTY GEOLOGY

This summer the University of Wisconsin established its field-geology camp in Curry County, with headquarters at the Ben Gardner ranch on Pistol River south of Gold Beach. Enrolled in the field session were 20 geology students, including three girls, under the direction of Dr. Robert Dott, Jr., professor of geology at the University of Wisconsin. Also from Wisconsin and working with the students were Dr. Gordon Medaris and Robert Laudon. The study area for the field session included the Cape Sebastian and Pistol River regions.

This part of the state was chosen by Dr. Dott because of its complex geology, which gave the students a real challenge in learning to map structures and formations. In previous years Dr. Dott had small groups of graduate students in Curry County deciphering the geology of the coastal region between Port Orford and the California border. Results of some of their work have been published in The ORE BIN (March, 1961; August, 1961; August, 1962; March 1966; and May 1966).

* * * * *

AUSTIN DUNN DIES

Austin Dunn, native of eastern Oregon, prominent Baker lawyer, and former state senator (1946-1950), died July 15 at the age of 58. He was active in many state and community affairs and was the author of the Dunn Bill that first established community colleges in Oregon. Mr. Dunn served on the Department's governing board from 1953 to 1957.

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GRANT COUNTY GEOLOGY HAS TOURIST APPEAL

Geology is much more than just rocks. For Grant County it is a potential for attracting tourists. As a result of the comprehensive research by Dr. Tom Thayer of the U.S. Geological Survey, geology in Grant County will receive nation-wide publicity through the publication of a leaflet by the Department of Interior, according to the Blue Mountain Eagle.

Thayer conducted a two-day trip August 15 and 16 to show the recreational geological areas to approximately 70 persons, including representatives from federal, state, and local agencies and citizens of Grant County. Arrangements for the two-day tour were made by the Grant County Planning Commission under the direction of C. L. Smith, assisted by Gordon Glass, Phil Hirl, Ralph Denny, and Bill Farrell. On the first day the group traveled along the John Day River to Kimberly and then on to Long Creek and Fox Valley, seeing many geological features on route. On the second day, stops were made at a fault east of John Day and at Hall Hill, Dixie Mountain viewpoint, and Strawberry Lake. The photographs on the opposite page show Tom Thayer (rear center in upper photograph) explaining the geology of the area to members of the tour, and (lower photograph) the glaciated volcano on Strawberry Mountain (photographs courtesy of Blue Mountain Eagle).

KENNECOTT SUBSIDIARY LOCATES COPPER CLAIMS

Kennecott Copper Co. has located, through its wholly-owned subsidiary the Bear Creek Mining Co., a total of 38 mining claims in the Keating area of Baker County. The claims are situated in the well-known "copper belt" which extends for a considerable distance in the northeastern part of the county. The area is dotted with old mines, some of which have produced a considerable quantity of gold. Bear Creek has already commenced exploration work, but details of plans for future activity have not been announced.

The Department made a geochemical examination of a part of the district near the Burkemont mine in 1960. Samples were restricted to the Clover Creek Greenstone of Permo-Triassic age. Geologic mapping has been conducted in the area. The Department published a geologic map of the Sparta quadrangle in 1962, and a similar map of the Durkee quadrangle has just been issued.

* * * * *

IRON ORE MINED IN JACKSON COUNTY

Keldon G. Adams of Medford, Oregon, is selectively mining high-grade iron ore from the Tolman iron property near Gold Hill in Jackson County. Lump magnetite is screened and concentrated by using a belt with magnetic pulley. Adams is shipping 200 tons to the Hanna Nickel Smelter, where it will be used in the smelting process. The quality of the magnetite in this first shipment will be the basis for negotiating a contract for Hanna's future magnetite needs.

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GEOLOGIC MAP OF DURKEE QUADRANGLE PUBLISHED

The Department has published "Preliminary Geologic Map of the Durkee Quadrangle, Oregon" by Harold J. Prostka. The map is designated as GMS-3 and consists of a single sheet, 22 by 26 inches in size, with a multi-colored map, cross section, and explanation on one side and with a text on the other. The publication can be purchased for $1.50 from the Department's offices in Portland, Baker, and Grants Pass.

The Durkee quadrangle lies in Baker County in northeastern Oregon immediately south of the Sparta quadrangle, which was also mapped by Prostka (GMS-1). The Durkee quadrangle is underlain by Permian and Upper Triassic metamorphosed volcanics and sediments and two ages of intrusive rocks. Complex folding and faulting of metamorphosed rocks make age relationships somewhat uncertain. Miocene lavas, Pliocene lake beds, and Pleistocene alluvium occupy fairly large areas in the quadrangle.

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NEW DRILLING PERMIT ISSUED

The Department issued Drilling Permit No. 59 to William G. Craig of Tacoma, Wash., on July 17, 1967. Mr. Craig plans to drill a shallow gas test in Marion County near the site of the Portland Gas & Coke Co. "Wiedehker 1," which was drilled in 1935. Gas shows were reported in the old hole between 490' and 1600'. The William G. Craig "Gilmour 1" is located approximately a mile northeast of the Buena Vista Ferry in the SW$\frac{1}{4}$ sec. 24, T. 9 S., R. 4 W., Marion County. Coordinates are approximately: 3170' N. and 685' E. from the southwest corner sec. 24.

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GROUND-WATER STUDIES PUBLISHED

Two ground-water studies recently issued by the U.S. Geological Survey are: Water Supply Paper 1833, "Geology and water resources in the French Prairie area, northern Willamette Valley, Oregon," and Water Supply Paper 1839-I, "Ground water reconnaissance in the Burnt River valley area, Oregon." Author of both reports is Don Price. The two papers are concerned with the availability of ground water for irrigation and both contain geologic and hydrologic maps. They may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. WSP 1833 on the French Prairie area sells for $1.50; and WSP 1839-I on the Burnt River valley sells for 55 cents.

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L. L. HOAGLAND TO RETIRE

L. L. Hoagland, assayer-chemist for the Department for the past 24 years, retires September 17, and all of his friends both inside and outside the Department wish him the best of years ahead.

Mr. Hoagland, better known as "Hoagy," is a native of Utah. He majored in chemistry at the University of Utah and during his student years he was employed as an assayer at Bardwell Assay Office in Salt Lake City and at Magma Copper Mill of the Utah Copper Co. He became assistant chemist and later chief chemist at the Portland Cement Co. of Utah. In 1928 he moved to California to accept the position of assistant chemist and plant investigator for C&H Sugar Refining Co. Later he worked as assayer for Alabama-California Gold Mines Co.

In 1943 Hoagy moved to Portland to become the Department's first assayer-chemist at its Portland office. During his 24 years in the Department's assay laboratory he has handled 32,000 samples requiring approximately 96,000 determinations. The above photograph shows him performing one step in the fire assay for gold. In addition to making assays, Hoagy claims that he has made more than 5,000 pots of tea on the bunson burner for the staff lunchers.

Retirement for Hoagy is more a matter of shifting his locale than of quitting work -- in his leisure time he will run a small assay laboratory in his basement.

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RAY C. TREASHER, 1908 - 1967
An Appreciation by F. W. Libbey

Mr. Ray C. Treasher died suddenly at Duncans Mills, Cal., on June 25, 1967. He was born in Chicago. The family moved to Sunnyside, Wash., in Ray's early youth. He attended Washington State College at Pullman (now Washington State University) and graduated with B.S. and M.S. degrees, majoring in geology. After graduation, he taught school at Longview, Wash. In 1935 he was appointed Economic Geologist on the staff of the Oregon State Planning Board and, with Dr. E. T. Hodge as co-author, he compiled the "Bibliography of the Geology and Mineral Resources of Oregon," which the Board published in 1936. At this time the U.S. Army Corps of Engineers conducted a survey of non-metallic mineral resources of Oregon, Washington, and Idaho in relation to the market potential for electric power to be generated at Bonneville Dam, and Mr. Treasher was a geologist in the study group.

In 1937 Ray was the first geologist appointed to the staff of the then newly formed State of Oregon Department of Geology and Mineral Industries with head office in Portland, and originated the name "Ore Bin" for the Department's monthly publication, first called "News Letter." He was co-author of the Department's Bulletin No. 6, "Preliminary Report on Some of the Refractory Clays of Western Oregon" with Dr. Hewitt Wilson, professor of ceramic engineering at the University of Washington. This report was in great demand just before and during World War II, when the government was actively investigating high-alumina mineral resources because of anticipated shortage of bauxite. He was the author of the widely used geologic map and text in the report entitled "Geologic History of the Portland Area" (Short Paper No. 7). While he was stationed in Portland, he also authored various other papers on Oregon geology published in The ORE BIN, the Newsletter of the Geological Society of the Oregon Country, Northwest Science, and Geological Society of America Abstracts. He also compiled, in collaboration with members of the Department staff and Dr. Lloyd W. Staples of the University of Oregon, Bulletin No. 16, "Field Identification of Minerals for Oregon Prospectors and Collectors," published in 1940.

Later, as field geologist stationed at Grants Pass, he constructed a geologic map of southwestern Oregon. At this time his field work included studies of the mines of this area, together with the accompanying file reports generally incorporated in the Department's "Metal-Mines Handbook."

In December 1943 Ray accepted a position as geologist with the Corps of Engineers at Sacramento. Here he became Assistant Chief of the Geology Section (1945-1950) and received several commendations for various projects. He was project geologist for the Folsom Dam and Reservoir project near Sacramento.

Upon completion of his work at Folsom, and because he was recognized as an outstanding engineering geologist, Ray was offered and accepted the position of Chief Geologist at the San Francisco District (1953).* While he was with the San Francisco District, he almost single-handedly developed and supervised the geologic exploration, design, and construction of numerous civil works projects as well as military installations, most notable of which are the "Coyote Dam" near Ukiah, Calif., and the "Comprehensive Survey Report on San Francisco Bay." Out of these projects came several professional papers, which he authored, that stand today as outstanding contributions to the field of engineering geology.

Ray was never one to sit still very long, nor was he satisfied with a standard eight-hour day. He, among others, recognized the potential importance of the field of engineering geology. In 1957 the Association of Engineering Geologists (formerly the California Association of Engineering Geologists) was formed. It is now a national organization encompassing more than 1,000 members. His part in this organization was initially as a charter member, later as Chairman of the San Francisco Section, and finally as Honorary Member. He was a long-standing and active member of the Geological Society of America and became a "fellow" in 1957.

Following his retirement in 1961, Ray acted as consultant engineering geologist for various construction companies, primarily in search of structural stone of good quality, in which work he was a noted expert.

Ray was a charter member of the Geological Society of the Oregon Country and its fourth president; a member of the Monte Rio Community Church, and a World War I veteran. His wide acquaintanceship and professional activities made him a host of friends. They surely will miss his fellowship at future professional and social meetings.

He is survived by his wife, Jessie A. Treasher, Duncans Mills, Cal.

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* The material concerning his work in California up to the time of his retirement was furnished by his successor, Mr. Ronald H. Gelnett, Chief Geologist, Corps of Engineers, San Francisco District.

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STATE OF OREGON NUGGET ON DISPLAY

Proof that large gold nuggets are still found in Oregon can be seen in the Department's museum display case at its Portland office. A flattened nugget resembling the shape of the State and weighing 1-1/3 ounces was found by Wes Pieren of Grants Pass while he was mining the Leipold placer on Galice Creek in Josephine County this spring. The specimen is on loan to the Department for an indefinite length of time.

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Pacific Northwest Metals & Minerals Conference

Portland, Oregon-April 19,20,21 1967

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Contents

The ORE BIN
Vol. 29, No. 9
September 1967

Palynology and its Paleoecological Application in the Coos Bay Area, Oregon

By William S. Hopkins, Jr.*

Introduction

In recent years the study of fossil plant spores and pollen has become a rapidly growing field of endeavor. From mid-Paleozoic to the present time, terrestrial plants have been abundant and diversified, covering most of the land areas of the world. Plants produce enormous quantities of spores and pollen and with the coming of each flowering season these are widely dispersed by wind, water, insects, birds, and occasionally mammals. Coupled with the tremendous production of spores and pollen is the fact that most are incredibly resistant to destruction. A hard, cutinous coating aids in their preservation under a variety of depositional environments, and permits them to survive the rather rigorous treatment they undergo during maceration. Furthermore, a wide diversity in morphology including size, shape, and ornamentation makes many of them readily identifiable. These three factors then, abundance, resistance to destruction, and morphologic diversity, make spores and pollen very valuable for studying and reinterpreting the past record of plant life.

Most continental, and many marine, sediments contain fossil pollen and spores, a partial record of the flora extant at the time of deposition. From spores, pollen, and other plant microfossils various data can be derived, such as information on the environment of deposition, suggestions as to plant evolution, genetic relationships, and the age of the enclosing rock. And finally, correlations of time-equivalent sedimentary rocks are frequently possible, depending on the number of microfossils present and their degree of preservation.

Recently I have had the opportunity to examine a number of rock samples from the Coos Bay area of southwest Oregon. The three formations with which I was concerned are the Coaledo (upper Eocene), Bastendorff (upper Eocene-lower Oligocene), and Tunnel Point (middle Oligocene). This paper presents some of the results of this investigation.

Geology

The geology of the Coos Bay area has been described by a number of investigators over a period of many years, so I will not attempt a detailed synthesis here. The two most recent works are by Ehlen (1967) who provides an interesting account of the

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* Palynologist, Pan American Petroleum Corporation, Tulsa, Oklahoma.

geology of the Cape Arago area, and by Baldwin (1966) who revises some of the earlier interpretations. Dott (1966) discusses the Eocene sedimentation in the Coos Bay area in considerable detail. A popular discussion of Oregon geology, including the Coos Bay area, appears in Baldwin (1964). A brief, but readable, geologic history of western Oregon and Washington is given by Snavely and Wagner (1963). Youngquist (1961) briefly discusses the individual Tertiary formations of western Oregon and Washington. The general relationship of the Coos Bay Tertiary rocks to other Tertiary sedimentary rocks of the Pacific Coast is presented in tabular form by Weaver and others (1944). Useful and up-to-date geologic maps are contained in Ehlen (1967) (see page 173 of this report), Baldwin (1966), and Dott (1966). The Geologic Map of Oregon West of the 121st Meridian (1961) shows the regional relationships of the coastal Tertiary rocks in Oregon.

The following paragraphs present only a very brief summary on the stratigraphy of the three formations dealt with in this paper. For the reader wishing a more complete discussion of Coos Bay geology I suggest examination of the above-mentioned publications and the numerous references contained in them.

The Coaledo Formation is 5840 feet thick and subdivided into three members whose approximate thicknesses are, from bottom to top, 1600 feet, 2525 feet, and 1715 feet. The formation is essentially clastic, composed largely of sandstone, siltstone, and minor shale. Some coal is present in both the lower and upper members. According to Baldwin (1966, p. 195) "...the formation was laid down as deltaic shallow-water sediments with swampy margins and interfingering continental beds in which primary sedimentary features such as cross-bedding, scour and fill channeling, and slump structures occurred."

The Bastendorff Formation is a marine shale, conformably overlying the Coaledo Formation. Its thickness is variously given as 1500 feet (Weaver and others, 1944), 2300 feet (Allen and Baldwin, 1944), and 2900 feet (Baldwin, 1966). Schenck (1928, p. 18) states that these sediments were deposited "...in quiet waters where only weak currents and no strong wave action prevailed; it resembles a histogram of silt deposited in harbors." Baldwin (1964) suggests that the "lower third of the type section is late Eocene and the upper two-thirds is early Oligocene."

The Tunnel Point Formation is a tuffaceous sandstone unit approximately 800 feet thick, which conformably overlies the Bastendorff Formation. Invertebrate fossil remains indicate a middle Oligocene age and a marine origin for this unit.

All three formations appear to have been deposited in brackish to marine waters with marine conditions predominating. Evidently the Coos Bay area was close to the strand line during the upper Eocene to middle Oligocene interval.

Palynology

General remarks

The basic principles behind the use of palynology in Tertiary stratigraphic studies are two assumptions: 1) That plants evolve, and 2) that floras migrate in time and space under the influence of environmental change. The evolution of plants affects not only their extreme gross form but also the microscopic reproductive parts.

Briefly speaking, spores and pollen are reproductive units of plants. The spores are produced by the "lower" land and aquatic plants such as fungi, algae, bryophytes, and ferns. They are produced in special organs of the plants and at an appropriate time are disseminated by wind, water, insects, or birds. If they land in a favorable site they will eventually develop into a form of living tissue known as a gametophyte. With further lengthy and complicated development a complete plant will eventually result.

Pollen, on the other hand, are an elaboration of spores and are produced by the "higher" plants, that is, the flowering plants and conifers. They are the male part of a flower, and by wind, water, insect, or bird transport they are carried to the same or different flower, where the female element, the egg, is fertilized. Development of this egg leads eventually to a viable seed. Reference to any good elementary botany textbook will provide more information on the purely biologic aspects of pollen and spores. We are not concerned with that aspect here.

As mentioned in the Introduction, pollen and spores are produced in tremendous quantity, and only a minute percentage ever fulfills nature's purpose of reproduction. Many of the remainder, because of their toughness and resistance, are transported to favorable sedimentary environments where they are incorporated into accumulating sediments. Unless these are later destroyed by some geologic or biologic process, a permanent record of the flora is preserved.

Because the evolution of plants is reflected in the morphology of the pollen and spores, and because during the Tertiary wholesale plant migration occurred, we have a record of these plant changes, a record based on the microscopic parts known as spores and pollen.

Sampling

In general, fine-grained clastic rocks of clay size and carbonaceous sediments, especially coal, are the most productive of plant microfossils (pollen and spores). In most cases, siltstone or sandstone yield no plant microfossils; if they were ever present, physical damage or corrosion has made them unrecognizable. As a general rule, the depositional environment of sand is one of considerable turbulence which almost always results in physical abrasion, destruction, or washing out of any contained microfossils. Furthermore, the higher permeability of sandstone, as contrasted with shale, permits the entrance of atmospheric oxygen into the sands, with the concomitant growth of destructive fungi and bacteria. Although a number of silty and sandy shale samples were prepared for examination, virtually all of the material on which floral conclusions are based was derived from shales and coals.

The collecting of the Coos Bay samples was done during the summer of 1965. The distribution of the palynologically analyzed samples is as follows: two from the Tunnel Point Formation, 35 from the Bastendorff Formation, and 27 from the three members of the Coaledo Formation. All of the samples were taken in stratigraphic succession from beach exposures between Cape Arago and Coos Head. (See map p.173.)

Maceration procedure

The extraction of plant microfossils from a rock and the preparation for examination is a process known as maceration. The basic procedure is standard, although minor variations are introduced to suit specific cases.

Six to 10 grams of sample are crushed so that the maximum particle size is about 3 mm. This crushed sample is placed in dilute hydrochloric acid for as much as 24 hours to remove any carbonate present. Following this treatment the sample is washed using distilled water and centrifuge, then placed in dilute hydrofluoric acid to remove the silicate minerals. This particular operation takes from one to three days. At this stage little remains of the original rock but the contained organic material which includes the spores and pollen.

Usually the plant microfossils are coated with carbonaceous material which must be removed by oxidation. This is done with nitric acid, and the residue of this operation is cleared up by the use of very dilute potassium carbonate. The remaining spores and pollen are then dyed with a chemical stain (usually safranin), and then mounted permanently on glass slides using a clear plastic cement. They are then ready for microscopic examination.

Taxonomy

The identification and classification of the pollen and spores is known as taxonomy. The system which I have used here is the so-called "natural classification," in which the pollen grains are assigned to existing natural plant groups. This procedure is possible only with Upper Cretaceous and Tertiary microfossils, because during this period of time most of the extant plant genera made their first appearance. Throughout the Tertiary the floras of the world were taking on an ever more modern aspect with most, if not all, of the modern genera appearing before the end of the Pliocene. By comparison with both the literature and modern reference material, many Tertiary pollen and spores can be assigned to modern genera.

Fossil species are a more difficult problem and for the most part are created on the basis of minor morphological variations within microfossils of the established genus. These may or may not represent true species in the botanical sense, and in most cases probably do not. Some palynologists have assigned modern specific names to microfossils as old as the Miocene (for example, Macko, 1957, 1959), but for several reasons this is a dubious procedure. In the first place, it seems unlikely that a species would survive for 25 or more millions of years without change, especially during the Tertiary with its world-wide climatic changes and constant tectonic instability. In the second place, pollen grains are seldom so perfectly preserved that they can be compared in every respect with modern material. In late Pliocene or Pleistocene rocks, assignment of modern specific names is often possible and desirable, but in rocks older than Pliocene this is not valid. For rocks older than Upper Cretaceous, identification of spores or pollen is tenuous, assignment to modern genera is usually not possible, and the usage of some "artificial" system becomes mandatory.

For grains which cannot be assigned to modern extant genera I have used the form generic names which have been assigned by various other investigators. In this paper I restrict myself to natural generic names only, because for a discussion of ecology the artificial specific name has little value.

Discussion of results

In the study of these three formations, a total of 77 distinctive pollen and spore types was encountered. In this group are about 34 natural genera which can be used to give us some idea as to the flora present during the late Eocene-middle Oligocene. The remaining plant microfossils are assigned to form genera which are useful to stratigraphic correlation, such as an oil company might do in correlating offshore wells with surface exposures on the mainland. However, form genera are of little value to ecological interpretations unless their botanical relationships are known. In this particular paper I shall discuss only those forms which can be assigned to natural genera.

These are listed on table 1 along with their common names. Most of the identified genera occur in the Bastendorff Formation, a somewhat smaller number in the Coaledo, and the smallest number in the Tunnel Point Formation. This distribution is not surprising considering the lithologies involved and the number of samples taken.

The Tunnel Point is largely a sandstone unit with only a few thin shale zones and did not provide the distinct microfloral variation of the Bastendorff and Coaledo. Generally speaking, however, I believe it probable that the total flora was similar throughout all three formations, but because of geologic conditions during Tunnel Point time the preservation here was not good. All the evidence to date, both floral and faunal as well as geologic, indicates that the Tertiary generally was a period of cooling, with occasional temporary reversals but with the world-wide climate becoming colder. However, the interval of time between late Eocene and middle Oligocene was too short, and the cooling not sufficient, to make major changes in the local floral picture. By the Miocene, changes are reflected in the fossil pollen and spores indicating major climatic changes, but this is not evidenced in the much shorter interval of time with which we are concerned here. As a result, I shall discuss the floras of these three formations as a unit and attempt to draw some general conclusions.

Table 1. Natural genera present in Coaledo, Bastendorff, and Tunnel Point Formations

Genus*	Common Name**
Alnus	alder
Betula	birch
Bombacaceae	tropical trees
Carpinus	blue-beech
Carya	hickory
Castanea	chestnut
Cicatricosisporites	fern
Corylus	hazel
Ephedra	gymnosperm
Fagus	beech
Glyptostrobus	cantonwater pine
Ilex	holly
Juniperus	juniper
Liliaceae	lily family
Liquidambar	sweet gum
Lycopodium	club moss
Magnoliaceae	magnolia family
Metasequoia	dawn redwood
Myrica	wax-myrtle, bayberry
Osmunda	fern

* Because of similarity between pollen of various genera, identification is only to family level in several cases.

** In some cases there is no common name, in which case only a general designation is given, for example, "fern."

Table 1. Continued.

Genus	Common Name
Picea	spruce
Pinus	pine
Platycarya	angiosperm, tree
Podocarpus	conifer
Polypodiaceae	fern
Proteaceae	angiosperm, tree
Pterocarya	angiosperm, tree
Quercus	oak
Salix	willow
Sparganium	aquatic herb
Taxodium	swamp cypress
Tilia	basswood
Typha	cattail
Ulmus	elm

Paleoecological Interpretations

General

Ideally, plants are the most sensitive of the terrestrial ecological indicators. Animals can roam and move about if climatic conditions become unfavorable, but plants are rooted to one spot and must tolerate the environment in which they grow. Furthermore, their tolerance of environmental changes is less than that of most animals. Because the most critical stage in a plant's entire growth cycle is at germination, a changing environment will allow survival of the reproductive propagules only if they fall in a favorable site. Because of this, a changing climate can markedly alter the flora in a comparatively few years. As a consequence, analysis of fossil floras should provide data on climatic conditions at the time of growth.

And indeed they do, but several problems loom large. In palynology, as in all paleontology, a generally accepted truism is the old saw, "The present is the key to the past." In paleoecological interpretations one must assume that organisms, whether plant or animal, reacted to a given environment in much the same way as their modern counterparts. In other words, an alder or elm would have had the same ecological requirements in the Miocene as it does today. The difficulty of applying this assumption is that we are not really familiar with the complete ecological requirements and the range of tolerance of most genera and species of plants. This is true with temperate species, and is even more so for tropical and subtropical species. Furthermore, within any given genus the range of variability may be (and usually is) high, with each species requiring slightly different conditions. However, in virtually all studies where plant microfossils are used to interpret paleoecology we are not dealing with a natural species but only with natural genera. Palynologists usually take the total range of variables within a genus, and utilize as many genera as possible to interpret paleoecology. Thus a large microfossil assemblage should give a qualitative estimate of the climatic conditions at the site of deposition while the particular flora was in existence.

The other problem is whether or not a given sample is truly representative of the extant flora at the time of deposition. As pointed out previously, differential preservation is always a factor -- some pollen grains survive bacterial and fungal attack, oxidation hydrolysis, and rock diagenesis more readily than others. Furthermore, pollen and spores are produced in vastly different quantities in different genera. For example, a 10-year-old branch system of beech has been estimated to produce 28 million pollen grains per year, while an equivalent branch system of pine may produce 350 million grains (Faegri and Iverson, 1964). This difference will obviously be reflected in the quantities of pollen grains obtained from maceration of rock samples used in slide counts.

The method of pollen dispersal also reflects relative quantities. Wind-pollinated species (for example, Pinus) which usually produce pollen in enormous quantities will be abundant in the fossil record, whereas insect-pollinated plants (for example, Acer) produce relatively few pollen grains. As a result, Acer may be underrepresented in a microfossil spectrum and its importance in the assemblage will be underrated. In the case of Acer (maple), a pollen grain which is also easily destroyed, the combination of low relative productivity and comparative fragility may result in its absence entirely from the pollen record.

Factors such as these undoubtedly lead to complications of interpretation and must always be borne in mind when arriving at ecological conclusions. Provided enough samples are collected, both laterally and vertically, in a formation, a fairly satisfactory interpretation of some aspects of ecology should be possible. However, when using samples which are taken only at arbitrarily selected stratigraphic intervals, any conclusions of paleoecology must be regarded as tentative and can be presented only in general qualitative terms. This is what I have done in the following section, with brief interpretations of the over-all floral picture from late Eocene to middle Oligocene. Reference can be made to table 2, where generalized statements are made on both habitat and climatic requirements of the more common genera.

Interpretation

Definite statements about climate 45 million years ago based on 34 modern natural genera require that one tread cautiously. However, as the data in themselves are of no value without interpretation, we shall see where the available information leads.

Reference to table 2, under the climatic column, shows that most of the genera indicated range in climatic requirements from temperate to subtropical and most appear to be warm temperate. Interestingly enough, only one family appears to be exclusively tropical, and that is Bombacaceae. In fact, this family appears almost anomalous in this generic list, and perhaps can be accounted for only by assuming that all of these genera were living at the warm end of the warm temperate category. Bombacaceae is an omnipresent element of Eocene floras in both western Oregon and Washington, and even if not a dominant element of the Eocene flora, it was at least widespread.

Several other genera appear somewhat anomalous in this flora. Ephedra, which is a peculiar little shrub distantly related to the gymnosperms (such as conifers, cycads, ginkgo) is a xerophytic plant which grows in rocky or sandy soil in areas where there is little precipitation. This is not in keeping with the climate indicated by most of the other genera, and so it is possible this is one genus which has changed its ecological requirements through time, and that it has not always been xerophytic. Although never common, it is virtually always present in Eocene-Oligocene floras of the northwestern United States. Also surprising, from an ecological point of view, is the presence of the family Proteaceae, most of whose modern genera are xerophytic. Possibly the same explanation applies here as to Ephedra. The remainder of the microfossils, however, fit together nicely and give us an admittedly incomplete but at least consistent picture of the late Eocene-middle Oligocene flora.

The bulk of the flora from these three formations is composed of genera whose modern counterparts are warm temperate to subtropical. Most of the genera such as Taxodium, Glyptostrobus, Salix, Alnus, Ilex, and Typha are characteristic of a low, moist, and poorly drained coastal area.

The abundance of Taxodium and Glyptostrobus is an indication of large bodies of standing water in a warm temperate to subtropical climate. These two genera fill identical ecological niches, but at the present time Glyptostrobus is restricted to China, whereas Taxodium is found only in the southeastern United States and northeastern Mexico. During the Tertiary, both of these genera were widespread over North America. At present, these genera require 50 to 60 inches of precipitation yearly and a temperature that rarely falls below 32° F. The abundance of Sparganium attests to the apparently rather extensive bodies of standing water. Typha and Ilex, both abundant in warm swampy environments, also inhabited these lowlands.

On slightly higher uplands, behind the low coastal plain, stood a hardwood forest much like that currently present in parts of the eastern United States and eastern Asia. Typical trees in this association were Tilia, Castanea, Ulmus, Carpinus, Myrica, Liquidambar, and Quercus. Such trees have a modern distribution in moderately well drained sites where the annual precipitation is 40 to 60 inches (Chaney, 1940) with both winter and summer rains.

Other plants are present which suggest a more upland habitat. These include Fagus, Pinus, Picea, Podocarpus, Carya, and Corylus. How far these trees were growing from the site of deposition is uncertain, but their low frequency of occurrence would suggest it was some distance away. Pinus, whose pollen is produced in prolific amounts, is a moderately common microfossil in the Coos Bay rocks. However, the bladdered conifer grains are seldom well preserved and are often physically broken and almost inevitably corroded. The implication is that their habitat was a considerable distance away, probably to the east and south, and if Dott's (1966) paleogeographic interpretations are correct, possibly on volcanic islands to the west. Transport to the depositional site was probably largely by streams to the marine waters, followed by gradual settling in the basin of deposition. This long history of transport probably accounts for the poor physical preservation of the pollen grains. Although we do not know the prevailing wind directions during the early Tertiary, they probably ranged from northwest to southwest, as at present. This would substantially reduce the number of pollen grains transported from the highlands to the east and southeast.

Still farther back from the coastal plain were more pronounced uplands, probably mountains, that supported at least some coniferous genera such as Pinus and Picea. Abies has not been found in the Eocene-Oligocene rocks, so presumably any site of growth during this time was well removed from the coast. In modern floras, Abies generally grows at a considerably higher elevation than Picea, so probably no highlands of sufficient height existed to support Abies.

In summary, the Eocene-Oligocene in the area of Coos Bay, Oregon appears to have been warmer and more humid than at present, probably subtropical, but certainly not tropical. Highlands must have surrounded the basin of deposition, but relief was far less than at present. Precipitation was probably 50 to 60 inches annually and was more or less uniformly distributed throughout the year.

Table 2. Range and ecological requirements of modern genera which have been identified from the upper Eocene-middle Oligocene of the Coos Bay area, Oregon.*

Genus (or family)	Habitat and geographic range	Climate
Polypodiaceae	Moist areas, cosmopolitan	Variable
Lycopodium	Most are mesophytic, cosmopolitan	Temperate to tropical
Osmunda	Swamps, shaded moist woodlands, mainly northern hemisphere	Temperate to tropical
Picea	Moist soils, mainly northern hemisphere	Cool temperate, generally high altitude
Pinus	Swamps to rocky highlands, predominantly dry sites, northern hemisphere	Variable
Glyptostrobus	Associated with evergreen oak forest, generally moist to swampy habitats, southeast China	Warm temperate to subtropical, 50-60° precipitation
Metasequoia	Well-drained slopes in damp climates, China	Temperate to warm temperate
Taxodium	Swamps and flood plains of southeastern United States and Mexico	Warm temperate to subtropical, 50-60° precipitation
Podocarpus	Moist woodlands and mountains of the southern hemisphere, Caribbean, and South America	Warm temperate
Ephedra	Xerophytic, rocky, sandy sites; shrub, North and South America, Eurasia	Warm temperate
Magnoliaceae	Trees and shrubs, some climbing, cosmopolitan	Warm temperate to tropical
Liquidambar	Tree, component of oak-hickory forest, northern hemisphere	Warm temperate
Salix	Damp thickets, swamps, cool woods, cosmopolitan	Variable

* Modified after Rouse (1962) and Hills (1965), with additions from Bailey (1949), Lawrence (1951), Graham (1965), Smiley (1966), and Willis (1966).

Table 2, Continued.

Genus (or family)	Habitat and geographic range	Climate
Fagus	Often forms homogeneous forests, northern hemisphere	Temperate
Myrica	Almost cosmopolitan	Cool temperate to warm temperate
Alnus	Swamps, wet woods, stream margins, cosmopolitan	Variable
Betula	Uplands to bog and wooded swamp, northern hemisphere	Cool temperate
Carpinus	Upland woodlands to coastal swamps, northern hemisphere	Cool temperate
Bombacaceae	Mainly western hemisphere	Tropical
Ulmus	Lowlands, river valleys, northern hemisphere	Temperate
Corylus	Thickets, woodlands, northern hemisphere	Temperate
Castanea	Dry woods, thickets, northern hemisphere	Cool to warm temperate
Quercus	Wide range of habitats, northern hemisphere, mountains of tropics	Variable
Carya	Variable habitats, China, Southeast Asia, eastern North America	Cool temperate to subtropical
Platycarya	Japan and northern China	Warm temperate
Pterocarya	Northern hemisphere of Old World	Temperate
Tilia	Low slopes and along streams, northern hemisphere	Temperate
Ilex	Bogs, moist depressions, cosmopolitan	Warm temperate to subtropical
Proteaceae	Mostly xerophytic, restricted to southern hemisphere	Most indicate long annual dry season
Liliaceae	Cosmopolitan	Variable

Table 2, Continued.

Genus (or family)	Habitat and geographic range	Climate
Typha	Marshes, along river banks, cosmopolitan except south of equator in Africa	Temperate to tropical
Sparganium	Aquatic herb, northern hemisphere, Australia, New Zealand	Temperate

This picture of early Tertiary floras and geography, determined independently on the basis of fossil spores and pollen, agrees with Dott's (1966) interpretation of the geologic picture during the late Eocene-early Oligocene. He has concluded (1966, p. 373) that "Eocene sedimentation occurred in an open embayment of the Pacific....Minor volcanic islands existed near the present northern Oregon coast. The embayment lay adjacent to a low, swampy subtropical coastal plain, beyond that lay forested uplands with volcanoes."

Filling of this off-shore embayment apparently took from the late Eocene until the middle Oligocene, with the rocks now exposed locally, and known as the Coaledo, Bastendorff, and Tunnel Point Formations. Many of the plants growing on the coastal lowland are represented by pollen which became incorporated in this offshore fill. The palynological evidence supports the conclusions of Chaney (1948) that this lowland climate was humid and supported a lush subtropical vegetation.

Farther to the east and southeast on the hills comprising what is now known as the Klamath uplands grew the more temperate vegetation including Tilia, Castanea, Ulmus, Carpinus, and Liquidambar, which suggests at most a warm temperate climate. Still farther back, possibly on the slopes of volcanoes, occurred the truly temperate Picea. A modern-day analogy might be on the west side of the island of Luzon in the Philippines, bordering Lingayen Gulf. A sea-level coastal plain supports a thick tropical flora including ferns, palms, and bananas. One-half mile to one mile inland mountains rise abruptly, culminating in peaks up to 6500 feet in elevation. A steady vertical change in flora occurs with various conifers and other cool, temperate forms making an appearance at the higher elevations. Although this area has not been examined palynologically, it is probable that a mixture of cool temperate to tropical pollen grains are accumulating in modern sediments immediately off the Luzon coast. Although the example cited here is somewhat more extreme, I believe a similar situation prevailed in the Coos Bay area during the early Tertiary.

Summary

Palynological evidence supports and adds to the total environmental picture evolving from geologic work and the study of plant microfossils. During upper Eocene-middle Oligocene time the Coos Bay area lay on or near a low, broad, swampy coastal plain in a subtropical climate and was covered with lush and dense vegetation. To the east, highlands supported a warm temperate vegetation not greatly unlike the hardwood forests of the eastern United States. The higher portions of the mountains, well away to the south and east and probably quite distant from the coast, were clothed in still more temperate genera.

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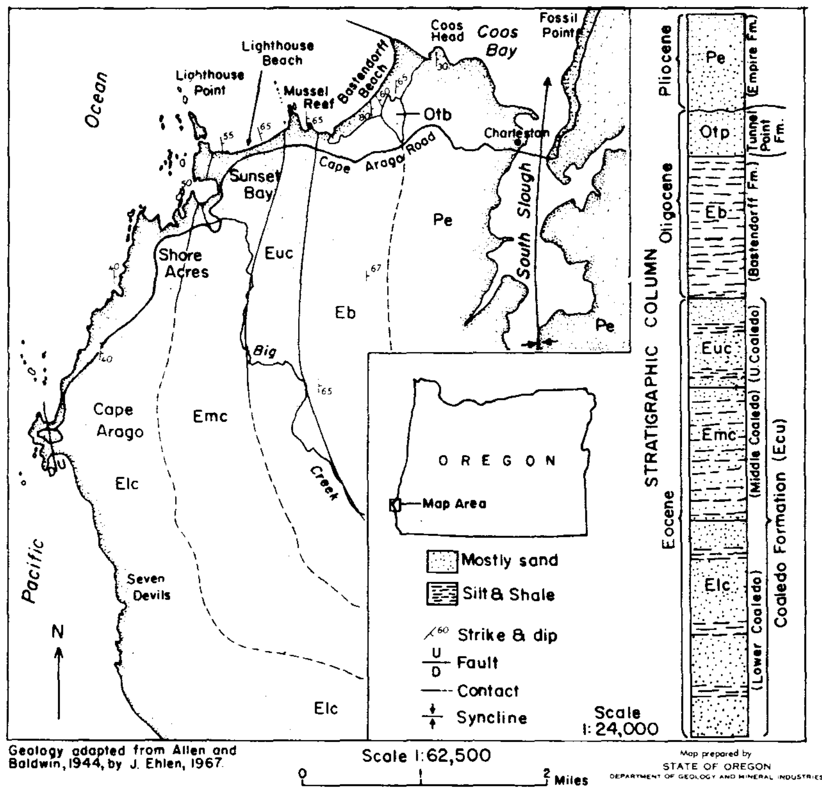

Plates

The following photographs are presented to show some of the ranges in size, variations in shape, and types of ornamentation of some common spore and pollen types found in the rocks of the Coos Bay area.

Plant pollen and spores are microscopic in size and are measured in microns (µ) which are units 0.001 millimeters (mm) in length. Most plant microfossils range in size from 15 to 130 µ or roughly 0.015 to 0.13 mm.

The photographs on the following pages were taken through a Leitz Ortholux Research microscope and printed at varying magnifications of 600 to 1100 times. On the plate explanation are given the generic name, the common name (see footnotes to table 1), and the maximum dimension in microns (µ) of the microfossil.

No attempt has been made to illustrate all the various spores and pollen grains found in these three formations. However, the illustrations include most of the morphological types, regardless of whether or not they can be assigned to modern genera.

PLATE 1

1. *Lycopodium*, club moss, 35 μ

2. *Osmunda*, fern, 40 μ

3. *Cicatricosisporites*, fern, 50 μ

4. Polypodiaceae, fern, 45 μ

5. Polypodiaceae, fern, 56 μ

6. *Laevigatosporites*, fern, 45 μ

7. *Pinus*, pine, 70 μ

8. *Picea*, spruce, 125 μ

PLATE I

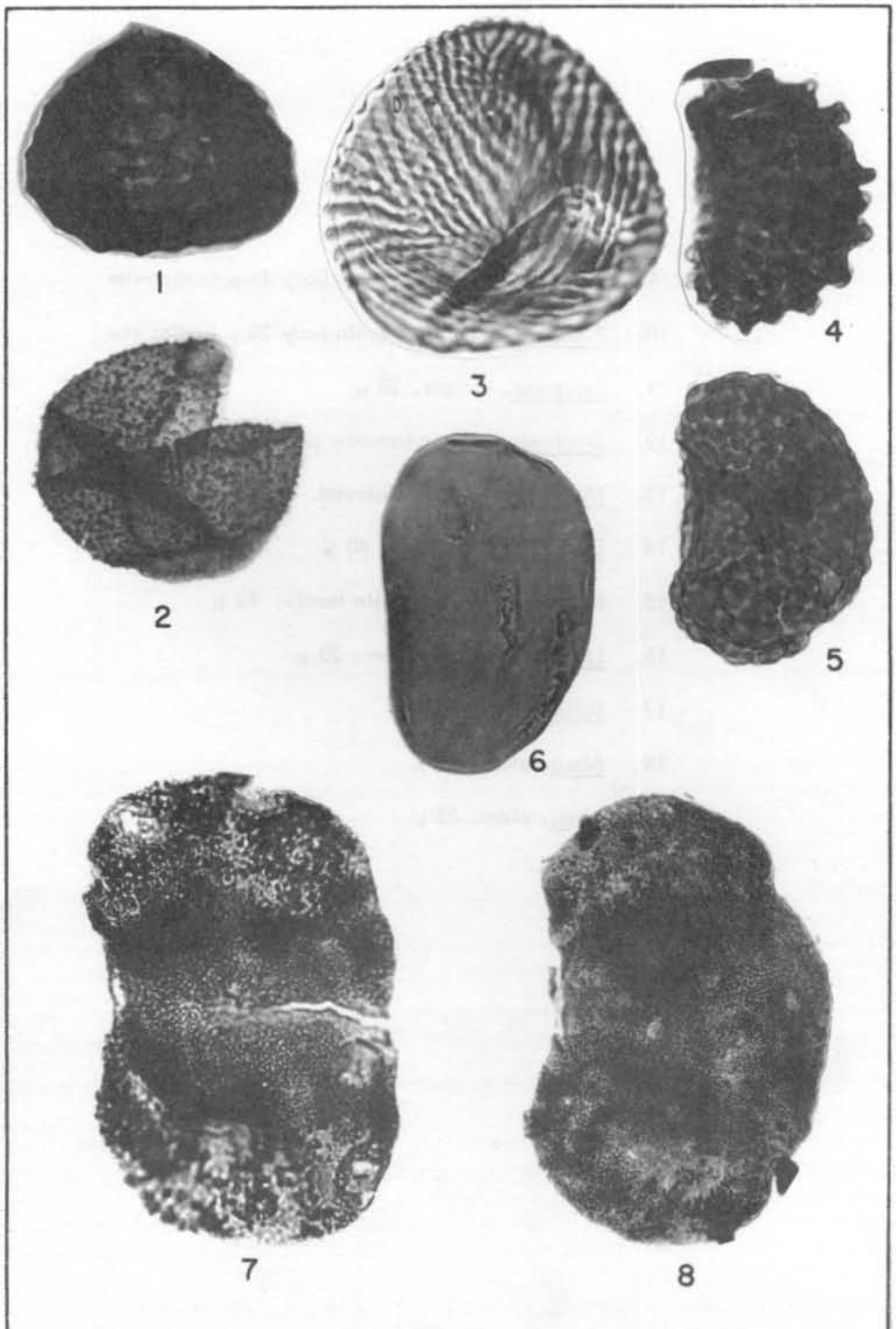

PLATE 2

9. *Podocarpus*, conifer, grain body 25 μ in diameter

10. *Podocarpus*, conifer, grain body 20 μ in diameter

11. *Juniperus*, juniper, 20 μ

12. *Glyptostrobus*, cantonwater pine, 28 μ

13. *Metasequoia*, dawn redwood, 24 μ

14. *Ephedra*, gymnosperm, 40 μ

15. Magnoliaceae, magnolia family, 40 μ

16. *Liquidambar*, sweet gum, 23 μ

17. *Salix*, willow, 34 μ

18. *Alnus*, alder, 19 μ

19. *Alnus*, alder, 23 μ

PLATE 2

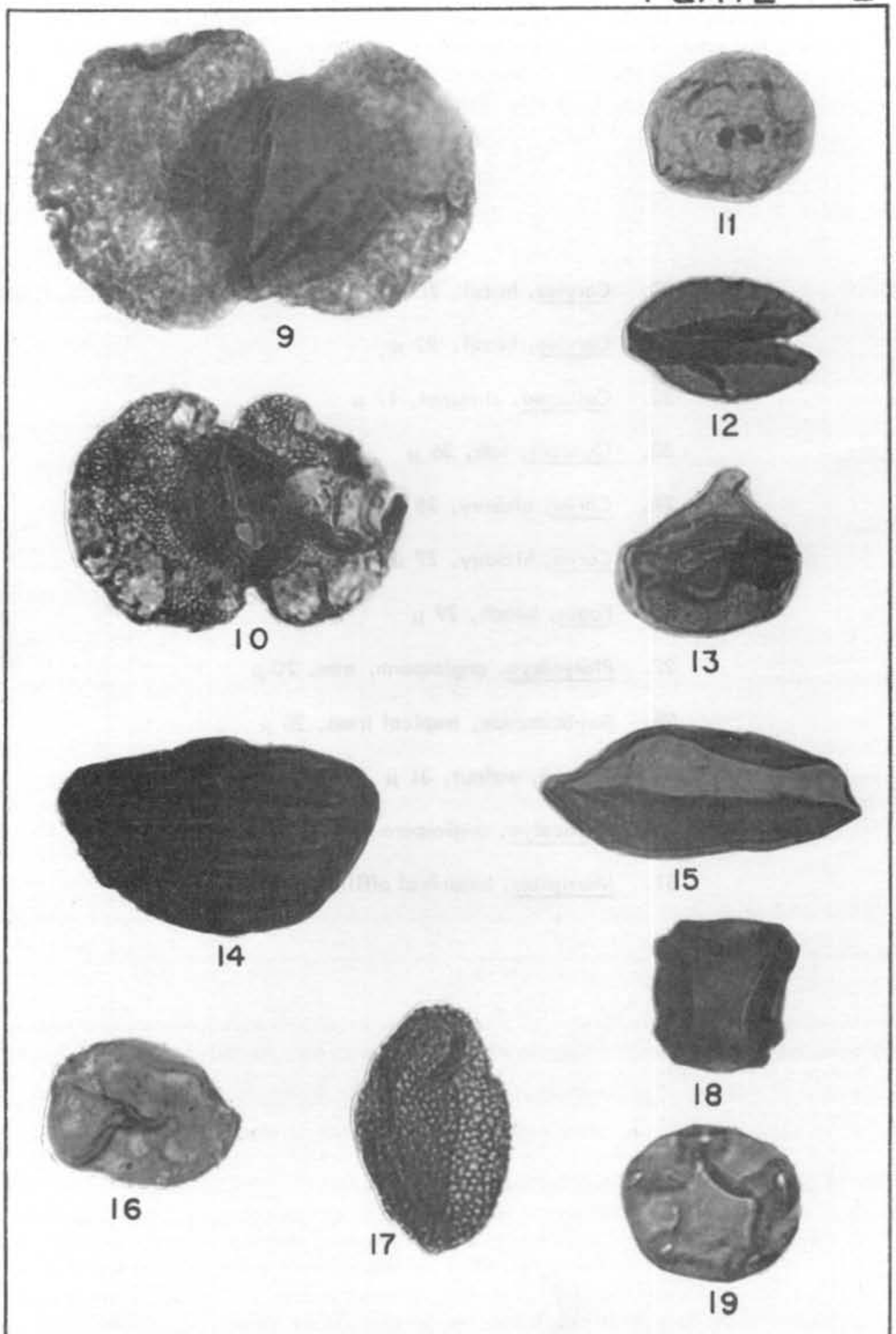

PLATE 3

20. *Corylus*, hazel, 27 μ
21. *Corylus*, hazel, 22 μ
22. *Castanea*, chestnut, 17 μ
23. *Quercus*, oak, 36 μ
24. *Carya*, hickory, 35 μ
25. *Carya*, hickory, 27 μ
26. *Fagus*, beech, 29 μ
27. *Platycarya*, angiosperm, tree, 20 μ
28. Bombacaceae, tropical trees, 28 μ
29. *Juglans*, walnut, 31 μ
30. *Pterocarya*, angiosperm, tree, 27 μ
31. *Momipites*, botanical affiliation unknown, 14 μ

PLATE 3

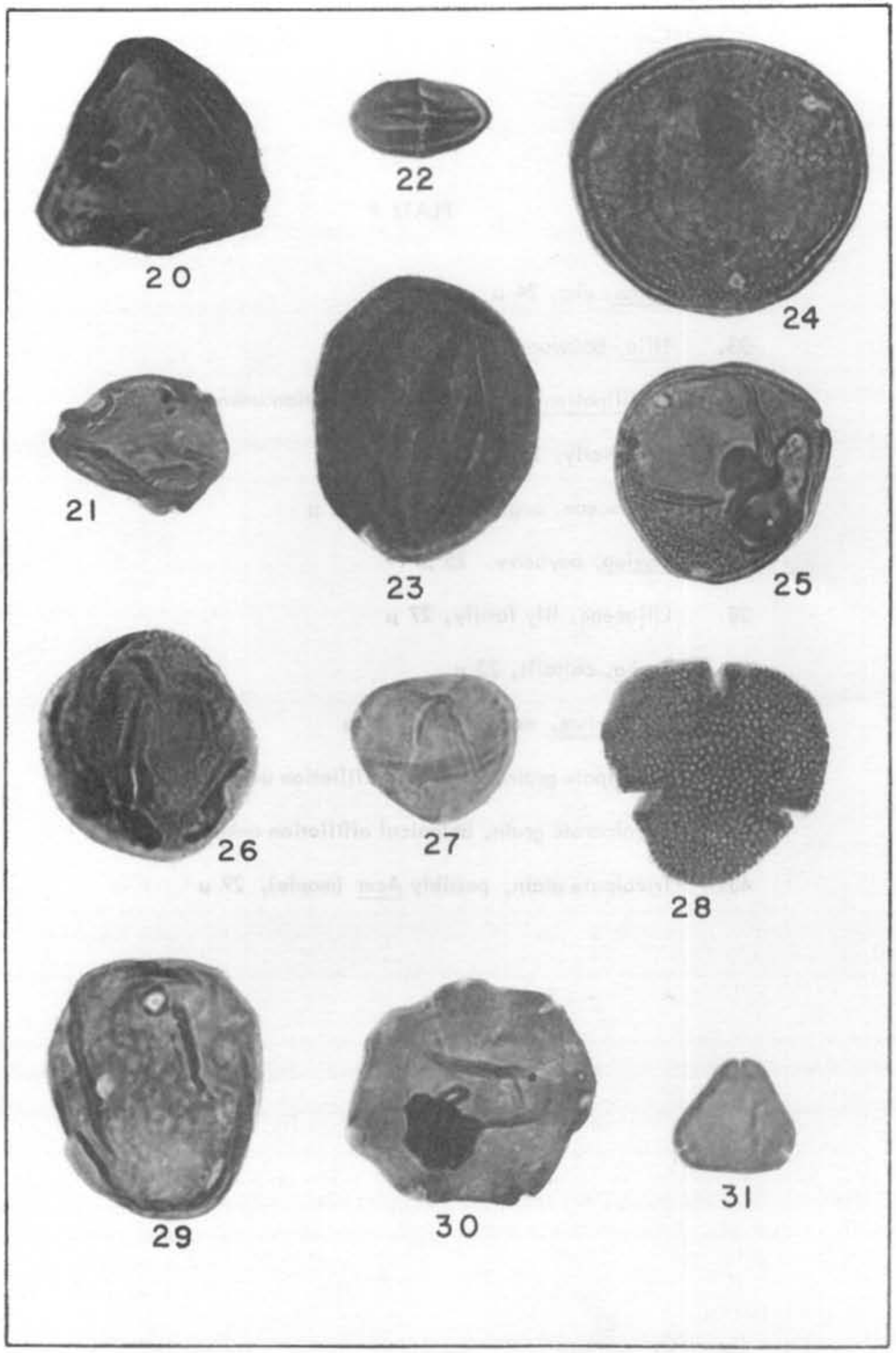

PLATE 4

32. *Ulmus*, elm, 24 μ

33. *Tilia*, basswood, 30 μ

34. *Pistillipollenites*, (botanical affiliation unknown), 22 μ

35. *Ilex*, holly, 24 μ

36. Proteaceae, angiosperm, tree, 22 μ

37. *Myrica*, bayberry, 25 μ

38. Liliaceae, lily family, 27 μ

39. *Typha*, cattails, 23 μ

40. *Sparganium*, aquatic herb, 29 μ

41. Syncolpate grain, botanical affiliation unknown, 27 μ

42. Tricolporate grain, botanical affiliation unknown, 25 μ

43. Tricolpate grain, possibly *Acer* (maple), 29 μ

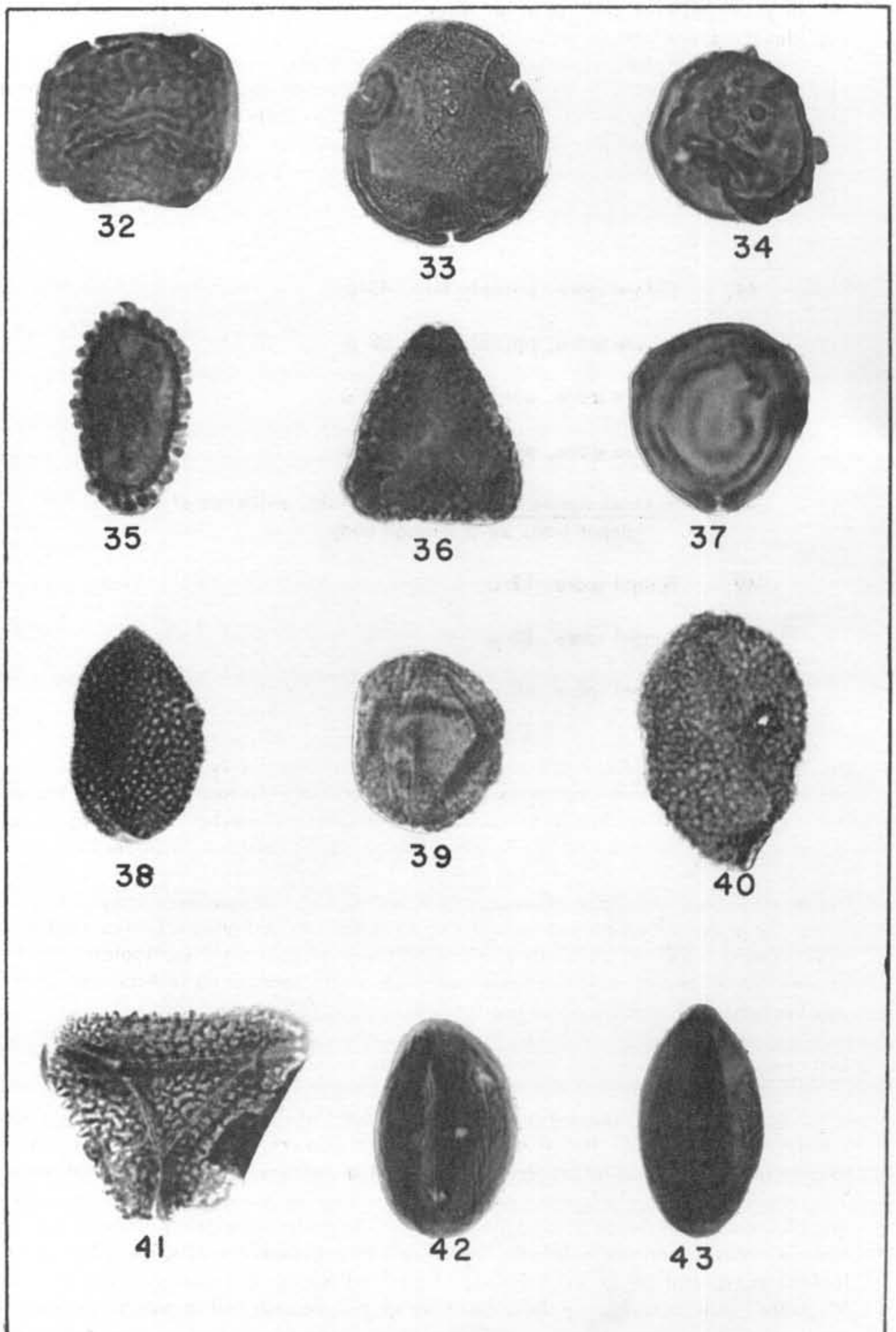
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PLATE 5

44. Trilete spore, possibly fern, 45 μ

45. Trilete spore, possibly fern, 38 μ

46. Trilete spore, possibly fern, 40 μ

47. Trilete spore, possibly fern, 35 μ

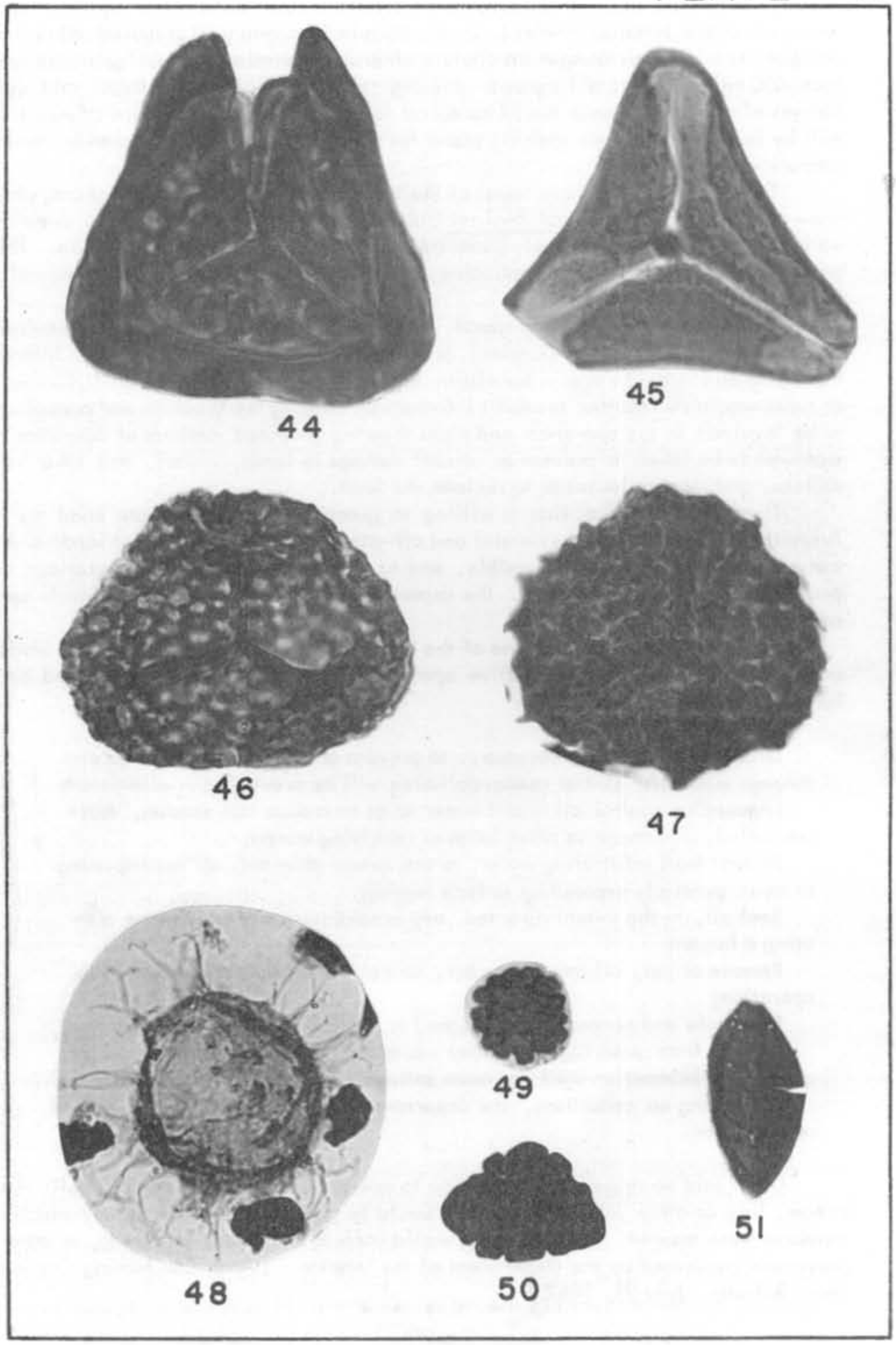
48. *Hystrichosphaeridium*, dinoflagellate, evidence of marine deposition, 22 μ through body

49. Fungal spore, 12 μ

50. Fungal spore, 20 μ

51. Fungal spore, 40 μ

PLATE 5



INTERIOR PROPOSES NEW RECLAMATION REGULATIONS

Secretary of the Interior Stewart L. Udall on July 17 announced proposed regulations designed to minimize damages from future mineral exploration and mining on the more than 500 million acres of land under his department's jurisdiction. Udall said that holders of permits or leases issued hereafter for exploration or extraction of minerals will be required to submit specific plans for restoring areas to be affected by their operations.

Covered under the Department of the Interior's proposed new regulations, which were published in The Federal Register July 20, are leasable minerals and common varieties of sand, stone, gravel, pumicite, cinders, clay, and petrified wood. The proposed regulations are not applicable to disposal of minerals under the general mining laws.

Under the department's proposal, "permission to operate" would be required before any exploration, development, or extraction operations could start on Interior-administered lands. To obtain permission to operate, the holder of a permit, license, or lease would be required to submit information showing the location and area of land to be involved in the operation and plans showing proposed methods of operation, measures to be taken to prevent or correct damage to lands, waters, and other resources, and steps to be taken to reclaim the land.

Unless the person or firm is willing to guarantee by performance bond the financial costs of minimizing on-site and off-site damages to the federal lands and waters for which they are responsible, and to reclaim the site of the operations in accordance with approved plans, the department would not grant permission to operate, Secretary Udall said.

Hereafter, the holder of one of the new permits, licenses, or leases -- while engaged in exploration or extractive operations on federal lands administered by Interior -- would be required to:

> Divert waters, where necessary, to prevent or reduce the flow into and through workings, so that stream pollution will be prevented or alleviated;
>
> Impound or control all runoff water so as to reduce soil erosion, sedimentation, or damage to other lands or receiving waters;
>
> Protect from infiltrating water, to the extent directed, all acid-forming or toxic materials exposed by surface mining;
>
> Seal off, to the extent directed, any breakthroughs of acid water creating a hazard;
>
> Remove or bury all metal, lumber, and other refuse resulting from the operation;
>
> Dismantle and remove all abandoned or useless structures and equipment;
>
> Refrain from removing equipment necessary to accomplish reclamation until such reclamation work has been satisfactorily completed and approved.
>
> Depending on conditions, the department would require backfilling and revegetation.

Udall said no request for permission to operate within 100 feet of a public road, stream, lake or other public installation would be granted unless adequate protective measures were assured. Such measures would include diversion, screening, or other provisions prescribed by the Department of the Interior. [American Mining Congress News Bulletin, July 21, 1967.]

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A IS FOR ALBANY, Z IS FOR ZIRCONIUM

By R. W. deWeese* and R. S. Mason**

Albany, Oregon and zirconium are inextricably linked, at least in the thinking of the metallurgists in the Free World who concern themselves with the space-age metals. It was at Albany in 1945 that Dr. W. J. Kroll started work with the United States Bureau of Mines on a research program to develop a process for producing ductile zirconium. At that time zirconium was practically a laboratory curiosity - and a metal with great promise but with recalcitrant metal-working qualities. Two years later the Kroll process for ductile zirconium was perfected, and a pilot plant capable of turning out 60-pound batches of metal was operating.

Such was the beginning of a development involving many other metals which was to change the economy and character of the city of Albany, and indeed to affect the entire state. The transition from an abandoned small college campus to a nationally recognized center for exotic metals required only 10 years. Starting with an original investment of $140,000 for the old Albany College buildings and ground, the federal government's Albany installation is now valued at $4.5 million.

But the U.S. Bureau of Mines operation is only a part of the metallurgical complex that has developed in Albany. Wah Chang Albany Corp. with 950 employees and Oregon Metallurgical Corp. with 250 employees both located plants in sight of the Bureau's center directly because of the latter's presence there. In addition, two other companies, Northwest Industries and REM, Inc., have located in Albany, directly as a result of the Bureau's activities. Currently metallurgical payrolls exceed $12 million annually, with approximately 1,500 men employed on a year-around basis. The stabilizing effect of this continuous employment on a community that has been traditionally tied to an economic yo-yo, controlled by seasonal agriculture and lumbering, has been tremendous. The metallurgical industry in general and the exotic metals field in particular, as exemplified by the Albany operations, require highly skilled technicians, carefully trained metallurgists

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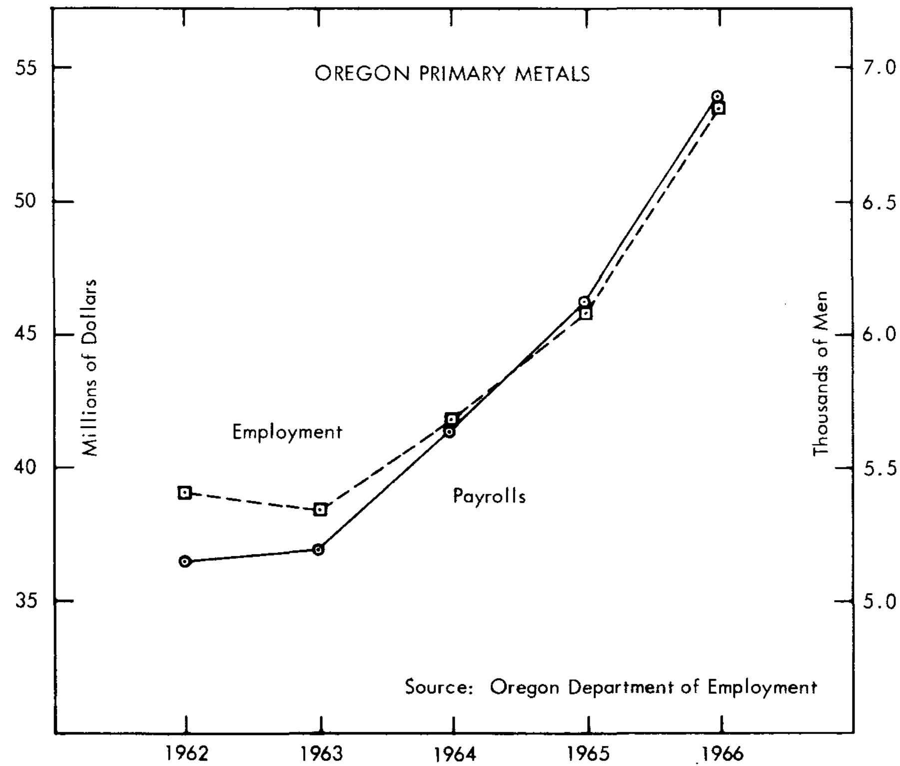
Note: This article is based upon a talk by Mr. deWeese before the House Planning and Development Committee, Salem, Oregon May 2, 1967.

Graph showing payroll and employment trends in Oregon's primary metals industry.



and scientists, and an administrative group able to relate the metallurgical demands of the future to the capabilities of the present. The materials and services required by the Albany complex are substantial, despite the fact that all of the mineral raw materials used originate outside of the state.

Albany is twice fortunate in having the metallurgical complex in its midst. Any industry or, for that matter, any human activity, creates some pollution of either air or water or both. The Albany metallurgical complex very probably produces less air and water pollution per payroll dollar, tax dollar, or value of product dollar than any other type of industry in the state. Space-age metals prices have been decreasing as technologies have improved and volume has increased, but the metals are still bought and sold by the pound rather than by the ton. Every bit of scrap metal is saved and reprocessed, since even it has a value of quite a few dollars per pound.

The question has often been asked: "Why is Albany a metallurgical center?" The answer is simple. The establishment of the U.S. Bureau of

Aerial view of Wah Chang Albany Corporation plant at Albany, Oregon.

Mines Northwest Electrodevelopment Laboratory at Albany provided the opportunity for research into electroprocessing of metals. The U.S. Bureau of Mines is essentially a research organization, and once the new process was perfected at the pilot-plant level it was turned over to industry for commercial production. From a purely logistical standpoint the commercial plants could have been located anywhere in the United States, since the transportation of raw materials plays a very small part in the over-all cost. The decision to build the plant at Albany was made purely on the basis of proximity to the Bureau staff which developed the process and to available trained nontechnical personnel. The decision has proved to be a mutually happy one, not only for the commercial plants but for the Bureau as well. Technical and scientific know-how have been traded freely between the various organizations. The fruits of this scientific cooperation are now being harvested as a formidable list of "new" metals now available to modern technologies. Included in this list are: titanium, columbium, hafnium, molybdenum, tungsten, tantalum, and of course zirconium. In short, the Albany exotic-metals complex exists because of the intimate interchange of ideas rather than because of materials. The Albany complex is a tribute not only to the U.S. Bureau of Mines which provided the opportunity for research, but to Dr. Kroll, who perfected the basic processes - and to the many metallurgists whose close cooperation at all levels has made it possible to develop the various space-age metals rapidly enough to keep this country competitive both industrially and defensively. At times the weather may be a bit damp in Albany, but the scientific climate is wonderful the year around.

The space-age metals that leave Albany are destined for many exotic and special uses. Some are excellent heat-resisting metals; others withstand the corrosive effects of hot acids or ice-cold sea water. Several have special properties which suit them for use in nuclear applications, and some have been found to have peculiar capabilities which permit them to be used in rebuilding parts of the human anatomy without upsetting the chemical balance or degrading tissues. Even the ubiquitous photographer's flash bulb gets its blinding light from finely shredded zirconium metal foil made at Albany.

Man has practiced the art and science of metallurgy since the dawn of the Bronze Age. Early man could refine only the simplest of metals, such as copper and iron. Today's metallurgist produces metals which are not only difficult to refine from their ores but which show an amazing, but annoying, tendency to recombine with other elements before they can be used. To this end many special techniques have had to be developed. Melting in oxygen-free atmospheres overcame some of the problems, but vacuum melting which excludes all gaseous elements is practically a standard procedure in exotic-metals plants today. Some exceedingly high-purity metals must be refined with the aid of electron-beam melting, a process which selectively vaporizes impurities in a high vacuum. It has been found that the

High-temperature Metals	Specific Gravity	Melting Point	Boiling Point
Nickel	8.9	1452°C	2900°C
Cobalt	8.9	1480	2900
Chromium	7.1	1615	2200
Zirconium	6.4	1700	2900
Vanadium	5.8	1715	3400
Titanium	4.5	1800	3000
Columbium	8.4	1950	3300
Hafnium	13.3	2207	3200
Molybdenum	10.2	2620	3700
Tantalum	16.6	2850	4100
Tungsten	19.3	3370	4727
Iron	7.86	1535	3000

presence of even minute amounts of impurities such as oxygen, hydrogen, nitrogen, or carbon seriously affect the workability of many of the space-age metals.

Needless to say, the specifications established for the metals are studded with maximum impurity limits located well to the right of the decimal point. The story is told of a plant which was in danger of having its space-age metal castings rejected because of high boron content. The raw material did not contain boron, nor did the metal during the various stages of refining. Sample drill chips did, however, reveal too much of the offending element. After much checking and searching, it was discovered that a can of nationally advertised powdered hand soap used in the washroom was the source of the contamination.

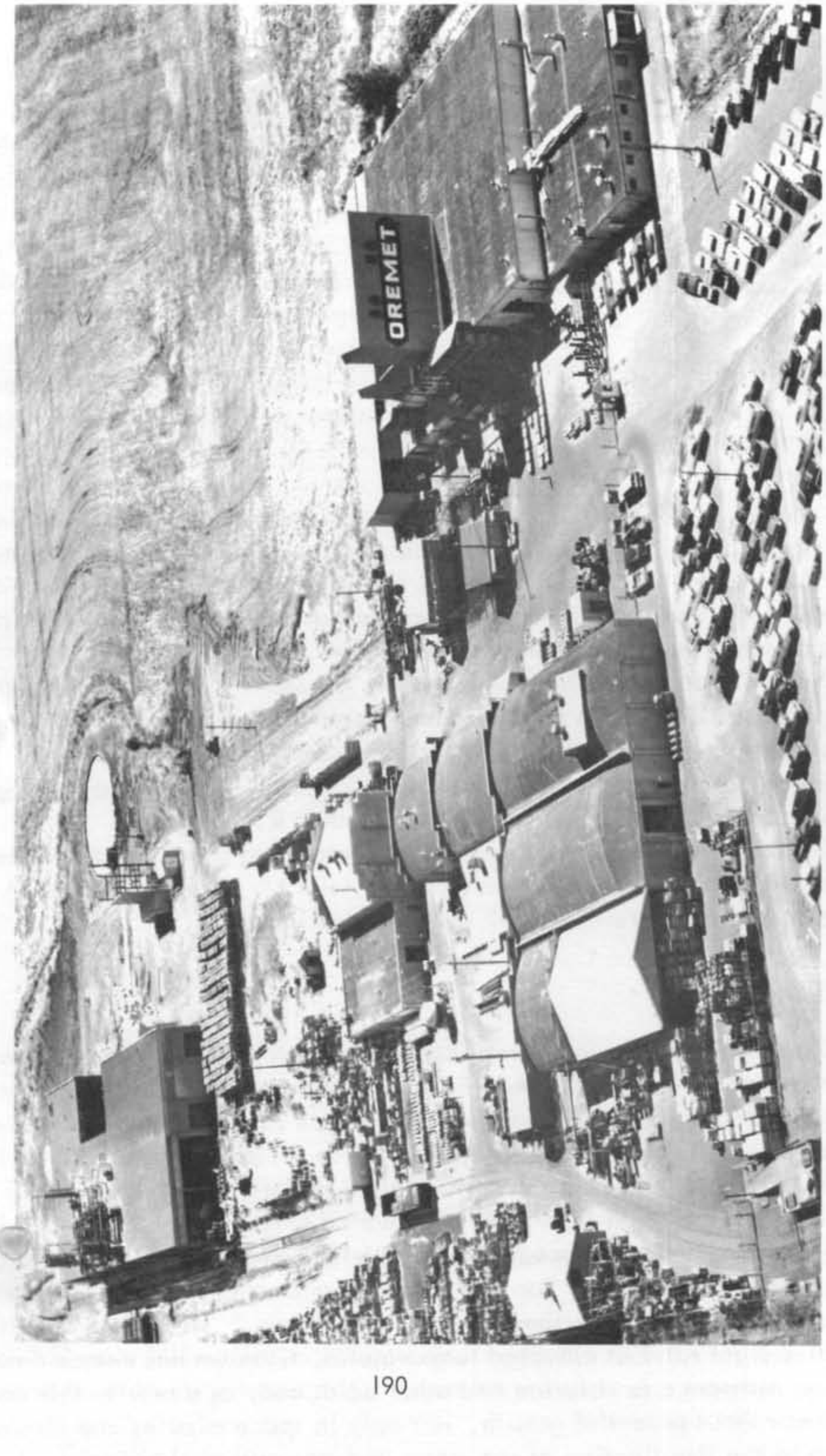
The accompanying table, which gives the specific gravities, melting points, and boiling points for the space-age metals, clearly reveals why some of them are so eagerly sought for high-temperature applications. By comparison, ordinary cast iron has a specific gravity of 7.86, a melting point of 1535°C., and a boiling point of 3,000°C.

Brief descriptions of the space-age metals being processed at Albany are contained in the following paragraphs, together with some notes on the development of the area's metallurgical capabilities.

Titanium

Titanium is an unusual metal. It is the fourth most plentiful element on the surface of the earth, although it occurs in forms in which the extraction is complex and costly. The most common source is a sand bearing the name "rutile," which is chemically titanium dioxide. Titanium and its alloys have approximately 60 percent of the weight of steel, but have unusual properties of higher strength than steel at elevated temperatures. The metal must be melted under vacuum because it reacts with oxygen, nitrogen, and hydrogen in the atmosphere. For that reason it and some of its sister metals such as zirconium are described as "reactive metals." In addition to its high strength-weight ratio at elevated temperatures, titanium has extraordinary corrosion resistance to chlorine and other acids and, as a result, this metal has a tremendous potential growth, not only in space missiles and aircraft, but also in the desalination of sea water and many other chemical processes.

Titanium first became evident on Oregon's scientific horizon in the late



Aerial view of Oregon Metallurgical Corporation plant at Albany, Oregon.

1940's and early 1950's at the Bureau of Mines in Albany. Work that was done there under the direction of Dr. Kroll resulted not only in refinements on what is now known as the Kroll process for the reduction of titanium, but also significant experimental work in zirconium.

The commercial history of titanium in Oregon, however, began late in 1955 and early in 1956 when a group of 13 individuals made the decision to invest approximately one and a half million dollars in what was at best a highly speculative venture. The group possessed the technical knowledge and leadership of Mr. Stephen M. Shelton, who subsequently resigned from the Bureau of Mines to assume the presidency of Oregon Metallurgical Corp., plus approximately 30 technicians who had been working in reactive metals for the previous nine years. In the 11 years from 1956 when the corporation was formed to 1967, Oremet has experienced both great achievements and great disappointments. For 11 years the directors, the officers, and the staff of Oremet have been searching for new methods, new processes, and new products, in order to assure its future growth and to create new opportunities for development.

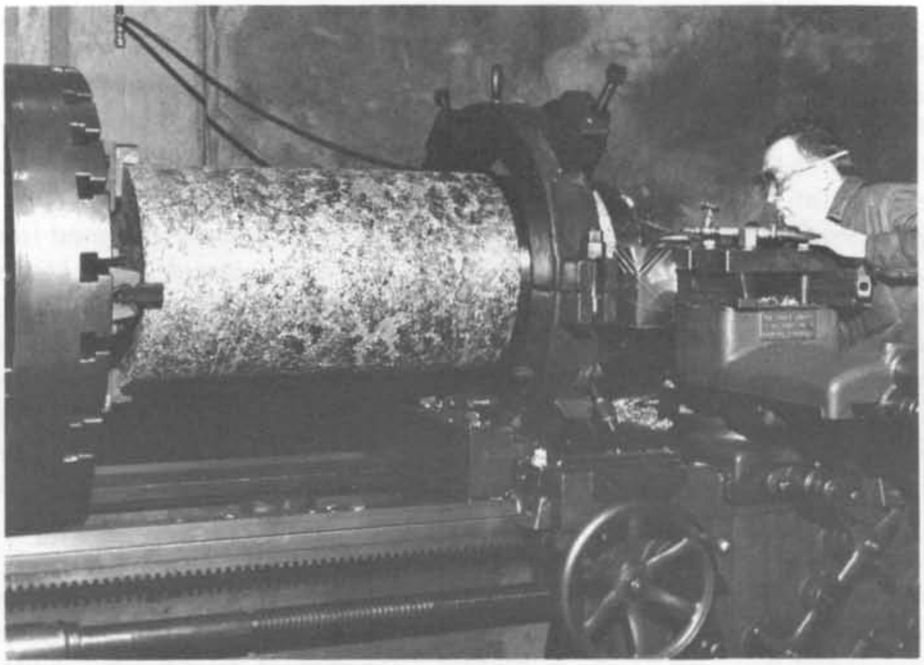
Approximately two years ago, Oremet began the initial experimental work in a new process for producing and refining titanium sponge. The initial secretive work was highly promising and indicated that if it were completely successful it could reduce the cost of producing sponge approximately 25 to 30 percent below the prevailing estimated cost of other titanium-sponge producers in the United States.

The major producers then and today in the United States and in the world are the Titanium Metals Corp. of America in Henderson, Nev., and Reactive Metals Corp. of Niles, Ohio. These two companies were the sole producers of titanium sponge in this country until Oremet undertook its present expansion.

The new Oremet process was developed behind "closed doors," patents were applied for, and pilot-plant production was authorized. In January 1966 the first furnace went on stream, and by June the new processes were achieving the projected results.

Oregon Metallurgical Corp. began producing titanium sponge early this year. The sponge is the raw material from which titanium-mill products such as sheet, plate, bar, and wire are made. Production is at the rate of approximately 300,000 pounds per month, or 3,600,000 pounds per year. The estimated total national production of titanium in 1966 was 30,000,000 pounds, and it is therefore evident that in the first stage of current development the plant will have approximately 10 percent of the nation's capacity for this critical metal.

Interest in the new process was apparent among several large American corporations, all eager to share in titanium's future. At least five major companies explored the possibility of some form of association, merger, or joint venture as a means of participating in the full exploitation of the Oregon Metallurgical Corp. processes.



Machining zirconium ingot preparatory to shipment from OREMET plant.

Within two years Oregon Metallurgical is expected to be a fully integrated titanium sponge and ingot plant. Rutile, probably shipped from Australia, will be converted to titanium tetrachloride and then to titanium sponge. Projected capacity in sponge will be 12,000,000 pounds per year.

Zirconium

The element zirconium is a reactive metal of the same general physical appearance and properties as titanium. Zircon-rich sands in Florida supply most of the domestic ore production, with Australia providing the bulk of foreign ore. Its unique properties consist of corrosion resistance and nuclear properties often referred to as the "cross sectional area." In a nuclear reactor, neutrons that are released by uranium or any other fissionable fuel are under normal circumstances absorbed or slowed down by the material which surrounds or clads the uranium. Zirconium absorbs a minimum of neutrons, and hence is of primary importance in virtually every nuclear reactor in operation today, because it can be used efficiently as the protective physical envelope for uranium fuel.

This metal first became of importance to Oregon in the early 1950's, when the Bureau of Mines began to scale-up a laboratory process to a practical method of removing minute percentages of the element hafnium from zirconium.

Metallic zirconium normally contains from $1\frac{1}{2}$ percent to 2 percent hafnium. Hafnium is an extraordinarily high absorber of neutrons and would make the zirconium virtually useless in an atomic reactor. In other words, the neutrons that are being released by the uranium fuel would not pass through the hafnium-contaminated zirconium and the speed of the reaction would be decreased. The neutrons would be absorbed by the $1\frac{1}{2}$-percent hafnium dissolved in the zirconium matrix. The Bureau of Mines developed a production-scale process, secret at the time, known as liquid-liquid exchange, which was and is the best-known commercial process of separating zirconium from hafnium.

Most people in Oregon are not aware of it, but in 1954 when the Nautilus submarine program began, the entire output of the Bureau of Mines in Albany was, in effect, commandeered by Captain (now Vice Admiral) Hyman G. Rickover, who as head of the nuclear power division of the Navy Bureau of Ships and head of the Atomic Energy Commission's Naval reactor branch, ramrodded the development of this revolutionary vessel. Planes flew from Washington or from other key parts of the eastern United States to Portland, and the reactor-grade zirconium was conveyed under personal guard to the point of use. On several occasions, Captain Rickover made trips to the Bureau of Mines at Albany in order to assure himself that progress was being made in the production of the then-scarce nuclear-quality zirconium.

In 1955 when the Bureau of Mines facility was being diverted to other purposes, the Wah Chang Albany Corp. took over the equipment and has continued to produce zirconium sponge in a reaction similar to that which is employed for the production of titanium. Wah Change is the largest producer of reactor-grade zirconium today. In addition, zirconium is further processed at Wah Chang on a Sendzimir mill, where this highly reactive metal is rolled into almost tissue-thin coils of metal four or five ten-thousandths of an inch in thickness and subsequently sold to the photographic flashbulb manufacturers.

Other than this one commercial use, it is substantially true that 100 percent of the zirconium produced in Oregon today finds its way into the atomic energy program, either industrial or military.

Columbium and tantalum

Because tantalum and columbium always occur together in nature, it is necessary to separate them completely, with a result that normally a metal producer such as Wah Chang will produce both elements.

Tantalum derives its name from the Greek myth of Tantalus, because it was so tantalizing to extract and reduce to metal. Niobe was the daughter of Tantalus and from this came the designation niobium (columbium). The renaming of columbium is discussed at some length by J. Lawrence Smith in an article which appeared in the American Journal of Science, Third Series, Vol. XIII, No. 77, May 1877.

Wah Chang Albany Corp. is probably the major producer of columbium and tantalum in the United States. Principal ore-producing countries are Nigeria and Brazil; essentially no columbium ore is mined in the United States, although it was first discovered on the East Coast. This metal, called niobium in European scientific circles, is almost entirely employed for atomic shielding and containers of various elements of small nuclear power plants such as the now-discontinued nuclear-powered aircraft project. High-purity columbium is refined in electron-beam furnaces, a very advanced and extremely expensive form of melting equipment. The price structure for columbium in its normal form probably ranges now between $30 and $40 per pound. Columbium in the form of ferro-columbium is also used in the production of stainless steels to stabilize or to improve the corrosion resistance of these alloys under certain conditions, such as welding. Steel pipe or tubing containing small amounts of columbium can be field-welded without preheating.

Tantalum has been used for many years for its resistance to corrosion. This property, coupled with its ductility, has made it extremely popular in the industry. Its electrical properties make it useful in the manufacture of powder and foil capacitors. Wah Chang produces the capacitor powder and foil in addition to ingot, forgings, sheet, rod, and other mill products.

Nickel

Until approximately 10 years ago, the United States, the world's largest user of the element nickel in the production of corrosion and heat-resistant alloys, was entirely dependent upon Canadian or other foreign supplies. Even at the present time, the Hanna Mining Co. and the Hanna Nickel Smelting Co. mine and smelter in Riddle, Oregon, produce the only nickel within our 50 United States. In Douglas County, near the town of Riddle, exists a relatively large deposit of lateritic nickel ore. This ore contains approximately $1\frac{1}{2}$ percent nickel, in a rather complex mixture of other materials. The Hanna Mining Co., using a patented French process, developed a commercial process of refining this ore and producing nickel in the form of ferro-nickel. The commercial alloy produced there is a metallic pig containing from 49 to 53 percent nickel and the balance iron. It is used for the production of many corrosion-resistant alloys that are essential in the chemical, food, space, and aircraft industries. The Hanna organization has a great investment in southern Oregon and its contribution to the mining development of Oregon has been unique. Constant exploration is being undertaken through much of that region in order to expand the known laterite deposits and to extend the life of this important mining operation.

In excess of 90 percent of the nickel used in the United States comes to us from Canada. Other available supplies are New Caledonia and Australia in the South Pacific, with potential developments in Guatemala, and large Finnish deposits near Petsamo on the Arctic Circle. Nickel is being sought throughout the world.

Obviously, these supplies in other nations are in demand by the steel industry of Asia, Russia, and Europe. Without Canadian nickel supplies, the United States production of many critical alloys would come to an almost complete halt.

Other exotic metals

Vanadium: Oregon Metallurgical Corp. is the nation's major producer of high-purity vanadium, which is up-graded from low-purity vanadium by a method of electrorefining. High purity is critically important in the alloying of other metals such as titanium, and a number of experiments are being conducted in order to determine its useful nuclear properties. At the present time, high-purity vanadium sells for about $22 per pound.

Yttrium: Yttrium and gadolinium might be termed "laboratory metals." Yttrium itself is among the group that is catalogued as "rare earths" and is sometimes employed in mixed form in the production of phosphors, which coat most of our newer color-television tubes. Yttrium-hydride, as a metal, has some potentially valuable nuclear properties and experimental work is continuing. There is no way to set a price on this metal, because of the fact that its production is in such minute quantities. To a large extent the same thing is true of the metal, gadolinium, which again may have nuclear properties as yet not clearly defined.

Hafnium: The world supply of hafnium is derived through the separation process in making reactor-grade zirconium, since it always occurs in nature with zirconium. Because hafnium has a very high neutron-absorption factor, it can be used for the control rods or safety mechanisms in an atomic pile. Hafnium is an extremely heavy metal, weighing $2\frac{1}{2}$ times as much as steel. Being a sister metal to zirconium, it results as a coproduct of the zirconium separation. There are an increasing number of uses for this very interesting metal. One important application is as an alloying ingredient with columbium for space-vehicle construction, and another as a highly refractory carbide.

Alloy steels

Even though Oregon does not possess any large deposits of basic raw materials such as iron ore and coal, the state is a significant producer of Fe-Cr-Ni alloys for corrosion, heat, and abrasion. ESCO Corp. in Portland, as an example, is a world leader in the production of nuclear-quality castings for the generation of atomic power. Ninety percent of all these alloys are destined for industrial use, not for military purposes. Precision Castparts, in Milwaukie, Oregon, is acknowledged as an innovator and pacesetter in the manufacture of precision castings used in jet engines, space research, and the manufacture of aircraft.

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WORLD MINERAL PRODUCTION IN 1966 SETS NEW HIGH

World mineral production reached a new high in 1966, according to the U.S. Bureau of Mines. On the basis of a detailed study of 65 mineral products that normally account for a large proportion of the value of all mineral output, the bureau estimated that production of 37 of the 65 commodities reached new peaks in 1966; 7 showed gains in 1966 over 1965 but failed to reach or exceed former highs; 2 remained the same; and 19 recorded decreases.

The bureau's appraisal showed that aluminum production in the world was 8.3 percent above its former record of 1965. Production of bauxite increased 5 percent. Copper also reached a new world peak in 1966; mine output was 4.8 percent larger than in 1965. Production of lead, zinc, and tin rose 6, 5, and 4 percent respectively over 1965.

World production of steel ingots and castings in 1966 was 3.4 percent higher than 1965. A record tonnage of pig iron was required to meet the 1966 demand for steel.

Of the precious metals, gold rose to a new high, more than 0.86 percent above 1965. Silver production declined 0.43 percent in 1966 compared with 1965. Output of platinum-group metals also declined 0.67 percent.

Coal continues as a principal source of power. Its proportional share of total energy requirements, however, continued the declining trend which has generally prevailed since the middle of this century. The production of coal increased 1.6 percent over 1965, while petroleum rose 9 percent.

Fourteen of the 23 nonmetallic minerals included in the Bureau of Mines tabulation rose to new production highs in 1966. The 14 minerals were asbestos, barite, hydraulic cement, gem diamonds, feldspar, fluorspar, gypsum, phosphate rock, potash, pyrites, salt, sulfur (native), talc, and vermiculite. Notably, world output of hydraulic cement advanced 6.7 percent over 1965. (American Mining Congress News Bulletin, Oct. 10, 1967.)

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MINING POLICY ESTABLISHED

The following resolutions were included in the declaration of policy which was adopted by the American Mining Congress in session at Denver, Colo., September 10, 1967.

Public lands

Our growing population, expanding economy, and modern armament require a constant increase in the supply of metals and minerals, and recent forecasts indicate that the requirements for minerals and mineral fuels will double by 1980. The responsibility of searching out and putting into production the necessary ore bodies will be that of the American mining industry. As the nation's hidden mineral resources cannot be developed and their value to the country determined until after they are discovered, public lands should be kept open wherever possible to mineral exploration and the location of new discoveries.

The Public Land Law Review Commission is demonstrating that it is making a thorough and comprehensive study of the Public Land Laws of the United States, among which are the laws relating to the acquisition of titles to mineral lands. The approach of the Commission's membership has been objective, and we expect its conclusions and recommendations will be in the best interest of the public and the mining industry.

We are confident that this study will recognize the importance of preserving the fundamental principles of the mining laws, which are based upon the right of individuals to search for, discover, develop, and acquire title to the metals and minerals lying within the public domain.

The law of discovery, as intended by the Congress in enacting the mining laws and as interpreted by the decisions of the courts, has encouraged the search for and development of new ore bodies. However, the Office of the Solicitor of the Department of the Interior continues to distort the law of discovery so as to discourage rather than encourage this search. The original concept of discovery should be maintained.

Exploration must, for the most part, be directed to the discovery of nonoutcropping and often deeply buried mineral deposits. Hence, appropriate supplementary legislation, in keeping with the basic concepts and intent of our mining laws, is required to afford reasonable prediscovery protection to one who is in good faith engaged in seeking a discovery of minerals. Such protection is needed to encourage expenditure of the large sums necessary to carry forward mineral exploration.

We recognize that the public lands should be used in as many ways as their resources permit, and we again express our agreement with the principle of multiple use. The public domain should be open to compatible uses even where one use predominates. No area should be closed to exploration for minerals or to mining in the absence of a compelling national interest demonstrated in a public hearing.

We endorse pending legislation which would limit withdrawals of public domain by governmental agencies without prior congressional authorization. The Congress should explicitly and with care spell out the limits within which the administrative agencies are permitted or required to act in administering public lands.

We urge the Department of Agriculture and its Forest Service, the Department of the Interior and its Bureau of Land Management, and all other governmental agencies dealing with the public lands to be consistent with the spirit and letter of statutes when preparing and promulgating regulations. Regulations affecting the public lands should not become effective until the public has been given an opportunity to comment or protest and until after a public hearing, if requested. Regulations should always be administered fairly and uniformly and in a manner which will encourage -- not discourage -- the development of our mineral resources.

The administration of public lands is a proper subject of concern in the states in which such lands are located. Therefore, we believe that the views of such states relating to policy for the utilization of resources within their respective boundaries should be considered.

Land, air, and water use

Mining is vital to the economy and security of the nation; its growth must be encouraged to provide our expanding economy with adequate sources of raw materials. Mining must be recognized as one of the most important uses to which land may be put.

The mining industry realizes that undesirable side effects of mining may occur in some cases and that it is the industry's continuing responsibility to minimize these effects to the extent practicable. Where land reclamation is desirable and feasible, the concerted efforts of our industry are increasingly directed to programs designed to bring about reclamation for such uses as may be appropriate.

The mining industry also supports the need to maintain the quality of our nation's air and water. The industry has made substantial contributions toward such environmental maintenance, and recognizes that even greater efforts will be necessary in the future.

We believe that the following principles should govern efforts to conserve and improve our land, air, and water resources:

1. Programs for environmental maintenance must be approached with the over-all public welfare in mind, including the need for production and jobs, and with the realization that it is not possible to have a technological society without producing wastes which require disposal.
2. Programs and regulations must vary with geographic locations and local needs and desires; the establishment of uniform national standards

would be unrealistic and wasteful.

3. Because of widely varying local conditions, the regulation of air and water quality should be vested in the smallest jurisdiction -- local, state, or regional -- able to accomplish the desired purpose.
4. Air and water quality criteria should accurately reflect scientific knowledge and consensus.
5. Necessary regulations and quality standards should be established only after careful determination and evaluation of the facts, and in the light of control methods that are technically and economically feasible.
6. Provision must be made for appeal and judicial review of all administrative decisions.
7. Much additional coordinated research by industry and government is needed to develop improved techniques and equipment for (a) enhancing environmental quality, and (b) determining the effects of different concentrations of various contaminants in air and water.
8. The economic impact of corrective efforts must be fully recognized by all concerned. Anticipated benefits should be weighed against the direct and indirect costs, which can be great and which must ultimately be borne by the public.
9. To accelerate progress in improving environmental quality, the burden of uneconomic capital expenditures should be eased by appropriate measures, such as additional income tax investment credits, accelerated depreciation deductions, and ad valorem tax exemptions.

The problems involved in maintaining appropriate environmental quality, as well as a strong and viable economy, are such as to require the utmost objectivity and the most delicate balancing of interests. The tendency to deal with these problems on an emotional basis and to exploit them for political purposes presents a constant threat of hasty and ill-conceived regulation. The mining industry can best meet this threat by taking the lead in seeking and implementing sound solutions now.

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LEASE MINING NOT HARMFUL TO UNIQUE TREES

The U.S. Forest Service has applied for the withdrawal of 160 acres in the Malheur National Forest from location under the mining laws to preserve a unique stand of Alaskan cedar. The withdrawal stipulates that there will be no prohibition against the mining of minerals covered by the leasing act (essentially all nonmetallic minerals). The timber stand is located in parts of sections 22 and 23, T. 14 S., R. 28 E., in southeastern Grant County.

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KAHN NAMED DEPARTMENT ASSAYER

William M. Kahn joined the Department staff September 1 of this year as chemist and assayer. He occupies the position formerly held by L. L. Hoagland, who recently retired (see August ORE BIN). Kahn, a native Oregonian, attended grade and high schools in Portland. He graduated from Oregon State University in 1938 with a Bachelor of Science degree in chemistry. Since that time he has been employed as a chemist with American Distilling Co., Pittsburgh Paints, Sherwin Williams (as a technical representative), and Reynolds Metals Co.

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LEASE MINING NOT HARMFUL TO ADMINISTRATIVE SITES

The U.S. Forest Service has applied for the withdrawal of 155 acres in the Rogue River National Forest from location under the mining laws to protect two administrative sites in northeastern Jackson County. The withdrawal stipulates that there will be no restriction against the mining of leasable minerals. The sites are located in sections 15 and 32, T. 33 S., R. 4 E.

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ALMEDA MINE REPORT PUBLISHED

"The Almeda Mine, Josephine County, Oregon" has just been published by the Department as Short Paper 24. The author is Mr. F. W. Libbey, consulting mining engineer and former Director of the Department. The Almeda mine is situated in an extensive mineralized zone known as the Big Yank lode. The prospect was worked sporadically 50 years or more ago. Mr. Libbey reviews the history of underground exploration and mining and presents evidence to show that the property still has potential commercial value in gold, silver, copper, and barite under modern methods of mining. An appendix to the Short Paper contains abstracts of out-of-print reports about the mine and two recent reports prepared expressly for this printing: one on geochemical stream sampling in the area by R.G. Bowen, Department geologist, and the other on the structure and mineralization of the region by M. A. Kays, associate professor of geology at the University of Oregon.

The 53-page booklet contains geologic maps, mine maps, photographs, and assay and drill-core data. It is for sale by the Department at its offices in Portland, Grants Pass, and Baker. The price is $2.00.

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MINING VIEWS PRESENTED*

Observations and Proposals

The Northwest Mining Assn. and the Idaho Mining Assn. welcome this opportunity to join in presenting to this Commission their observations and proposals with respect to the public land laws as they relate to mining.

The Northwest Mining Assn. is regional in scope and maintains offices here in Spokane, Wash. It is said to be the oldest mining association in the country. The Idaho Mining Assn. is confined largely to Idaho interests, with offices in the State Capitol at Boise.

There exists a considerable amount of duplication in the membership of both groups, but between them they represent and speak for virtually all the principal mining interests in Idaho and the Northwest.

The record of previous hearings before this Commission and the files which it has accumulated in its relatively brief existence are doubtless replete with testimony and evidence relative to the complete dependency of our industrial economy -- in fact, our very existence -- upon mineral raw materials. This fact, as well as the projected explosion in mineral requirements within the next generation, has been thoroughly documented in numerous objective studies by Resources for the Future, Inc., the Department of Interior, and other equally reputable groups. We do not believe it would serve any useful purpose to belabor this point.

However, we are persuaded that this presentation of our views and proposals will represent an exercise in futility unless they are made and received within a framework of mutually accepted premises.

These premises are briefly as follows:

1. That the operation and progress of our industrial economy and the security of our nation and way of life are absolutely dependent upon an adequate and assured supply of mineral raw materials.
2. That this utter dependence demands the maintenance of a strong, vigorous and aggressive domestic mining industry as a first line of defense against uncontrollable and unpredictable foreign encroachment or interference with established channels of supply.
3. That the new domestic mineral resources needed to satisfy future requirements and avoid undue dependence on foreign sources cannot and will not be found and developed unless a comprehensive program of mineral exploration is diligently and continuously pursued.
4. That the lands remaining in public ownership, particularly those in the federal public domain in the West, provide the largest and best targets for exploration.
5. That our historic mining law, despite abuses and shortcomings, has served this nation and its people extremely well in developing and sustaining

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* Statement presented to the Public Land Law Review Commission Hearing, Sept. 2, 1967 at Spokane, Wash., by Northwest Mining Assn. and Idaho Mining Assn.

our unsurpassed economic and military might in both war and peace.

If we can agree on these premises, we can proceed with optimism to examine the abuses and shortcomings of existing law and seek to correct them without destroying or seriously handicapping our tried and proven statutory framework of private ownership and free enterprise.

Most of the abuses and deficiencies of our present mining laws derive from the fact that these laws were designed to serve a time and a philosophy far different from that which prevails today. They contemplated mineral locations based on the discovery of surface or near-surface outcroppings, particularly veins or fissures which could be traced and claimed as the basis for extralateral rights. They were based on a government philosophy which encouraged the disposal of a maximum amount of public lands into the hands of private owners who would develop and exploit the resources, mineral and otherwise, for the benefit of both the local and the national economy. And they were designed to serve the needs of areas lacking in public surveys and to protect the claimant against private intervenors or "claim jumpers," rather than to meet the public requirements of multiple use.

Today the prevailing government philosophy is retention of public lands under multiple-use management. We recognize that this change of public policy requires some modification and refinement of existing laws and established practices thereunder. We submit, however, that this can and should be done without doing violence to the basic concepts of statutes which have conclusively demonstrated their value and effectiveness over nearly a century.

Two of the most criticized deficiencies of the present mining laws -- that they permit private acquisition of public lands for uses other than mining and that they hamper and sometimes prevent effective management of surface resources -- have already been corrected through the restrictions on surface use imposed by Public Law 167.

Abandonment of claims: The problem of clearing the public domain of abandoned claims could be just as easily resolved by enactment of a statute stipulating the terms and conditions of "presumptive abandonment" on claims for which no affidavit of assessment work or notice of intent to hold has been filed over a specified period of time.

Location and identification of claims: The difficulty of locating and identifying claims on the ground -- a common complaint of mine operators as well as public land administrators -- could be remedied by statutory enactment requiring the filing of a declaration of interest in existing claims and imposing stricter and uniform federal requirements for staking and recording of new claims, including the attachment of a reasonably accurate map to the location notice or declaration of interest. This map should be tied in to a public survey, or, where corners of the public survey are not available, to some permanent, identifiable landmarks. We believe the only recording necessary to validate the claim, either old or new, should be in the county where the claim is located and where title searches are normally made. However, if it is deemed necessary that Federal Bureau of Land Management have and maintain duplicate records on claim locations, we would not oppose a requirement that the county filing be in duplicate, the copy to be sent by the county recorder to the appropriate Federal Land Office.

Discovery shafts: The much-complained-of creation of eyesores and indiscriminate destruction of the surface which often results from the present requirement of establishing discovery on each claim could readily be stopped by abolishing the discovery shaft requirement.

Such relatively minor changes would take care of most of the administrative problems which impede multiple-use management. However, they do not resolve the mining industry's problems under the federal policy of retaining federal lands.

One of the major shortcomings of the multiple-use concept is that its vertical dimension covering subsurface values often receives a low-priority rating or is ignored entirely because the subsurface values, even when present, cannot be seen and cannot be readily evaluated without extensive exploratory probing. As a result, mineral entry is almost invariably barred from all types of special purpose withdrawals and reservations, and these involve many, many millions of acres, much of which has good-to-excellent potential for mineral production now or with the advent of improved technology.

Other considerations: We believe it is time to consider and recognize the separate and independent values of surface and subsurface resources in all withdrawn areas and to provide for exploration and development of the subsurface resources of those areas under reasonable restrictions that will minimize interference with the surface resources.

One of the most pressing needs of the mining industry today is for a statutory procedure for locating and acquiring deep-seated mineral deposits or widely-disseminated low-grade deposits of metalliferous minerals which have no surface manifestation andwhich often require a substantial acreage for economic development. For such situations the requirement of a discovery cut serves no useful purpose and there is no present procedure for holding the ground lawfully until valuable mineral in place has been exposed in each claim.

Much serious study and consideration has been given to a proposal for establishment of a procedure for acquiring "pre-discovery" rights which would entitle the holder to exclusive possession of a specified area for a specified time pending the discovery of mineral justifying a mine-claim location. We believe this proposal has considerable merit, but would like to propose as an alternative the enactment of a statute authorizing the location of mining claims based on mineral potential established by geologic inference, geophysical or geochemical analysis, the physical exposure of mineral at the surface or by diamond drill or any means that may be developed in the future for establishing such potential.

These claims would be 40 acres more or less, conforming to the public land survey where such exists and reasonably thereto where it does not exist. The claims would not carry extralateral rights, and they would be subject to the restrictions on surface use imposed by Public Law 167. They could be held as long as the good-faith assessment work was duly demonstrated and, for reasonable periods or indefinitely in justifiable circumstances -- such as where the claims underly a withdrawn area -- could be protected by paying the equivalent amount of the assessment work requirement to the treasurer of the county in which the claims are located.

A patent on such claims would convey title to only the mineral rights and to as much of the surface and surface resources as needed for the extraction and beneficiation of the mineral deposit. In the case of open-pit mines this would require considerable surface area, but for underground mines the surface acreage would be minimal.

We are satisfied that the owners of existing mining claims have vested interests which cannot be affected by subsequent legislation, including the right to patent under the laws of 1872. However, they should be permitted to validate their claims under any new standard that may be established, if they are willing to accept the limited patent rights also imposed.

These proposals could all be incorporated within the framework of existing mining law, without diluting or destroying the vital incentive of eventual ownership of the fruits of the labor and investment involved. The premises on which these proposals are based demand that our nation's mining industry continue to grow and prosper. It can do so under the multiple-use concept if its vertical dimension is properly recognized.

We have studied these proposals in considerable depth and would like to submit for the record as an integral part of this testimony a supplementary statement which discusses them in greater detail.

Supplement

Observations

1. The basic laws relating to location of mining claims upon public lands have served the country and the industry well for almost 100 years, as is evidenced by the present industrial stature of the country, which has been the result of the development of our domestic mining industry as a source for its raw materials, and which would have been impossible without it. Most of the difficulty with the present statutory pattern arises out of the era in which the laws were enacted. The present location laws contemplate locations based upon discovery of mineral outcrops at the surface, particularly veins, in isolated areas where no adequate public survey exists. At the present time most new mineral locations are being made upon mineral deposits existing at depth, or upon low-grade deposits of a widely dispersed nature, which do not conform to the original concept of the mining laws.

2. Unlike most other industries, which have a substantial degree of flexibility in locating their operations, mining can be conducted only where there are economic concentrations of minerals which can be mined with a profit motive. The extremely small percentage of the lands of the United States encompassed in past and present mining gives some indication of the rarity of such concentrations of minerals. However, vast areas must be explored in detail, in many instances over many years, in order to discover the isolated tracts of land which bear the requisite concentration of minerals. Although most of the most obvious surface exposures of minerals have been subject to exploration effort by the industry, lower grade deposits and deposits which are not observable from the surface have not been explored thoroughly, although these deposits will undoubtedly prove to be the principal source of metals produced in this country in the future. It is essential that sufficient lands be and remain available over long periods of time for mineral exploration and development by private industry if we are to maintain the domestic source of metals and avoid becoming unduly dependent upon imported metals to support our industrial complex. The lands held by the United States government in various capacities represent the principal resource of the mining industry in attempting to maintain a domestic output of metals. It is stated categorically at this point that the mining industry must have access to the maximum amount of public land for exploration, development, and exploitation of mineral deposits which may be discovered, and have such access under conditions of claim or ownership which will attract the vast amounts of risk capital necessary to explore for and produce metalliferous minerals. It should be recognized that long periods of time necessarily elapse between first exploration and initial production. The industry is unalterably opposed to a leasing program for federal lands as a substitute for the present scheme of private rights. We believe that the adoption of any leasing program will result in a drastic reduction in funds available for mineral exploration in this country, and that the eventual result must be a drastic decline in domestic metalliferous production. The effects of this might not be seen for a number of years

because of the "lead time" involved, but the result is inevitable.

3. We believe that if the mining industry accepts the position that it should be entitled to utilize only so much of the public lands as is actually required for its particular purposes, all other users of the public lands should be restricted in a like manner. This includes withdrawals for reservoir purposes, both under the federal power act and otherwise, withdrawals for public highway, withdrawals for recreation purposes, and other surface usages. We believe that it is time to enact a statutory scheme of true "multiple use" with vertical dimensions as well as horizontal dimensions, under Congressional standards, and not leave the administration of the multiple-use policy to determination by federal agencies.

Proposals

Existing mining claims: We are satisfied that under existing mining claims the claimant has vested interests which cannot be affected by subsequent legislation, including the right to go to patent under the laws of 1872. However, a great deal of difficulty has been caused both for the mining industry and for the various federal agencies charged with administration of the public lands because of the inability to determine the physical location of claims which have been filed of record, and because of the necessity for an administrative determination in order to determine the validity of claims for which no proofs of labor have been filed.

A proposal of the Department of the Interior was introduced in the current session of Congress as S. 1651. This proposal related to the filing of a declaration of interest in existing mining claims and provided for filing of maps. We agree that it would be of assistance to all parties to require filing of maps defining the location of existing mining claims, which maps would be required to be filed within four years following enactment of the legislation, and which would be required by statute to be sufficiently accurate and detailed to permit a reasonably experienced person to locate the corners of the claim in place. In addition, we would propose a requirement that reasonable effort be exerted to maintain claim corners in place, adequately identified. In the event that reasonable search has been made by any person for any claim corner without success, at the request of the U.S. Bureau of Land Management the locator would be required to point out the claim corner in question to a representative of the U.S. Bureau of Land Management, or to re-establish and mark any corner which could not be located in place. In the event that any map-filing requirement is imposed and the same requires that the claims be tied to the public land survey, the government will have to bear the responsibility of replacing all survey monuments which have been lost or destroyed in order to permit compliance.

In addition to the foregoing, there should be a conclusive presumption of abandonment imposed unless the filing of the annual affidavit of labor performed is made prior to a date six months following the close of the statutory year in which the work is required to be done. It is believed that this can be done without transgressing upon any vested rights that mining locators possess under the present laws.

Future locations: We believe that the continued practice of location of mining claims by private individuals and corporations will be the only manner in which presently undiscovered mineral deposits in the public domain can be effectively developed, unless as a matter of government policy it is determined that only the very few large mining companies should be permitted to explore for and exploit mineral deposits in the public domain. However, if individuals and the small- and medium-sized mining companies are going to continue as an integral part of the mining industry, a modified claim procedure is the only arrangement which offers the necessary availability of land to permit exploration by the small- and medium-sized operator, and thus assure the maximum exploration effort which is available to the country. We believe that exploration should not be restricted to the handful of companies who would be able to operate under a system of large-scale exploration grants or rights, and that the eventual mineral production of the country will suffer if the public domain is so restricted. As a result of this, we suggest a modified program of mining locations, which has the added benefit of not being a drastic departure from the practice of the last 100 years, and which leaves the industry with some guideposts regarding the administration of its mining rights. We would propose the following:

1. We propose that mining locations be permitted in tracts of 1/16 section, conforming to the public land surveys as nearly as is practicable in surveyed areas, and in unsurveyed areas claims of 40 acres be permitted, laid out in a square configuration with the sides running north-south and east-west. In addition, we propose that there be no extralateral rights with future locations. The claimant would establish his right in the location by establishing corner posts at the approximate location of the corners of the claim, and filing a claim notice of public record, which would describe the legal subdivision claimed, assuming the claim was within surveyed areas. Location would be permitted by filing alone in areas where surface marking is not feasible, such as areas where the surface has been withdrawn. From and after the date of location the claimant would be entitled to remain in possession so long as he complied with the requirements for annual labor, or payment in lieu thereof, which is hereinafter discussed. By compliance with the foregoing requirements the claimant would acquire the exclusive rights to attempt to make discovery of mineral in place in the claim. In the event that it was proposed by any agency of the Federal government that the lands be withdrawn from mineral entry, or that some other disposition be made of the lands inconsistent with the rights of a mining locator, notice would be given to the claimant. At that point, in an appropriate proceeding, the claimant would have the right to show that the indications of mineral potential, and ultimate discovery of mineral in place, were such that "a reasonable, prudent man would be justified in the further expenditure of his labor and means." The showing of mineral potential could be established by geologic inference, geophysical or geochemical surveys, physical exposure at or near the surface, by diamond drill, or by any means that may be developed in the future for establishing such potential. If such showing could be made, the claimant would be entitled to retain his rights in the claim so long as he complied with the annual labor requirement. In the event that such showing could not be made, the proposed withdrawal or other disposition could be made and the claim would be invalidated.

2. A reasonable period should be allowed after the date the enabling legislation becomes effective in which the owner of an existing claim could elect -- by filing a statement in the county of record -- to hold his claim under the provisions of the new legislation, in which case the requirements as to discovery and the type of patent he would receive would be as hereinafter set forth. If no such election were made, he would continue to hold with all his existing rights, including the right to go to patent under the laws of 1872.

3. The annual labor requirement should be retained, with provision for in lieu payments for a reasonable period. However, the types of labor permitted should be only those directed specifically toward exploration, development, or exploitation of the minerals situated in the claim. In lieu of performance of annual labor, the

claimant would be permitted to make payment of $200 per claim. In addition, in the event that expenditures are made in excess of the annual requirement the locator should be allowed to accrue these expenditures against future labor requirements, for as much as five years. In practice the normal exploration program at the present time would call for large expenditures from time to time, but not annually. An annual filing of the proof of labor, with forfeiture in the absence of such filing, would apply.

4. Surface administration of unpatented mining claims would continue to be controlled by the essential portions of P.L. 167 (69 Stat. 368, 30 U.S.C. 612).

5. In lieu of the current procedures for purchase and issuance of patent we propose that patent be issued, without survey if the location was made in surveyed lands, upon a showing that minerals have been discovered in place which would justify "a reasonable, prudent man in the further expenditure of his labor and means." However, the patent would convey to the patentee only the minerals in place and the right to use the surface of the claim for mining or processing operations and uses reasonably incident thereto, with use of the surface being restricted to those uses reasonably required in the opinion of the patentee for mining or processing operations and uses reasonably incident thereto. Patent to the surface of a patented mineral claim might be issued in the manner described in the following paragraph.

6. Provision must be made for entry and location for surface facilities upon any lands for which the surface has not been otherwise appropriated, in conjunction with valid mineral claims, without regard as to whether or not the lands appropriated for surface facilities are mineral in nature. We would submit that one or more locations of 20 acres should be permitted for surface facilities, with use limited to mining or processing operations or uses reasonably incident thereto. The rights to be acquired under this type of location should be permitted to be maintained in a current status by payment of $5 per acre, or $100 per year, as would be permitted for payment in lieu of assessment work upon mineral claims. Patents should be issued to any locator who is the owner of either patented or unpatented mining claims in reasonable proximity to such location, upon application and payment for the appraised value of the surface to be patented.

7. One of the most important elements of our proposal would be that all withdrawals of Federal lands from mineral entry should be reviewed, and the agency or private individual or organization responsible for such withdrawals should be required to file within a reasonable time, possibly four years, a statement of the surface and subsurface rights required for its usage. All lands not claimed in this manner, whether surface or subsurface, would be reopened to mineral entry. All future withdrawals or reservations of Federal lands, whether for recreational purposes, reservoirs, Federal power sites, highway rights-of-way, or any other purposes, would be required to define the usage of lands, both on the surface and subsurface. There is no valid reason why mining cannot be permitted at reasonable depth beneath highways, reservoirs, campgrounds, or other local recreational areas, and other similar surface usages. Under the procedures suggested for location of mining claims, location would be possible without access to the surface, and with "in lieu" payments it would be possible to maintain a claim in good standing without access to the surface. However, a procedure should be established whereby the holder of a valid subsurface mining claim would be permitted to apply for restoration for access or otherwise of so much of the withdrawn surface or subsurface as is necessary or desirable in order to conduct mining operations, upon payment for or relocation of surface improvements, and some agency should be charged with the duty of determining the relative public benefit to

be derived from the conflicting usage, under standards established by Congress. Here it must be recognized that mining can be conducted only where mineral occurs, whereas most uses have optional locations available. In addition to the foregoing, access rights across other surface usages must be permitted in order to reach mining claims. The principal area of contention at the present time is the attitude the U.S. Forest Service has taken in regard to surface access, or even access by helicopter, to mining claims within the established Wilderness Areas. The right to locate mining claims is meaningless unless access is permitted.

8. A new, independent Public Lands Review Board should be established to hear all questions in regard to administration of the public lands which might be in dispute under any law or regulation, and that all such hearings be de novo. This board should be established in some relatively independent department of the government, giving it relative independence from pressures of various public land users. The present procedure of having quasi-judicial proceedings conducted in the very department which is one of the adversary parties is highly unsatisfactory.

General: All payments provided by our proposal should be made to the local County Treasurer in whose county the claim is situated. This would alleviate some of the problem which is present in counties where a large portion of the lands is held in government ownership, and the tax base is limited drastically. The philosophy proposed here is comparable to the revenue-sharing which is a part of the present timber-harvesting program. In addition, this would have the salutary effect of causing local county officials to enforce some of the requirements of the mining laws.

All filing should be done on the county level where land title searches normally take place. If it is desirable for some federal agency to have a complete set of records, duplicate filing could be required, with instructions to the local county officials to forward one copy to the federal agency. Duplication of filing locations is fraught with problems, and little is gained if a search of two sets of public records is required to determine the status or validity of any claim. We have recently had the experience of the U.S. Bureau of Land Management moving all of its essential records relating to federal lands in the state clear out of the State of Washington, and we must have a local set of records which are adequate to reflect the status of mining locations.

The lands included within any mining location under which the rights of the locator are terminated for any reason should be restored to the public domain and be subject to subsequent location under the mining laws.

Conclusion

The foregoing presents a proposal for consideration of the Commission which we believe sets forth the essential requirements of the mining industry, without maintaining some of the opportunities for abuse that currently exist. However, as an essential part of this proposal excessive use of public lands by other users, and consequent restriction of exploration and development of mineral resources, must be abolished. We want true multiple usage under standards adopted by Congress instead of multiple usage by administrative edict.

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Geothermal Potential of the Klamath Falls Area, Oregon
A Preliminary Study

By Norman V. Peterson* and Edward A. Groh**

The use of the earth's natural heat in the form of steam and hot water for the generation of electrical power, for residence heating, and for other industrial uses is becoming more and more important.

The successful exploitation of natural steam for generating power in Italy, New Zealand, and California is encouraging the search for other potential producing areas.

Oregon's extensive Pliocene, Pleistocene, and Recent volcanism and the faulted structures associated with this volcanic activity indicate an excellent potential for large local concentrations of heat near the surface.

The part played by the Oregon Department of Geology and Mineral Industries in the search for this new energy source is of a preliminary nature. So far, the general areas where favorable geologic provinces occur have been designated (Groh, 1966). As time permits, these areas will be studied to learn the general geologic setting, data on hot springs and water wells will be tabulated, and geothermal gradients will be determined. It is hoped that this preliminary information will encourage private companies to continue with detailed geologic studies and geophysical surveys in areas that show promise and will eventually lead to production of energy from Oregon's geothermal resources.

The first area chosen for study is the Klamath Falls area in southern Klamath County (plate 1), where surface indications appear favorable and where natural hot water has been used for space heating since the early 1900's.

Another slightly smaller geothermal zone on the southwest side of the Klamath Hills 10 miles south of Klamath Falls occurs in a similar geologic environment and is included in this report.

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Geography and History

Klamath Falls, a city of 17,000 population, is near the center of an elongate, northwest-trending structural valley called the Klamath graben. It is a complex structural valley about 50 miles long and 10 miles wide. Upthrown fault blocks, or horsts, bound the valley on both east and west sides. Upper Klamath Lake, Oregon's largest lake, and numerous other smaller lakes, ponds, and swamps occupy the lowest parts of the valley. Unlike the other large graben valleys of the Basin and Range geomorphic province of the western United States, which have internal drainage, Upper Klamath Lake is drained by the Klamath River that flows south and then west through the High Cascades to the Pacific Ocean.

In the early days of Klamath Falls several groups of hot springs and boiling mud pots were present in the flats and low, rolling hills where the city is now built. The Indians were the earliest users of the hot springs and they cooked fish and game and also, because they had great faith in the healing power of the water, bathed and soaked themselves in the overflow pools.

The early settlers used them infrequently for various things, including the scalding of hogs, and by 1915 there was a greenhouse built over one of the hot springs. By 1928 Klamath Falls boasted a modern Hot Springs Natatorium in which the pool water was completely changed daily. At the present time there are more than 350 relatively shallow wells that tap the natural hot water to heat schools, industrial buildings, apartments, and houses.

Geology

The stratigraphy of the Klamath Falls area is not easily deciphered. The abundant and widespread Pliocene and Pleistocene volcanic activity in the High Cascades just to the west and also within the basin, complex faulting, and sedimentation all happening concurrently have resulted in a heterogeneous sequence of volcanic and sedimentary rocks (figure 1). The thickness and composition of rock types varies greatly from place to place, making it very difficult to describe a complete stratigraphic section.

Previous work by Newcomb and Hart (1958, p. 21-22) in a ground-water study of the Klamath River basin describes a sequence of Pliocene and Pleistocene rocks that includes a lower unit composed of basaltic lava flows (0-800') that they called "lower lava rocks," which are overlain by a volcanic-sedimentary unit called the "Yonna Formation" (200' to 1000'), in turn overlain by a thinner unit of basaltic lavas (50' to 200'). Newcomb and Hart further divided the "Yonna Formation" into a lower phase predominantly of diatomite and lake-deposited sediments, and an upper phase of volcanic-sedimentary rocks, mainly brown lapilli tuffs of great lithologic variation. From meager fossil information, the Yonna Formation has been dated as middle Pliocene and the overlying "upper lava rocks"

Figure 1. Volcanic-sedimentary rocks exposed in road cut on U. S. Highway 97 along east shore of Upper Klamath Lake. Layers of cinders and scoria alternate with thin basalt flow units.

Figure 2. Fault-plane slickenside exposed at Rattlesnake Point on the east side of Upper Klamath Lake.

were believed to be Pliocene-Pleistocene.

For the purpose of this paper the rocks are considered to be an almost continuous interfingering depositional sequence, and on the reconnaissance geologic map (plate 1) they are shown as Pliocene-Pleistocene volcanic-sedimentary rocks. Where one rock type predominates in the sequence in a relatively large area, it is so indicated on the geologic map. The basement rocks are unknown but are probably Miocene andesitic and basaltic flows, volcanic breccias, and minor tuffs similar to the volcanic rocks of the Western Cascades described by Callaghan and Buddington (1938) and Peck and others (1964).

Complex faulting, most of which occurred in late Pleistocene time, has broken the whole area into a characteristic pattern of northwest-trending fault-block ridges and intervening down-dropped graben valleys. Tilted fault blocks are numerous within the Klamath graben.

Perhaps nowhere else in the United States is the geologic evidence for recent faulting so well displayed. At no less than nine separate locations the shiny, polished fault surfaces are starkly exposed. All are high-angle normal faults and dip from 55° to 70° into the valleys. One of the most spectacular faults has been exposed along the east side of Upper Klamath Lake (figure 2), where removal of talus has uncovered the fault plane for nearly a third of a mile in length and as much as 250 feet in height. Grooves in the slickensided surfaces indicate that the last and perhaps all of the displacement has been vertical (figure 3). At least 1600 feet of vertical displacement is indicated in the vicinity of Modoc Point, and movements of this order of magnitude can be estimated at other places where the steep fault escarpments are elevated about this much above the valley floors.

The northwest trend of the Klamath graben and its alignment with the Crater Lake caldera to the north and the Medicine Lake volcanic highland in California to the south cannot be ignored; there is almost certainly some association of the Recent climactic eruptions of Mount Mazama (Crater Lake) and the Medicine Lake highlands with the last faulting and adjustment of the crustal rocks of the Klamath graben.

Klamath Falls area

The Klamath Falls geothermal area is near the center of the graben in slightly tilted fault blocks that are elevated a few hundred feet above the valley floor. These tilted blocks are made up of impure diatomite, thin beds of tuffaceous sandstone, clayey tuff, and minor intercalated basalt flows. The tilted blocks have, in turn, been complexly faulted into elongate ridges that generally trend northwest. Because they are so easily eroded, they are now seen as low, rolling hills.

Well logs indicate that the diatomaceous tuffs and layered sediments are at least several hundred feet thick and in most places are impervious to the flow of water and act as a cap at the surface (figure 4). Broken lava

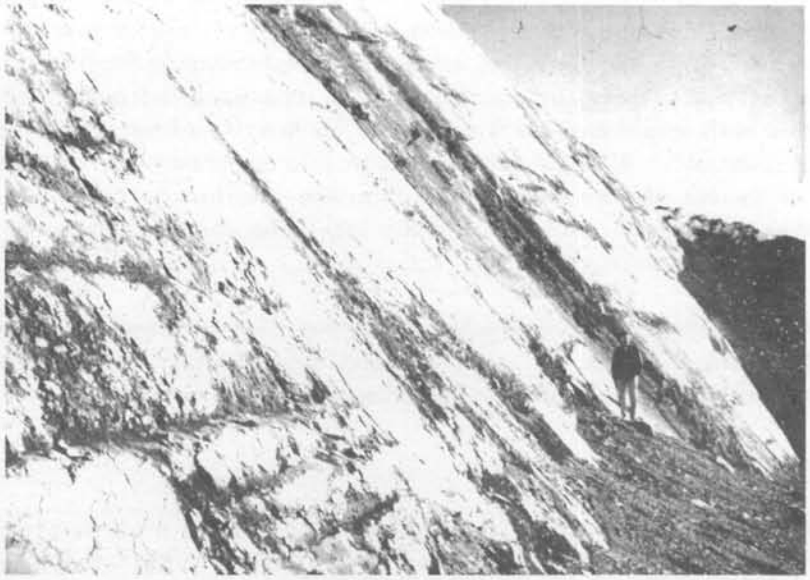


Figure 3. Closer view of slickensided fault plane shown in Figure 2. Striations show vertical movement.

Figure 4. Clayey tuff and impure diatomite are intricately faulted with minor displacement of beds.

flows and zones of scoria and cinders are encountered at various depths and in most cases in the thermal area these horizons yield large quantities of live hot water. At least one strong northwest-trending fault is present on the east side of the geothermal area, and the brecciated rocks associated with this fault could provide the conduit for the rise of hot water from a deeper reservoir. Although the heat source is not known and no surface rocks of Recent age are present, the Pliocene-Pleistocene dikes and sill-like masses that are intercalated in the lacustrine deposits (figure 5) may indicate the presence of a larger intrusive rock mass cooling at not too great a depth.

A long history of hot-spring activity is shown by the presence of bleached silicified rocks (figure 6), deposits of calcite and gypsum, and minor mercury mineralization in a broad halo surrounding the geothermal zone.

Klamath Hills area

Klamath Hills is a large, isolated fault block within the Klamath graben about 10 miles south of Klamath Falls. Large volumes of hot water (200° F.) are found at shallow depths in a narrow zone along the southwest side (figure 7). The geologic environment of this thermal zone is similar to that of the Klamath Falls area and a halo or border of silicified lake sediments and tufa is present. High-angle normal faults with a general northwest trend are common, and again the recency of faulting is shown by slickensided fault surfaces. Basalt flows and associated breccias, scoria, and cinders predominate in the Klamath Hills fault block. Drillers' logs from a few water wells indicate several hundred feet of lake sediments and layered tuffs in the Lower Klamath Lake basin south of Klamath Hills. A large area in the southeastern part of the Klamath Hills is underlain by cinders, scoria, and palagonitic tuff breccias, indicating that here a basaltic magma encountered water or saturated sediments near the surface and violent explosive eruptions resulted.

Present Natural Thermal Displays

The original hot springs in Klamath Falls have disappeared through lowering of the water table and culture changes. Temperature and flow data are not accurately known, but Stearns and others (1935) give a temperature of 185° F. and a flow of about 150 gallons per minute.

Two natural thermal displays still exist within the confines of the map area shown in plate 1. A spring on the north bank east of the irrigation flume crossing the Lost River at Olene Gap has a temperature of 165° F. The flow is estimated to be at least 100 gallons per minute, all of which passes into the Lost River. A slight trace of hydrogen sulfide was detectable. An analysis of this spring water is given in table 2. Another spring is located

Figure 5. Contact of highly fractured, sill-like mass of basalt and diatomite.

Figure 6. Low, rolling hills just south of the Oregon Technical Institute campus, where layered tuffs and diatomite have been silicified by former hot-spring activity.

at Eagle Point on the shore of Upper Klamath Lake. Here a temperature of 94° F. was measured at the bottom of an old cistern. The high level of the lake at that time was causing considerable dilution of the spring water. Some gas, which was not tested but is probably carbon dioxide, bubbles through the water along the shore and a faint odor of hydrogen sulfide is present.

Klamath Falls Geothermal Zone

Extent of the zone

Some 350 wells have been drilled to date, mostly for the space-heating requirements of more than 450 residences, a number of apartments, six schools, several business and commercial firms, and the new Oregon Technical Institute plant (figure 8). Many of the installations provide for the heating of the domestic water also. Most of the wells are concentrated in a zone extending northwesterly from the canal for about 1.5 miles and more than half a mile wide (plate 2a), and in this area practically all are for residential use. As new building progresses northward, more wells are being added to this concentration. Three wells at Oregon Technical Institute, the deepest of which is 1805 feet, constitute the northernmost extension of the known boundaries of this geothermal zone.

South of the canal into the business district and southeasterly for about a mile wells are more scattered and temperatures fall below 200° F. Two wells drilled recently at the new Mazama School are in the most southeasterly extension of the hot-water zone and lie about 4.5 miles from the Oregon Technical Institute wells.

Depth and temperature of wells

Depth of wells drilled ranges from as little as 100 feet to a maximum of 1805 feet. Most are in the 200- to 350-foot range. The water table generally seems to coincide with the elevation of Upper Klamath Lake, and static water level depths vary with the topography. Much of the rock penetrated in the geothermal zone is quite "tight" or impermeable, and perched water influences the height of the local water table in many cases. Drillers report drops of water levels amounting to as much as 50 feet from levels initially encountered as drilling proceeds to greater depths. Wells south of the canal generally are artesian or flowing wells, since the water table is near the surface in this area.

Temperatures of the wells in the geothermal zone range from 140° F. to 235° F. Wells below 140° F. are usually not considered by drillers to be satisfactory for a heating system. However, wells of lower temperature probably could be utilized under some conditions. The highest temperature gradients seem to cluster about two centers in the zone. One of the centers,

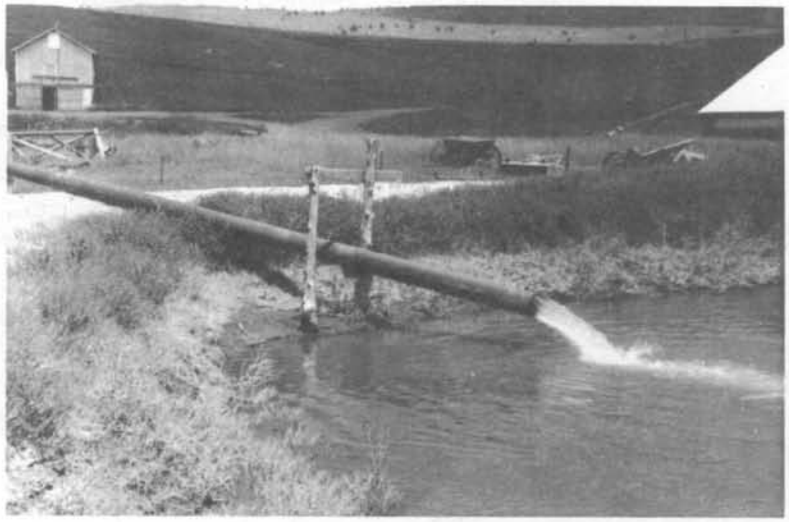


Figure 7. Hot well at the Liskey ranch in the Klamath Hills. This well, 285 feet deep, reportedly has a capacity of 1000 gallons per minute of 200° F. water.

Figure 8. Buildings and campus of the Oregon Technical Institute; Upper Klamath Lake and Cascade Range in the background.

Table 1. Well temperature logs, Klamath Falls, Oregon.

Depth in feet	Well location-L.H.Strid, Old Fort Rd. Elev. about 4190 feet. Static Level 73 feet. Temp. °F.	Well location, 155 N. Wendling Ave. Elev. about 4230 feet. Static Level 60 feet. Temp. °F.
50	130	136
75	164	180
100	166	206
200	199	218
300	211	218 T.D.
400	219	
500	225	
600	229	
700	233	
795	234 T.D.	

designated "A" in plate 2a, is located on Hillside Avenue between Dixon and Waring Streets, where high temperatures are reached at shallow depth. A well 100 feet deep at 341 Hillside Avenue emits dry steam with a pressure of several pounds per square inch (figure 9). It is probable that the steam is flashing into the well bore from a very limited water flow in impervious rocks at a temperature of about 230° to 235° F. Three similar wells are in the immediate vicinity but are drilled to depths of nearly 150 feet. The very high geothermal gradient in this area indicates heat flow approaching a hundred times that of normal and constitues an area of "warm ground."

The other center of high heat flow, labeled "B" in plate 2a, lies in the vicinity of Roosevelt School. The geothermal gradient in this area is slightly less than in the center "A"; temperatures of 200° F. and greater are reached at depths of 200 to 300 feet.

Because of the imperviousness of the rocks, temperatures and depths at which water flows are encountered vary to some degree from well to well. Drillers report measuring well-bore temperatures as high as 250° F. in some wells while still in dry rock. Upon striking a flow of water, well-bore temperatures then drop to the 220°-230° range. Apparently the rock in some places is reaching a higher temperature by conducted heat and is cooled slightly when water enters the well bore.

Temperature-depth logs of two wells are given in table 1. The wells were accessible and had been undisturbed for several years. Temperatures were taken with maximum-reading thermometers and may be considered as typical of wells in and near the high thermal gradient centers of the Klamath

Falls geothermal zone. Thermal gradients diminish with increasing depth and indicate a probable maximum or base temperature of 230° to 250° F. for the hot-water reservoir developed in the upper ground-water zone.

Use in heating

A heat-exchange system within the well is the predominant method of utilizing the thermal water for space and other heating. It also minimizes corrosion, waste, and discharge problems arising from its direct use. Klamath Falls has a city ordinance permitting hot-water discharge to the storm-sewer system, ditches, and the canal in only limited quantities.

After a well is drilled to a satisfactory depth for the desired temperature and flow conditions, it is cased to the bottom and perforated. A long, single return bend pipe coil is then lowered into the casing, extending to near the bottom of the well. The wellhead is then covered and welded or bolted shut. Hook-ups are made between the coil and the radiators which do the space heating. Clean domestic water is placed in the coil and radiator system which then circulates by the thermo-syphon method, receiving heat from the well water and passing this heat out at the radiators. Such a system has proven over the years to be simple and effective. Temperature control can be obtained through the use of a motorized or solenoid valve operated by a thermostat. Where two or more residences or a large installation are on a single well, a pump is used to provide a more rapid circulation than a thermo-syphon system alone can produce. Figure 10 shows a typical wellhead installation.

A rough estimate of the heat withdrawn from wells in the Klamath Falls geothermal zone, at this time, amounts to about 3000-4000 Btu/sec. averaged over the year. Conductive heat flow to the surface and heat lost through underground drainage are difficult to estimate, but they must be at least equal to and perhaps several times that presently withdrawn from wells.

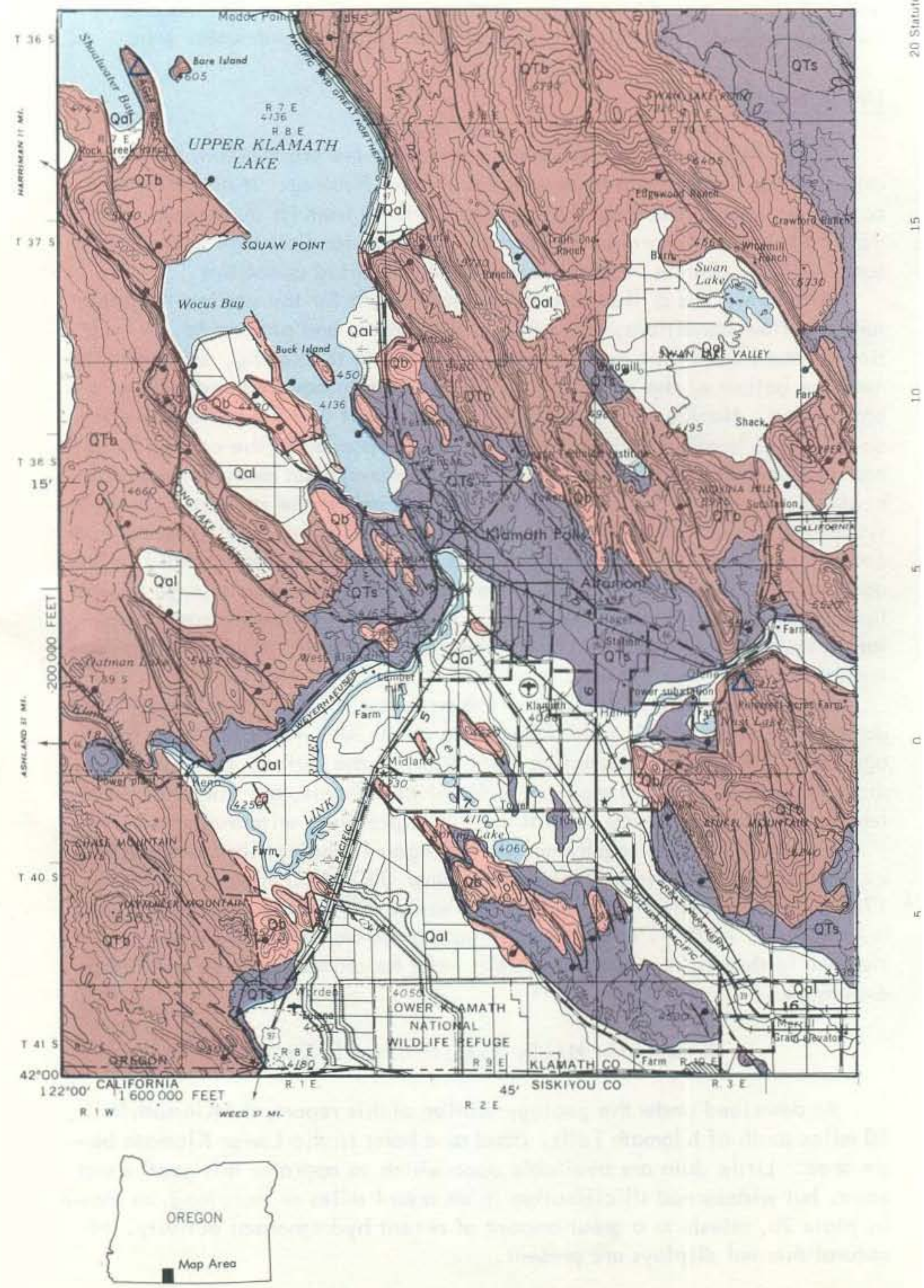
The large heating requirements at Oregon Technical Institute are met by a well 1716 feet deep equipped to pump 350 gals./min. of water at 193° F. Static water level is 358 feet below the surface. A temperature drop of about 100° F. occurs in the heating system before the water is discharged to the drain. Two other wells exist for standby service and future expansion.

Klamath Hills Geothermal Zone

As described under the geology section of this report, the Klamath Hills, 10 miles south of Klamath Falls, stand as a horst in the Lower Klamath basin area. Little data are available upon which to appraise this geothermal zone, but widespread silicification in an area 4 miles or more long, as shown in plate 2b, attests to a great amount of recent hydrothermal activity. No natural thermal displays are present.

PLATE 1

GEOLOGIC MAP OF THE KLAMATH FALLS AREA



EXPLANATION

Recent

Qal

Alluvium and other unconsolidated surficial deposits. Includes terrace gravels, talus, landslide debris, and possibly some areas of late Pleistocene lakebeds.

Pliocene and Pleistocene

Qb

Upper Basalt

Dark gray to black capping basalts. Mainly within the grabens. Includes black, dense intrusive masses, cinder and scoria mounds. Correlates in part with "upper lavas" of Newcomb and Hart (1958).

QTs

Layered sedimentary and pyroclastic rocks

Correlated with "Yonna Formation" of Newcomb and Hart (1958). Includes massive layers of impure diatomite, thin beds of tuffaceous sandstone, clayey tuffs, and, near eruptive centers, thick deposits of palagonitized basaltic tuff and tuff breccia. Also includes minor intercalated and/or interfingering basalt flows.

QTb

Undifferentiated basalt and pyroclastic rocks

Mainly dark gray diktytaxitic basalt flows with associated pyroclastic rocks (scoria, cinders, and agglomerate) that form broad, thick piles near eruptive centers. Includes tilted black, dense basalt flows that correlate with the "lower lavas" of Newcomb and Hart (1958). Probably includes some Qb in and adjacent to fault escarpments.

Contact, dashed where inferred.

Fault, dashed where approximately located, bar and ball on down side.

Hot spring.

A well located on the John Liskey ranch in sec. 34, T. 40 S., R. 9 E. uses hot water for irrigation after storage in a reservoir for a few days to allow cooling. This well (figure 7) pumps 1000 gals./min. of 200°F. water from a depth of 285 feet. Analysis of the water is given in table 2. A trace of hydrogen sulfide is present. At one time the well was test pumped at a rate of 7000 gals./min.

Another hot-water well at the Osborn ranch, about half a mile to the north, pumps 186° water from a depth of 418 feet at a rate of 450 gals./min., also for irrigation purposes.

Two wells in sec. 28, T. 40 S., R. 9 E., and three wells in sec. 1, T. 41 S., R. 9 E., shown on plate 2b, have temperatures around 80° F. The Liskey well would seem to be nearer the point at which the thermal fluid from depth is reaching the ground-water zone. The channel is probably along a fault bounding the Klamath Hills horst. It is likely that the thermal zone extends for some distance southward beneath the alluvium of Lower Klamath Lake basin, but the zone appears to be somewhat smaller in areal extent than the Klamath Falls geothermal zone.

Geochemical Data on the Klamath Falls Area

Ground-water analyses

Table 2 lists chemical analyses of eight thermal-water samples from a number of well locations within the geothermal zones and one from the hot spring at Olene Gap. Two representative samples, one a nonthermal water, Sample No. 10, and a slightly thermal water, Sample No. 11, were added for comparison purposes.

The most obvious impression gained at first glance is the uniformity of constituents among the samples of thermal water. This holds even for Sample No. 8 from the Liskey ranch, which is 12 miles south of Klamath Falls, and also for Sample No. 9 from Olene Gap Spring 8 miles to the southeast. Only one, Sample No. 7, shows some deviation, which is probably due to the lower temperature and its location on the margin of the Klamath Falls geothermal zone.

Among the most notable characteristics of the thermal waters is the high sulfate content and the fact that its ratio to chloride averages about 8. In relation to Sample Nos. 10 and 11, the thermal waters show a very great increase in sodium and sulfate and to a less extent chloride. Silica and calcium increase by 50 to 100 percent and bicarbonate drops by a factor of three or so.

The increase in sodium sulfate coupled with the small addition of sodium chloride in the Klamath Falls thermal waters is at variance with the generally accepted theories concerning hot springs and waters assumed to have a volcanic origin (White, 1957a,b; Ellis, 1964; White, 1964; and

Table 2. Chemical analyses of thermal and non-thermal groundwater of the Klamath Falls area (in parts per million).

Sample No.	1	2	3	4	5	6	7	8	9	10	11
Temperature (°F.)	178	164	160	193	205	196	143	200	165	45	69
Silica (SiO_2)	81	87	83	73	68	78	92	75	79	51	38
Iron (Fe) total	.04	.0	.0	.03	.04	.03	.09	.09	.03	.03	.12
Calcium (Ca)	23	25	22	25.1	27.3	27.3	5.4	27	34.9	15	11
Magnesium (Mg)	.0	.0	.0	1.04	< .2	< .2	1.04	1.89	1.09	11	4.3
Sodium (Na)	213	221	207	331	360	370	246	388	294	} 13	44
Potassium (K)	4.2	4.4	3.8	3.5	3.5	3.0	6.0	3.5	4.5		3.8
Bicarbonate (HCO_3)	32	32	*47	22	23	24	40	51	40	128	114
Carbonate (CO_3)	8	8	-	16	16	12	60	16	0	n.a.	n.a.
Sulfate (SO_4)	403	431	393	384	442	462	256	364	346	1.4	21
Chloride (Cl)	54	56	50	48	54	54	35	61	58	1.4	27
Fluoride (F)	1.2	1.6	1.4	1.12	1.18	1.18	1.0	1.3	1.12	.2	.1
Ammonia (NH_4)	n.a.	n.a.	n.a.	.54	.79	0.90	5.8	0.81	0.55	n.a.	n.a.
Nitrate (NO_3)	.0	.0	.2	< .01	.03	.09	.09	1.32	.91	1.9	.0
Boron (B)	.96	.91	.74	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	.0	.01
Aluminum (Al)	n.a.	n.a.	n.a.	.03	.03	< .02	< .02	.02	.03	n.a.	n.a.
Manganese (Mu)	n.a.	n.a.	n.a.	< .02	.06	.03	< .02	< .02	.06	n.a.	n.a.
Arsenic (As)	n.a.	n.a.	n.a.	.018	.037	.072	.005	.04	.027	n.a.	n.a.
Solids, total	833	881	812	816	821	902	631	833	812	158	214
Hardness as $CaCO_3$	58	62	55	67	66	67	18	75	92	83	45
Specific conductance	1160	1230	1100	1000	1100	1120	795	1080	1000	200	316
pH	8.8	8.7	8.5	8.6	8.5	8.4	8.7	8.4	7.3	7.7	8.3

*Contains equivalent of 4 ppm CO_3. n.a. = Not available.

1. Medo-Land Creamery, Klamath Falls, well (Newcomb and Hart, 1958, table 4).
2. J. E. Friesen, Klamath Falls, well (Newcomb and Hart, 1958, table 4).
3. Lois Merruys, Klamath Falls, well (Newcomb and Hart, 1958, table 4).
4. Oregon Technical Institute, Klamath Falls, well No. 5, analysis by Oregon State Board of Health laboratory.
5. Dr. Soule residence, 1945 Main St., Klamath Falls, well, analysis by Oregon State Board of Health laboratory.
6. Mills School, Klamath Falls, well, analysis by Oregon State Board of Health laboratory.
7. Mazama School, Klamath Falls, well, analysis by Oregon State Board of Health laboratory.
8. John Liskey ranch, Lower Klamath Lake Road, T. 40 S., R. 9 E., sec. 34, well, analysis by Oregon State Board of Health laboratory.
9. Olene Gap Spring, T. 39 S., R. 10 E., sec. 14, analysis by Oregon State Board of Health laboratory.
10. Fred Coleman ranch, T. 37 S., R. 10 E., sec. 30, well (Newcomb and Hart, 1958, table 4).
11. C. W. Lewis, T. 40 S., R. 10 E., sec. 28, well (Newcomb and Hart, 1958, table 4).

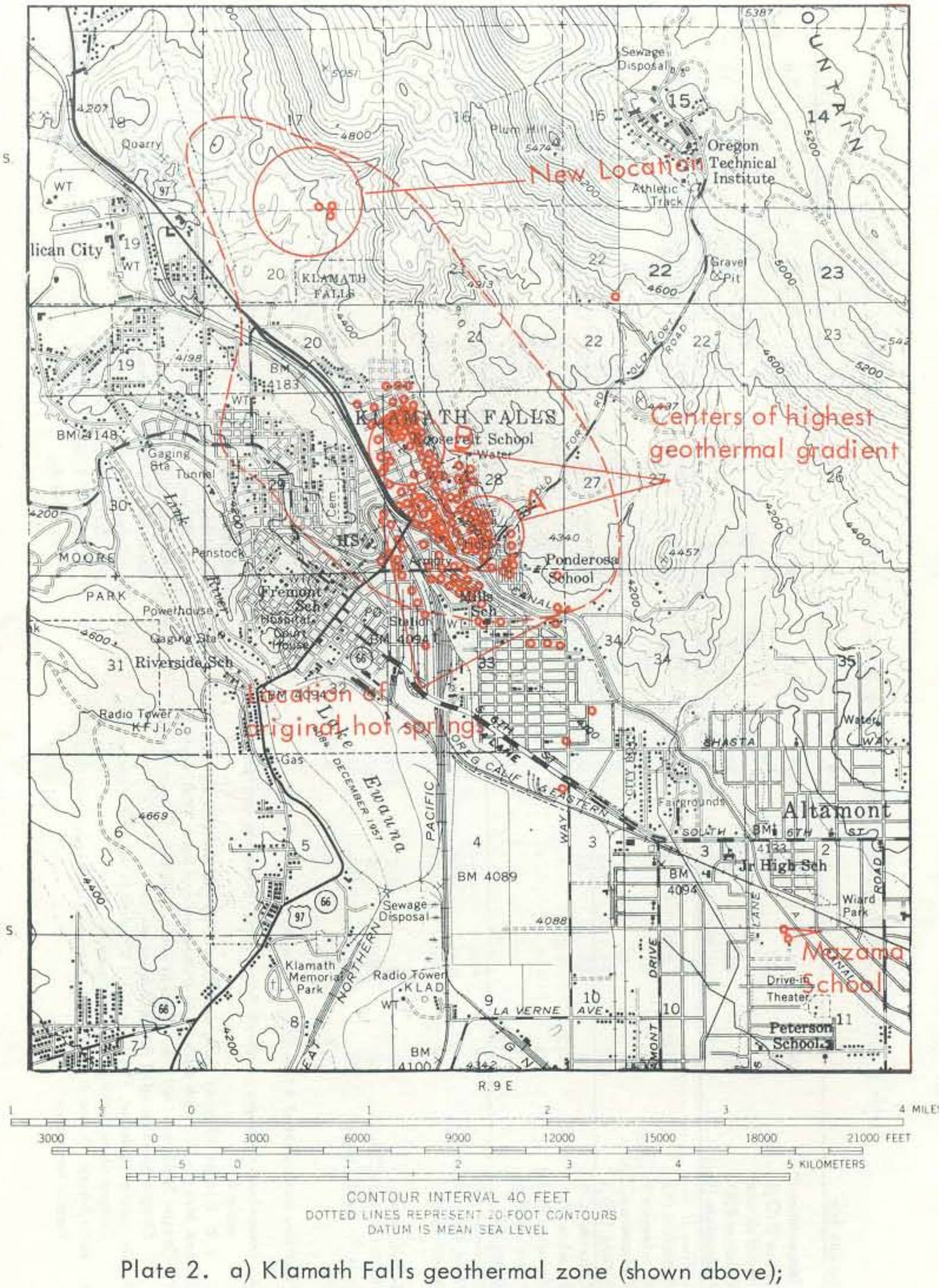
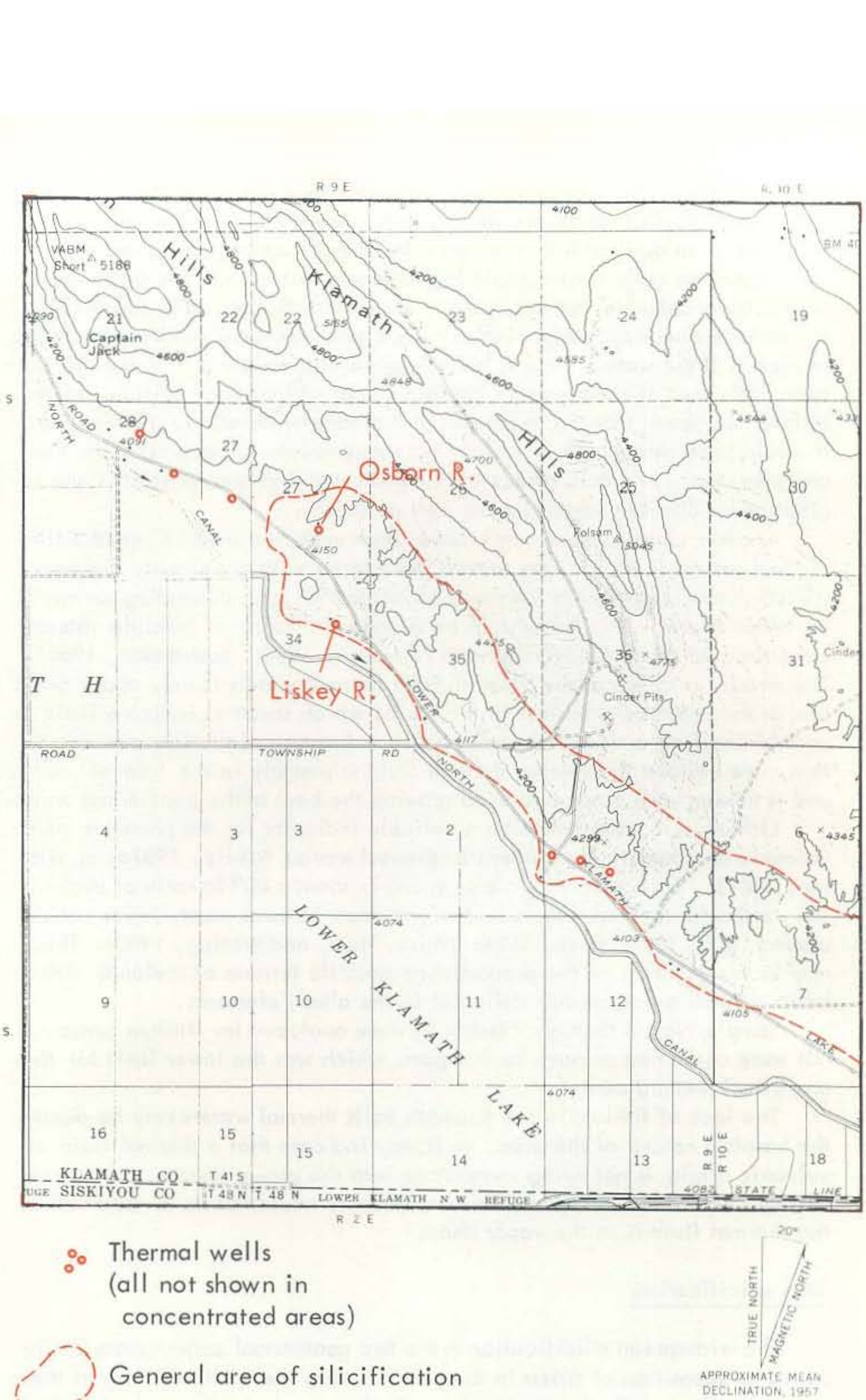


Plate 2. a) Klamath Falls geothermal zone (shown above);
b) Klamath Hills geothermal zone (on right).



R 9 E
R. 10 E
Klamath Hills
VABM Short 5188
Captain Jack
NORTH ROAD
CANAL
Osborn R.
Liskey R.
Folsom 5045
Cinder Pits
TOWNSHIP RD
ROAD
LOWER KLAMATH LAKE
CANAL
LAKE
KLAMATH CO
SISKIYOU CO
T 41 S
T 48 N
LOWER KLAMATH N W REFUGE
STATE LINE
R 2 E
40 S
41 S
TRUE NORTH
MAGNETIC NORTH
20°
APPROXIMATE MEAN DECLINATION, 1957
Thermal wells (all not shown in concentrated areas)
General area of silicification

Wilson, 1964). According to these theories, chloride is the dominant addition and SO_4/Cl ratios are usually low, around .05. The chloride is believed to be derived from a dense supercritical vapor passing out from magma and mixing with deep-circulating meteoric water. On the other hand, acid sulfate-chloride and acid sulfate waters are thought to be formed near the surface where accompanying sulfurous gases are oxidized by atmospheric oxygen. These waters have a low pH, generally below 3. Since the Klamath Falls area thermal waters contain traces of hydrogen sulfide, some sulfate may result from its oxidation in the zone of aeration. If this is so, it would seem reasonable to expect more magnesium to be present in the analyses, since any acid attack of the basic rocks characteristic of the region should dissolve magnesium as well as sodium.

Another constituent which is lower than expected in the Klamath Falls thermal waters is silica. For waters associated with a volcanic terrane, silica is usually present in the range of 200 to 600 ppm, depending somewhat on temperature. It is thought to be a good indicator of possible thermal conditions at depth (Bodvarsson and Palmason, 1964; Bodvarsson, 1966). The amount in silica of the Klamath Falls thermal waters is only about twice that of the nonthermal waters in the basin, which seems to indicate little or no addition from a deeper thermal source. Because of the low concentration, we believe the deeper thermal fluid is possibly in the form of steam and is mixing with groundwater to provide the heat of the geothermal zones.

Lithium is considered to be a reliable indicator for the presence of a volcanic or magmatic component in thermal waters (White, 1957a, b; Wilson, 1964). Such thermal waters generally show a Li/Na ratio of about .01, although thermal waters in Iceland seem to have much lower ratios, around .0005 (Bodvarsson, 1964; White, Hem, and Waring, 1963). This may be a reflection of the predominant basaltic terrane of Iceland, since basic magmas are somewhat deficient in the alkali elements.

Sample Nos. 4 through 9 (table 1) were analyzed for lithium content, but none contained as much as 0.1 ppm, which was the lower limit for the analytical method used.

The lack of lithium in the Klamath Falls thermal waters may be due to the basaltic nature of the area, or it may indicate that a thermal fluid of volcanic origin is not being introduced into the ground waters as a source of heat. On the other hand, lithium probably could not be transported if the thermal fluid is in the vapor phase.

Rock silicification

The widespread silicification in the two geothermal zones (plate 2 a, b) points to deposition of silica in the past. During the earlier history of these zones the thermal fluids entering from depth were probably much richer in dissolved silica and were able to precipitate the excess upon cooling. Why this is not so now is likely due to changes in the character of the deep

Figure 9. Dry steam well located at 341 Hillside Ave. in Klamath Falls.

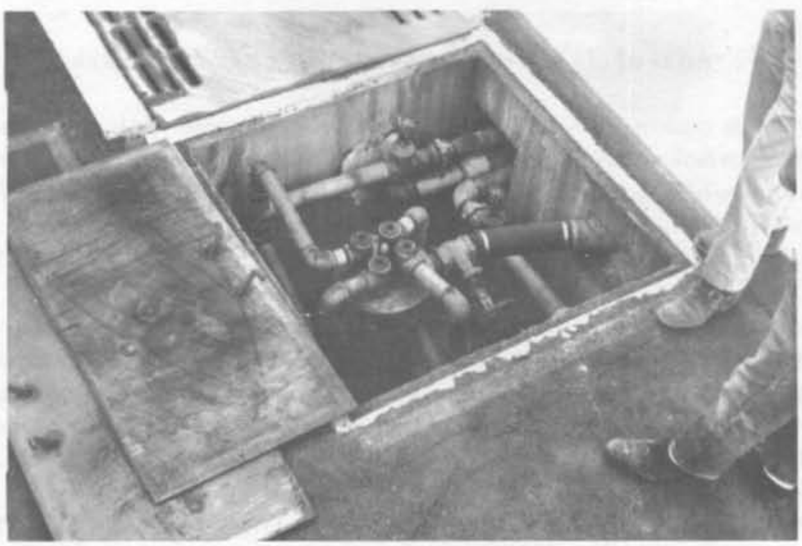


Figure 10. Typical hot-water wellhead installation at the Mills School. This particular well has two coils extending down the casing.

geothermal system, which for lack of data cannot be satisfactorily explained at this time.

A group of samples was taken from each of the two silicified zones and analyzed for mercury. All samples showed trace amounts of mercury ranging from 1 to about 10 ppm. One grab sample contained visible cinnabar and another ran 0.4 lbs./ton mercury. The presence of mercury is typical of low-temperature or epithermal mineralization and characteristic of hot-spring systems in volcanic areas.

Gravimetric Data on the Klamath Falls Area

Recently the State of Oregon Department of Geology and Mineral Industries published a series of three gravity maps entitled "Gravity Maps of Oregon (Onshore and Offshore)." One of this set, Map GMS 4-b, "Complete Bouguer Gravity Anomaly Map of Oregon" (Berg and Thiruvathukal, 1967), is constructed with contours at 10 mgal intervals and shows several anomalies are present in the Klamath Falls area. Most notable is a 20-mgal negative anomaly over the Lower Klamath Lake basin. The probable interpretation of this anomaly, as indicated by the structure and stratigraphy of the area, is that of a down-faulted block overlain by a fill of light tuffaceous and diatomaceous sediments. A 10-mgal negative anomaly south of Klamath Falls and another centered at the western edge of Swan Lake Valley may be similarly interpreted.

Potential Geothermal Resources at Depth

A large amount of heat is available in the Klamath Falls and Klamath Hills geothermal zones at depths ranging to 1000 feet or more. It is in the form of hot water with temperatures that vary from warm to above the boiling point. Such a thermal fluid is satisfactory for water heating and space heating, but it does not have the temperature and enthalpy needed for power generation.

As previously described in the geologic section of this report, Pliocene-Pleistocene volcanic-sedimentary rocks underlie the region. Subsidence, perhaps due to the late volcanism to the north, south, and west, has caused faulting and production of horst and graben structures. Such structures are considered to be favorable for the development of geothermal resources (McNitt, 1965).

The generally impervious properties of the Pliocene-Pleistocene rocks and their broad extent should provide a cover or "cap" to any existing deeper geothermal reservoir. Such a cap prevents the flow of geothermal fluids to the surface and consequent rapid dissipation of the reservoir heat (Facca and Tonani, 1964; Grindley, 1964). We believe the layered sedimentary-pyroclastic unit (plate 1) is performing this function in the Klamath Falls area. The present surface displays and the hot-water zones are only a manifestation of leakage along faults through these rocks from a hotter, deeper reservoir.

The rocks which compose this reservoir may be older basalt flows underlying the layered sedimentary and pyroclastic rocks which are correlative with the "lower lavas" of Newcomb and Hart (1958). Such a reservoir would have good permeability and would allow the circulation of thermal fluid in a convection system. If these basalt flows are thin or missing, the reservoir may exist in rocks equivalent to the Tertiary volcanic series of the Western Cascades. This assemblage of flows, breccias, and tuffs may have low permeability from alteration, although considerable fracture permeability may be developed from the great amount of faulting which has occurred in the Klamath area.

Chemical analyses of the thermal waters in the Klamath Falls area seem to show that the thermal fluid from depth is not adding significant minerals to the cool ground water with which it is presumably mixing. On this basis, we are inclined to believe the thermal fluid flowing upward into the geothermal zones is probably steam. The temperatures and quantities of heat involved seem to require a fluid having the enthalpy of steam to heat the ground water. The steam may be coming from a deep, dry steam reservoir (Grindley, 1964), or perhaps may be boiling off from superheated fluids contained at depth (Facca and Tonani, 1964). In either case, the presence of a higher-temperature geothermal source seems to be indicated, and hence economic possibilities may exist for the generation of power.

Exploration of a possible deeper geothermal reservoir in the Klamath Falls area can best be accomplished in and about the two major geothermal zones. Here the escape of steam from depth into the upper ground-water zone is apparently taking place and would, therefore, be the best location to probe the reservoir. Additional geophysical and geochemical studies may prove valuable in helping to define the nature of this reservoir, although a deep test well probably would provide the most information at this stage of exploration.

Acknowledgments

We wish to thank Mr. Alfred Collier and Mr. John Glubrecht of Klamath Falls for their cooperation in securing information about the early development of hot wells in Klamath Falls and for data of the hot springs and wells. Mr. James W. Pinninger of Oregon Technical Institute furnished well logs and other information, and many other people living in the Klamath Falls area were most helpful.

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* * * * *

Locating a promising geothermal system is a difficult problem. A system is apparent only when it is defective - when it is "leaking" hot water or steam to the surface. These obvious areas of hot springs and geysers are currently being explored, but it is entirely possible that the best areas are as yet undetected. Experts have said that the state of our knowledge regarding geothermal resources is comparable to that regarding petroleum resources at the turn of the century. (From U.S. Geological Survey news release.)

* * * * *

In the United States, serious interest in geothermal resources began about 1955, when The Geysers area, located about 75 miles north of San Francisco, was redrilled, and four strong wells began producing at a depth of less than 1000 feet. In 1958, the owners of the wells and the Pacific Gas & Electric Co. signed a contract arranging for the wells to supply steam to a plant erected for generation of electricity. Production was started in 1960 at a rate of 12,500 kilowatts, and the capacity has enlarged since to more than 56,000 kilowatts. The entire steam field at The Geysers is estimated to be capable of producing more than 1 million kilowatts. The Geysers operations has stimulated exploration through the western United States. (From U.S. Geological Survey news release.)

* * * * *

The electrical energy requirements of the United States are steadily climbing, and will probably continue to do so in the foreseeable future. Most of our requirements at the present time are met by energy produced from the burning of coal, oil, and gas, and other fuels. Although geothermal heat is now only of minor importance as an energy source, the quantities available in geothermal systems are large, and, with additional research and development, recovery is likely to increase greatly. (From U.S. Geological Survey news release.)

* * * * *

CRESCENT AREA MAPPED

"Reconnaissance geologic map of the east half of the Crescent quadrangle, Lake, Deschutes, and Crook Counties, Oregon" by G. W. Walker, N. V. Peterson, and R. C. Greene has been published as Misc. Geol. Invest. Map I-493 by the U.S. Geological Survey. This is the fifth in a series of Oregon geologic maps to be issued at this scale (1 inch equals approximately 4 miles) on AMS sheets, preparatory to publication of the eastern half of the State Geologic Map. The report covers a large region of the High Lava Plains of south-central Oregon, from the east flank of Newberry Volcano to within a few miles of the western edge of the Harney Basin. Rocks range in age from Eocene-Oligocene (Clarno Formation) to Recent, and comprise 26 geologic units shown on the map by color and pattern. One structural cross section also accompanies this report. Each unit in the explanation column is described in some detail and suggested correlations with other geologic formations in the state are given.

Copies may be obtained from the U.S. Geological Survey, Federal Center, Denver, Colo., 80225. The price is $1.00.

* * * * *

REGIONAL GEOLOGIC MAP OF OWYHEE UPLAND ISSUED

"Geologic map of the Owyhee region, Malheur County, Oregon" has been published as Bulletin 8 by the Museum of Natural History at the University of Oregon. The report includes much of the Owyhee Upland physiographic province of southeastern Oregon from the Malheur River canyon on the north to the Jordan (Morcom) Craters on the south.

A map of the northeast portion of this area, covering the Mitchell Butte quadrangle, was published by the Oregon Department of Geology and Mineral Industries in 1962.

Copies of Bulletin 8 may be obtained from the Museum of Natural History, University of Oregon, Eugene, Oregon 97403. The price is $2.00.

* * * * *

LEASE MINING NOT HARMFUL TO RESERVOIR SITES

The U.S. Bureau of Reclamation has applied for the withdrawal of a total of 110 acres in the Whitman National Forest from location under the mining laws to protect the Hardman and Dark Canyon reservoir sites in southern Baker County. The withdrawal contains no restriction on the mining of leasable minerals. The sites are located in section 28, T. 13 S., R. 36 E. and sections 20 and 21, T. 12 S., R. 41 E.

* * * * *

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PROGRESS REPORT ON THE GEOLOGY OF PART OF THE SNAKE RIVER CANYON, OREGON AND IDAHO

By Howard C. Brooks* and Tracy L. Vallier**

Introduction

This report presents a summary of the principal geologic and physiographic features of the upper part of the Snake River Canyon between Oregon and Idaho. The area discussed extends from Farewell Bend near Huntington, Oregon downriver to Granite Creek 6 miles below Hells Canyon Dam (figure 1), a distance of 94 miles. Photographs and a series of geologic maps (plates I to VIII) are included to illustrate the topography and geology. The information presented synthesizes the results of geologic mapping in progress by the writers and others. Future field studies will continue the mapping northward to the Washington State line and more detailed work will be done in parts of the area described here. When the mapping in the canyon is completed, the information will be published by the Department of Geology and Mineral Industries as part of its Geologic Map Series.

In the present report, the major stratigraphic units observed in the Snake River Canyon between Farewell Bend and Granite Creek are described in the order they appear as one traverses the canyon from south to north, rather than chronologically. Because the region is geologically complex and stratigraphic and structural relationships in parts of the area are imperfectly known, the stratigraphic column which accompanies the maps is subject to revision as work progresses. The geological coverage of the Oregon portion of the canyon from Farewell Bend to Powder River was prepared by Brooks. Map data for the Idaho part of this segment was furnished by Dr. George Williams of the Idaho Bureau of Mines and Geology with respect to the Mineral quadrangle, and Dwight Juras, candidate for graduate degree at the University of Idaho, in reference to the Olds Ferry quadrangle. The geology of the Powder River to Brownlee Dam section was taken from Livingston (1923). The material for the Brownlee Dam to Granite Creek section was prepared by Vallier and was extracted largely from his doctoral dissertation (Vallier, 1967).

Fossil identifications were made for the writers by Doctors Ralph Imlay and N.J. Silberling of the U.S. Geological Survey, Francis Stehli of Western Reserve University, and Takeo Susuki of the University of California at Los Angeles.

Previous Mapping

Previously, little geologic mapping has been done in the Snake River Canyon, although work in surrounding areas of easier access has facilitated geologic interpretations presented here. Lindgren (1901) included the area from Farewell Bend to

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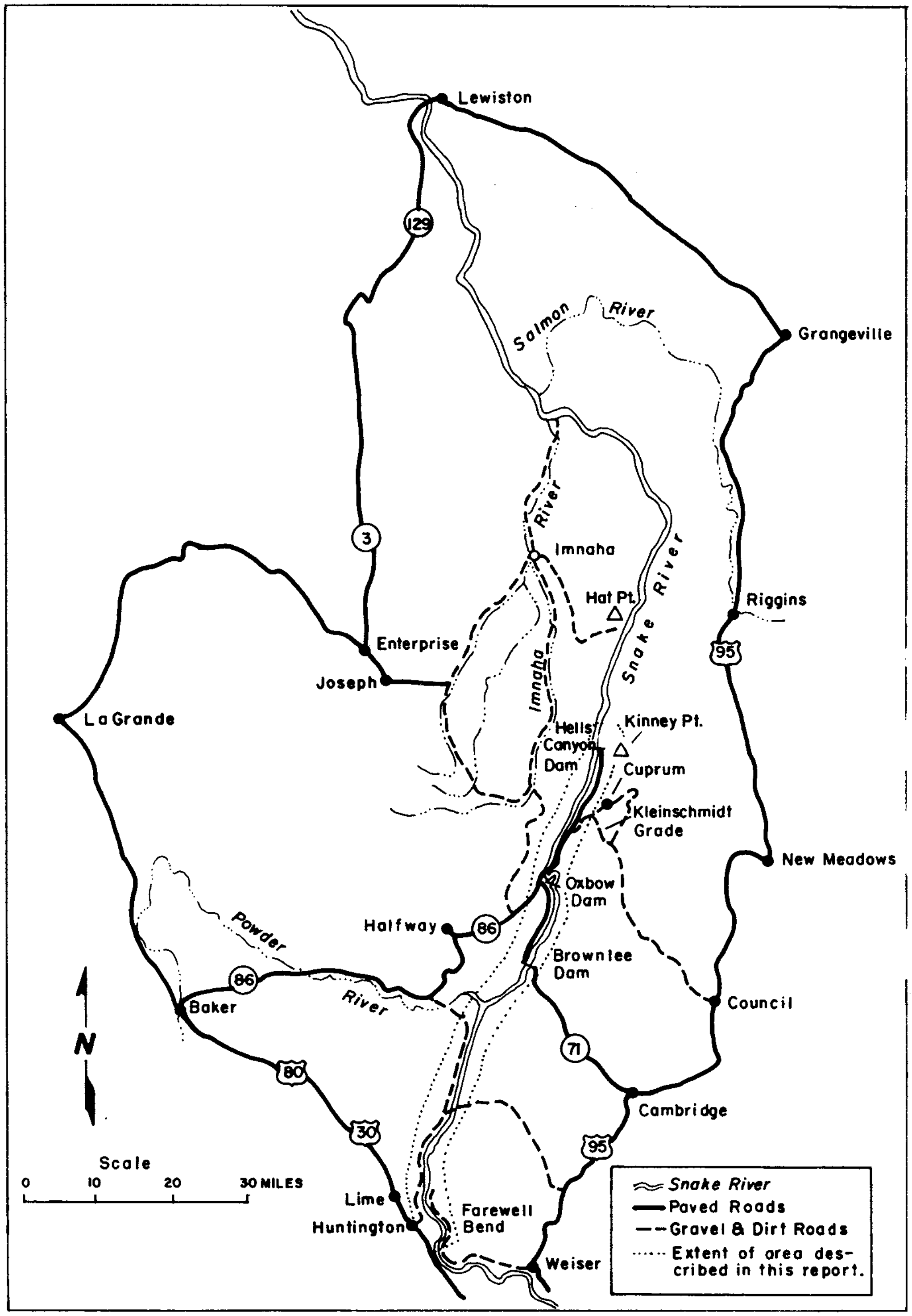


Figure 1. Index map of the Snake River Canyon and environs.

Ballard Creek in his large-scale geologic map of the gold belt of the Blue Mountains. Livingston (1923) mapped a narrow strip along both sides of the river from the mouth of Burnt River to Oxbow. Unpublished work in the Cuprum quadrangle during 1938-1941 by Ralph Cannon of the U.S. Geological Survey was adapted by Hamilton (1963). Parts of the Huntington and Olds Ferry quadrangles were mapped by Beeson (1955), Berry (1956), and Spiller (1958). A 20-mile section of the canyon in the vicinity of the Imnaha and Salmon Rivers, about 40 miles downstream from the area of this report, was mapped by Morrison (1963) for his doctoral dissertation.

Geography

General setting

At Farewell Bend, the Snake River leaves the relatively flat Tertiary lava- and sediment-filled Snake River Plain. From there northward for more than 160 miles the river flows in a deep canyon carved through the rugged mountains and gentle marginal slopes of the Blue and Seven Devils Mountains. Water-level elevation is 2077 feet at Farewell Bend and 860 feet at the Washington State line. Between Farewell Bend and Oxbow the river winds through an open, mountainous area characterized by long, narrow ridges, V-shaped canyons, and steep, predominantly soil-covered slopes cut by a multitude of draws and gulches. For most of this distance the canyon is 2000 to 3000 feet deep. At Oxbow the river makes a 180° bend and forms a curious topographic feature, the origin of which is described later in this report.

A few miles below Oxbow the river enters Hells Canyon, the deepest gorge in North America (figure 2). For more than 60 miles the canyon is 4000 to 6000 feet deep, as measured from the west rim. To the east the highest peaks of the Seven Devils Range tower nearly 8000 feet above the river. From promontories such as Hat Point on the west rim and Kinney Point on the east wall one sees a vast panorama of angular erosional features stepping precipitously down toward the river below. Nearly vertical cliffs, narrow benches, talus slopes, and countless sharply incised side canyons characterize the terrain. The river channel is generally narrow and in many places is deeply entrenched between sheer rock walls. Below Hells Canyon Dam, whitewater rapids are numerous. Some are navigable only on a downriver course by highly skilled boatmen.

Vegetation is sparse within the canyon and is limited chiefly to grass on the slopes and brush and small trees along water courses. Patches of timber grow above 4000 feet elevation. The climate is one of moderately severe winters and hot summers. Summer temperatures on the canyon floor can rise to more than 115°.

Settlements in the canyon area are widely separated. Operation and maintenance of the dams and the raising of cattle and sheep provide employment for most of the permanent inhabitants.

Access

From Hells Canyon Dam upriver nearly to Weiser, Idaho, the floor of the canyon is flooded by water impounded by three dams recently constructed by the Idaho Power & Light Co. These are, from south to north, Brownlee, Oxbow, and Hells Canyon. Access to the dams is by way of Oregon Highway 86 from Baker to Oxbow, and Idaho Highway 71 from Cambridge to Brownlee. Paved roads along the three resservoirs connect Brownlee Dam on the south with Hells Canyon Dam on the north. A

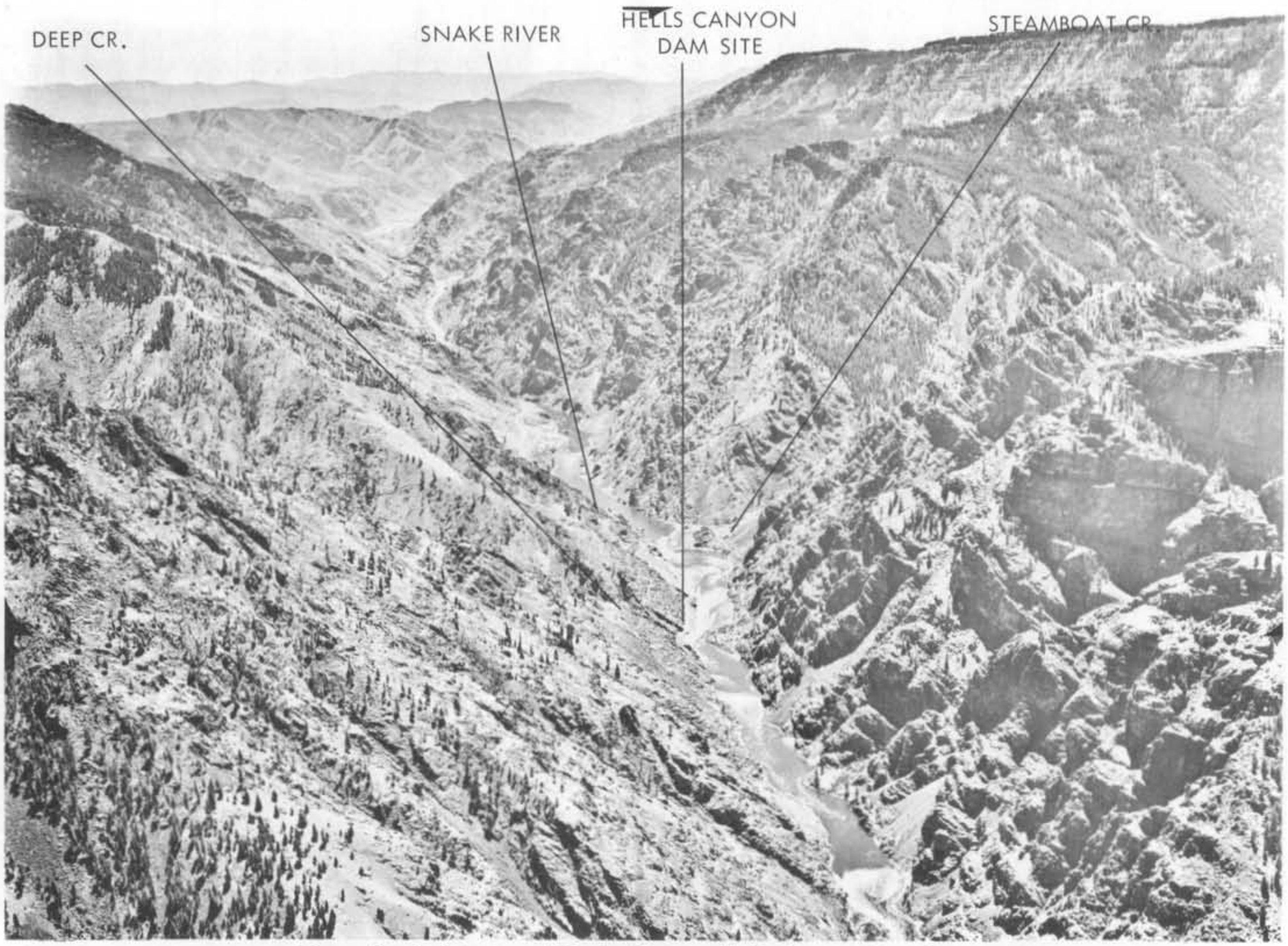


Figure 2. Aerial view of Snake River at Hells Canyon Dam Site.

gravel road from Huntington follows Burnt River to its confluence with the Snake, near the upper end of Brownlee Reservoir. This road then continues northward along the reservoir to the general vicinity of Sturgill Creek. From here it climbs out of the canyon and connects with Oregon Highway 86 at Richland. Gravel and dirt roads from Weiser, Idaho provide access to short segments of Brownlee Reservoir. The Kleinschmidt Grade climbs the canyon wall on the Idaho side from a point about 6 miles north of Oxbow to Cuprum. Between Hells Canyon Dam and the Washington State line there are no roads along the river and access is difficult.

Mineral Deposits

Although there is little or no mining at present, deposits of gold, silver, copper, and gypsum have been commercially exploited in past years. In addition, there are important limestone reserves in the Connor Creek and Big Bar areas. Known areas of mineralization are described in mining reports on the Seven Devils region by Livingston and Laney (1920) and Cook (1954); the Mineral and Cuddy Mountain districts by Livingston (1923); the Mineral district by Anderson and Wagner (1952); and the Iron Mountain district by Mackin (1953). Other reports concerned with mineral deposits in the Snake River Canyon are by Swartley (1914), Moore (1937), Libbey (1943), and McDivitt (1952).

Geology

Before the Snake River Canyon existed, the Blue and Seven Devils Mountains were partly, if not entirely, buried by Miocene basalt flows of the Columbia River Group. These lava flows poured out on rugged, mountainous terrain, accumulating to a thickness of thousands of feet in low places and forming a vast plateau. During Pliocene time the mountains were uplifted by folding and faulting, and much of the lava has since been eroded, exposing ancient metamorphic and igneous rocks beneath. For much of its length the canyon of the Snake River has been cut through the plateau-forming basalts and deep into the old mountains. The profile of the old land surface beneath the lavas is visible at many places in the canyon.

Livingston (1928) and Wheeler and Cook (1954) discussed the origin of the canyon and postulated that in late Tertiary time Snake River followed a far different course than the present one.

Pre-Tertiary rocks

Rocks representative of most of the major pre-Tertiary stratigraphic units of the eastern Blue Mountains are exposed on the canyon walls. They comprise a heterogeneous assemblage of eugeosynclinal volcanic and sedimentary rocks and a wide variety of plutonic rocks that represent at least two major stages of intrusive activity. The bedded rocks include thick sections of Paleozoic phyllite, chert, siliceous argillite, massive to schistose greenstones and limestone; Middle and Upper Triassic volcanic flows, volcaniclastic rocks, limestone, and conglomerate; and Upper Triassic (?)-Jurassic metagraywacke, slate and phyllite. The older group of plutonic rocks includes gabbro, diorite, quartz diorite, and serpentinized ultramafic rocks of Permian-Triassic age. The younger plutonic rocks, probably of Cretaceous age, are mainly granodiorite. A multitude of dikes, many unrelated to the major intrusive episodes, cut the pre-Tertiary units.

Figure 3. Air view of upper part of Brownlee Reservoir downstream from Farewell Bend. Union Pacific Railroad crosses the Snake River at mouth of Burnt River. Upper Triassic rocks are exposed along both sides of reservoir.

Figure 4. Air view northwest from a point about 5 miles north of Huntington. Contact (dashed line) between Upper Triassic greenstone sequence below and younger Mesozoic graywacke sequence above. Contact marked by red and green conglomerate layer. Old gypsum mine in center.

The bedded rocks and older intrusives have been folded and regionally metamorphosed to the greenschist facies. Rocks of higher metamorphic grade are found near the margins of plutonic bodies.

The pre-Tertiary strata have a general east-to-northeasterly trend and the river has cut diagonally across them. The prevailing strike of compositional layering, planes of schistosity, and major fold axes is east to northeast and dips are generally to the northwest. Many large and small faults complicate the structure.

Tertiary rocks

The Tertiary lava series consists mainly of a great number of superimposed flows. Most of the rocks are brownish olivine basalts. Volcaniclastic units, many of them light colored, are sparsely distributed through the sequence. The Tertiary rocks have in most places been only gently warped and are relatively little altered. They are cut by steeply dipping normal faults of predominantly north to northwesterly trend.

Geologic Traverse along the Snake River Canyon

The following eight sections describe the geology that one encounters in traversing this part of the Snake. Most of the 94-mile stretch is accessible by road. Exceptions are between Sturgill and Brownlee Dam and below Hells Canyon Dam.

1. Farewell Bend to Rock Creek

From Farewell Bend north to the mouth of Rock Creek most of the rocks exposed on the canyon walls are altered lavas and volcaniclastic rocks of Upper Triassic age (plates I and II). Massive andesitic flows and pyroclastic rocks intercalated with coarse breccias and conglomerates composed mainly of volcanic detritus are the dominant rock types. Thin-bedded tuffaceous sandstone, shale, argillite, and limestone interbeds found throughout the sequence locally contain abundant Upper Triassic marine fauna. The general area described is shown in figure 3.

A small granitic body is exposed about 3 miles by road north of the mouth of Burnt River. The age of this intrusive has not been determined. The rocks are metamorphosed to a slightly higher degree than is typical of the Cretaceous granitic rocks elsewhere in the region and hence may be somewhat older.

This predominantly volcanic sequence is unconformably overlain by a distinctive red and green sheared conglomerate unit, which is well exposed on the south side of the mouth of Rock Creek and above the old gypsum mine (figure 4). The unit is 300 to 400 feet thick and is almost continuously traceable in a northeast-southwest direction for more than 20 miles (Brooks, 1967). At Rock Creek the conglomerate is underlain by a thin limestone unit which is absent on the Oregon side of the canyon. The limestone may be buried beneath the conglomerate or possibly it was eroded prior to deposition of the conglomerate. Limestone again appears beneath the conglomerate farther west in the vicinity of Lime.

2. Rock Creek to Soda Creek

Overlying the red and green conglomerate unit and extending northward from the mouth of Rock Creek nearly to the mouth of Soda Creek is a thick sequence of

Figure 5. This photograph illustrates the steeply dipping, tightly folded aspect of the graywacke, slate, and phyllite sequence (mouth of Connor Creek).

Figure 6. Characteristic erosion surface of phyllite-greenschist-marble sequence in the Sturgill Creek area. Tertiary lavas in background.

sheared graywacke, slate, and phyllite with minor amounts of conglomerate, tuff, and limestone (plates II and III). The rocks are mainly thin bedded, tightly folded, and in most places dip steeply northwest (figure 5). Bedding and slaty cleavage are usually almost parallel. A faint silvery sheen is visible on cleavage surfaces in many of the rocks and is due to the development of sericite and chlorite.

The apparent thickness of the sequence is more than 20,000 feet. Probably there has been repetition of beds by isoclinal folding and faulting, so that the actual thickness may be considerably less. Upper and Lower (?) Jurassic fossils have been collected from strata in extreme southern parts of the sequence immediately above the red and green conglomerate unit (Livingston, 1932; Imlay, 1964; and Imlay, written communication, 1966). Although no supporting fossil evidence has yet been found, it is surmised that older Mesozoic rocks are also present.

About a third of a mile south of Soda Creek there is exposed in the road cut a major fault or unconformity which forms the northwest boundary of the graywacke sequence.

3. Soda Creek to the mouth of Powder River

The rocks north of the graywacke contact near Soda Creek consist of thinly layered siliceous to pelitic phyllites with lesser amounts of massive to schistose greenstones and marble (plates III and IV) (figure 6).

A thick marble unit, which forms the ridge south of Soda Creek, extends southwestward across the heads of Connor (figure 7), Fox, and Hibbard Creeks, and eastward into Idaho. Elsewhere marbleized limestone occurs as detached lenses and pods from a few inches to several hundred feet in longest dimension (figure 8).

Rocks included in the phyllite series are traceable westward into the Baker quadrangle, where Gilluly (1937) subdivided them into two formations: the Burnt River Schist of unknown age and the Elkhorn Ridge Argillite largely of Permian age. The phyllites are lithologically different and more intensely deformed and metamorphosed than the graywacke sequence to the south. Cleavage intersections and crenulations form lineations on planar surfaces in the phyllitic rock (figures 9 and 10). Sills, dikes, and small irregular masses of gabbro, diabase, and serpentine locally intruded into the sequence have been folded and metamorphosed to approximately the same degree as the enclosing rocks.

The pre-Tertiary section is in fault contact with basalt flows of the Columbia River Group at the mouth of Powder River (figure 11). Other post-Miocene faulting can be seen in this general region (figure 12).

4. Mouth of Powder River to Oxbow, Oregon

From the mouth of Powder River nearly to Oxbow, pre-Tertiary rocks appear only as small inliers surrounded by flat or gently dipping basalt flows (plate V). The flows are more than 2000 feet thick at Brownlee Dam. A serpentine body now almost inundated by the reservoir occurs about 5 miles above the dam. Metamorphosed pre-Tertiary rocks crop out in two places along the road between the Brownlee and Oxbow Dams. The Oxbow of the Snake River is also cut in pre-Tertiary rocks.

The first inlier occurs about 2 miles north of Brownlee Dam. Pre-Tertiary rocks rise nearly 1000 feet above the river on the Idaho side of the canyon. Metamorphosed quartz diorite, gabbro, and diorite are sheared along northeast-trending faults.

Figure 7. Headwaters of Connor Creek. Marbleized limestone in phyllite-greenschist-marble sequence forms rough, jagged exposure. Tertiary basalt covers the limestone at upper right edge of the photograph. Rounded slopes in foreground are underlain by Mesozoic graywacke.

Figure 8. Visible outcrops on the slope above are mostly detached pods and lenses of limestone that have been "tectonically scattered" by folding and shearing out of once continuous limestone beds.

Figure 9. Typical outcrop of siliceous phyllite. Steep southwest-plunging lineations parallel to fold axes mark intersections of bedding and axial plane cleavage.

Figure 10. Close-up of similar structural features in limestone. Note small, steeply plunging folds.

Figure 11. Air view down Snake River. Powder River is on the left. Pre-Tertiary rocks in the foreground are in fault contact with flat-lying Miocene lavas.

Figure 12. Large Tertiary fault at the head of Quicksand Creek drops Tertiary lavas about 1200 feet on the right-hand side of the creek.

Fluxion structure parallels the faults. Volcaniclastic rocks, limestone, and argillite of uncertain age are faulted against the plutonic rocks. These bedded rocks dip steeply and in places are isoclinally folded. Similar intrusive relationships probably occur on the Idaho side of the canyon.

Miocene volcanics are at river level for about 4 miles between inliers of pre-Tertiary rocks. Some basalt tuffs of Miocene age occur along the road. About a mile south of the Oxbow, near the mouth of Warm Springs Creek, travertine deposits jut out as white shoulders against the somber browns of the basalt.

The second inlier, at the mouth of Cottonwood Creek, is composed of sheared and mylonitized rocks of the Oxbow-Cuprum shear zone (Taubeneck, 1966). Across the river, dark-colored diorite and gabbro are exposed.

The Oxbow of the Snake River is a conspicuous physiographic feature that is characterized by abrupt bends and straight segments (figure 13). It probably was carved when the river was superimposed from the overlying Columbia River Basalt onto the pre-Tertiary rocks. Two wind gaps, representing former stream channels, cross the ridge of the Oxbow. The long, straight segments of the river are controlled by a set of pre-Miocene faults which trend N. 30° E. to N. 80° E. parallel to the Oxbow-Cuprum shear zone.

The geology of the Oxbow was described by Stearns and Anderson (1966). Rocks of the older intrusive complex are metamorphosed and consist of albite granite, quartz diorite, diorite, and gabbro. The plutonic rocks intruded Permian rocks and all were later sheared and mylonitized along the Oxbow-Cuprum shear zone (figure 14), which continues to the northeast for more than 20 miles. The northern part of the Oxbow-Cuprum shear zone is being studied by W. H. White, doctoral candidate at Oregon State University.

5. Oxbow, Oregon to the Kleinschmidt Grade

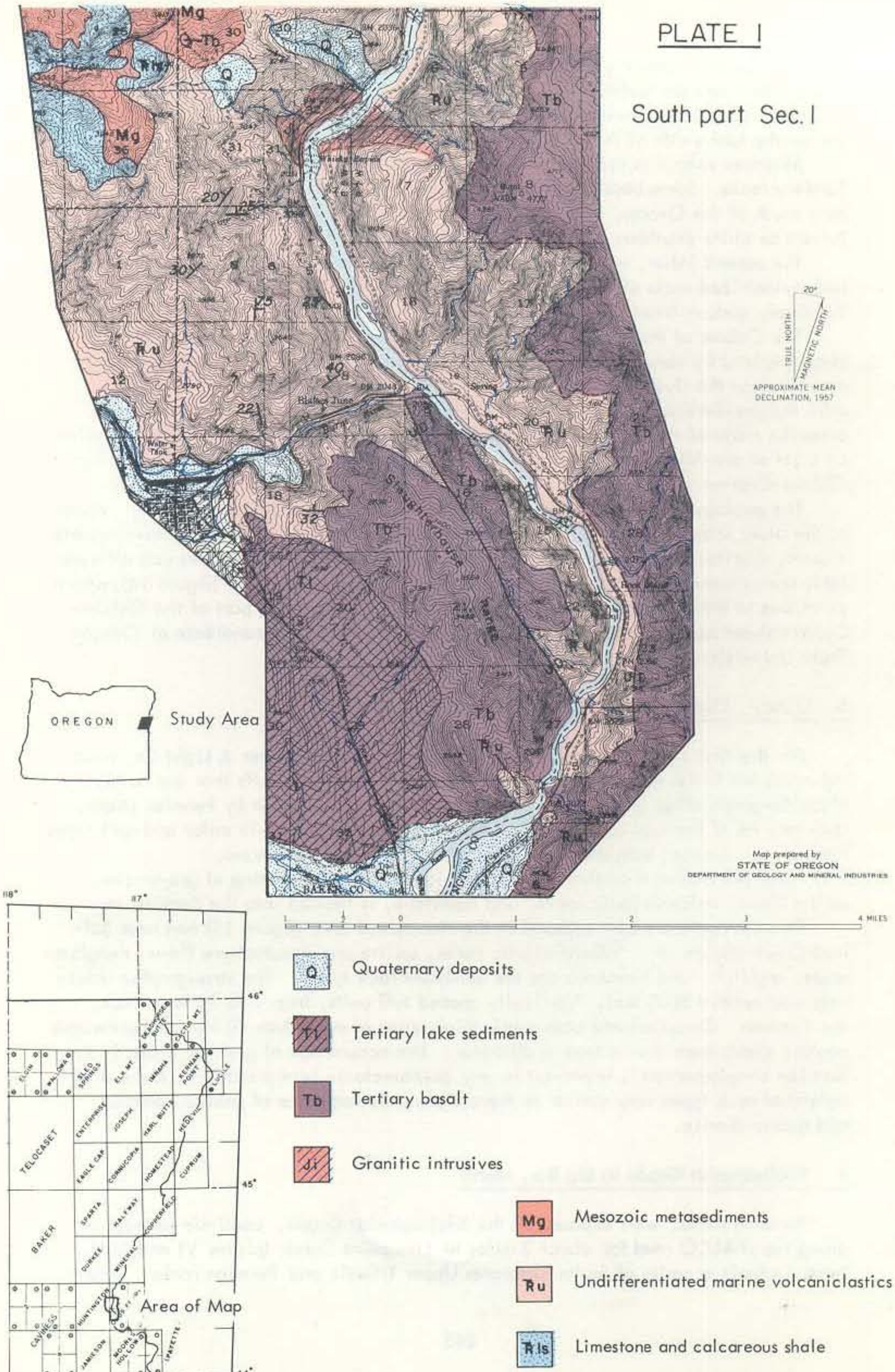
For the first $1\frac{1}{2}$ miles north of Oxbow, along the Idaho Power & Light Co. road, the rocks are bluish-green keratophyre flows and keratophyre tuffs that are cut by blackish-green dikes (plate VI). Since these rocks are overlain by Permian strata, they may be of Permian age or older. Along the road, changes in color and rock types mark a fault contact between the older rocks and the Permian strata.

Near Homestead a section of Middle Triassic rocks, consisting of graywacke, spilite flows, volcaniclastic rocks, and limestone, is faulted into the Permian strata.

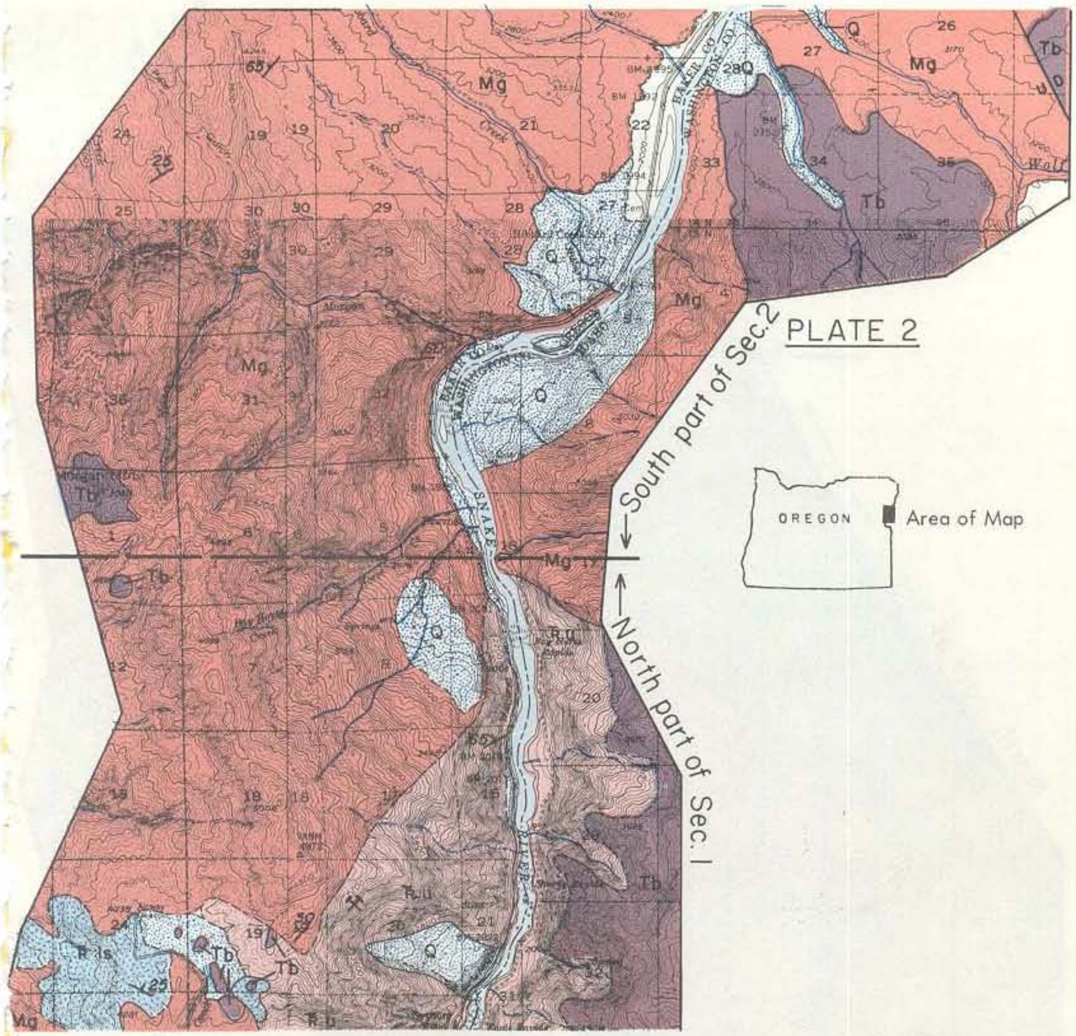
Permian rocks are best exposed in the Homestead area (figure 15) and near Ballard Creek (figure 16). Volcaniclastic rocks, spilite and keratophyre flows, conglomerate, argillite, and limestone are the dominant rock types. The stratigraphic thickness may exceed 8000 feet. Vertically graded tuff units, from 1 to 50 feet thick, are common. Conglomerate beds reach thicknesses of more than 40 feet and some beds contain clasts more than a foot in diameter. The occurrence of granitic clasts in the Permian conglomerates is important in any paleotectonic interpretations, since they consist of rock types very similar to the old plutonic sequence of gabbro, diorite, and quartz diorite.

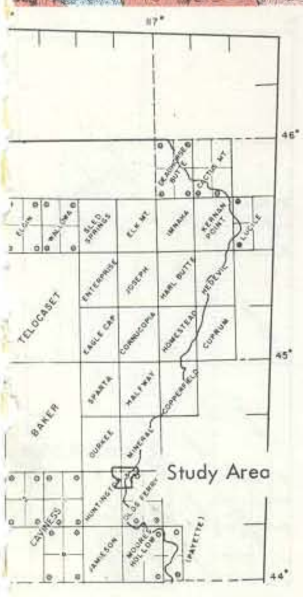
6. Kleinschmidt Grade to Big Bar, Idaho

Permian rocks, well exposed on the Kleinschmidt Grade, continue to crop out along the IPALCO road for about 2 miles to Limepoint Creek (plates VI and VII). Here, a fault or series of faults separates Upper Triassic and Permian rocks. About



See explanation on page 250.





Q	Quaternary deposits
Tb	Tertiary basalt
Mg	Mesozoic metasediments
Ŧu	Undifferentiated marine volcaniclastics
Ŧls	Limestone and calcareous shale

See explanation on page 250.

Map prepared by
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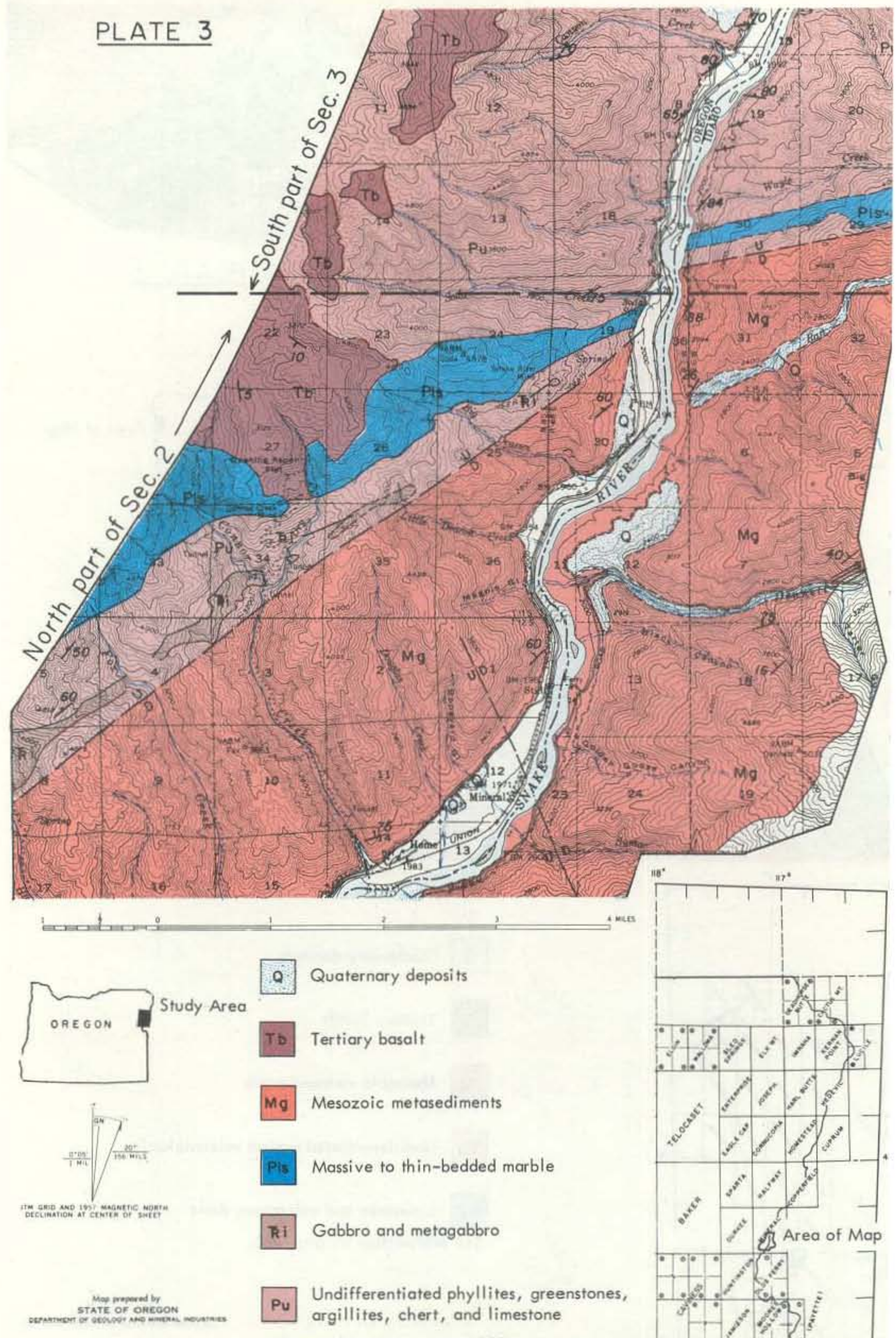
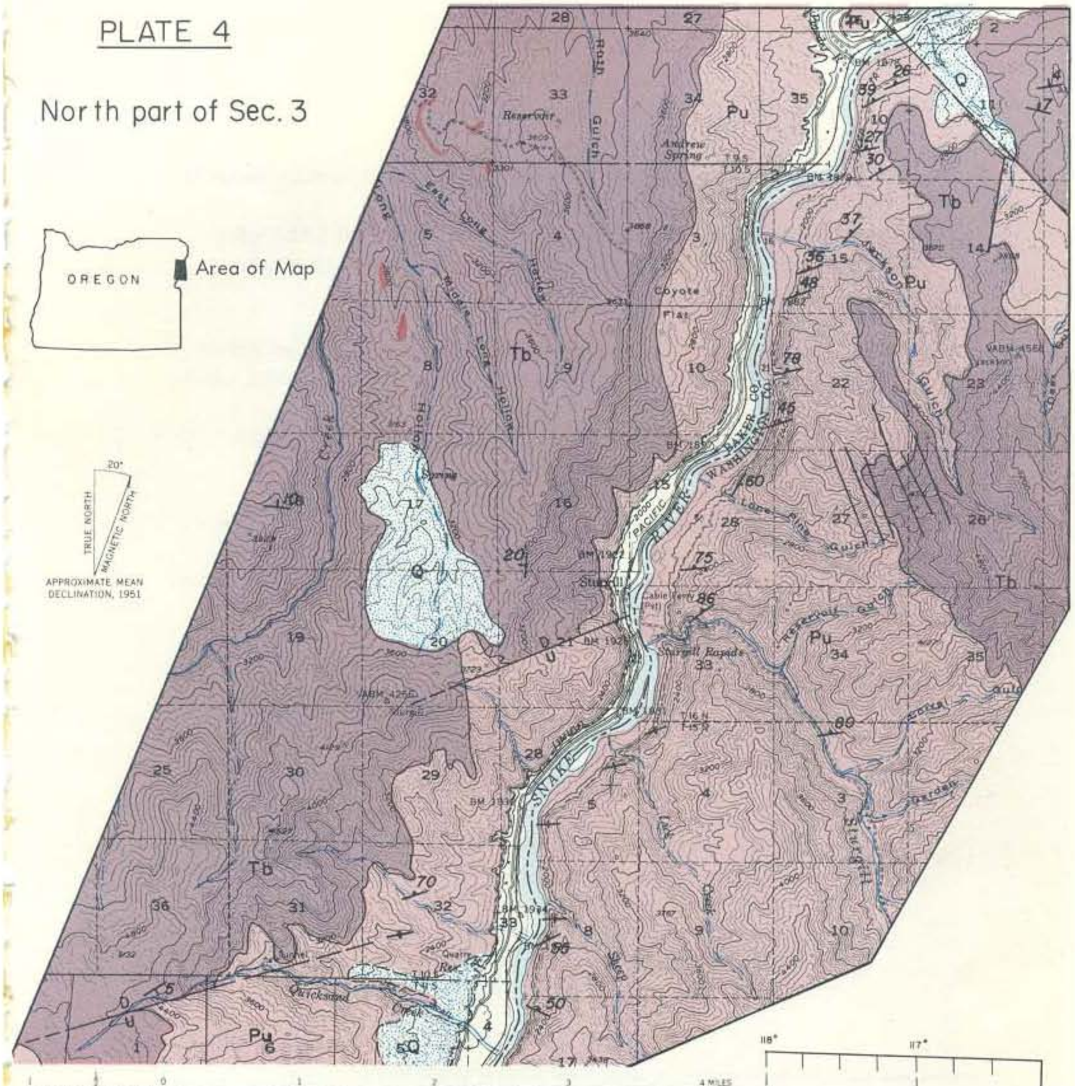


See explanation on page 250.

PLATE 4

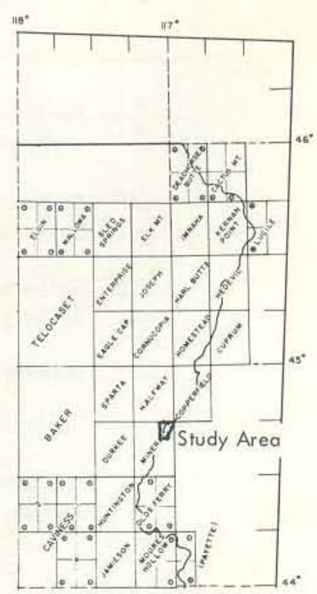
North part of Sec. 3



Distance between top of PLATE 4 and bottom of PLATE 5, 8.5 river mile gap. Only Tb is exposed.

Q	Quaternary deposits
Tb	Tertiary basalt
Pu	Undifferentiated phyllites, greenstones, argillites, shert, and limestone

See explanation on page 250.



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EXPLANATION

Q — Quaternary alluvium, landslide debris, and terrace deposits.

Tl — Tertiary lake sediments. Loosely consolidated tuffaceous mudstone and sandstone with intercalated gravels, tuff, and basalt flows.

Tb — Tertiary basalt. Correlates with the Columbia River Basalt Group. Mainly basalt flows with minor volcaniclastic rocks.

Ji — Granitic intrusive rocks, age uncertain, probably Late Jurassic-Early Cretaceous.

Mg — Jurassic and possibly older Mesozoic metagraywacke, slate, and phyllite with minor conglomerate, tuff, and limestone. Tightly folded. Southern contact marked by red and green sheared conglomerate unit 300 to 400 feet thick.

Tru / Trls — Upper Triassic. (Tru) undifferentiated marine volcanic and volcaniclastic rocks, with subordinate shale and limestone interbeds. (Trls) mostly limestone and calcareous shale.

Tri — Lower Triassic intrusives, mainly gabbro and metagabbro.

Pu / Pls — Intensely deformed rocks; probably mostly Paleozoic. Includes small Lower Triassic intrusive bodies (Tri). (Pu) undifferentiated siliceous, pelitic and calcareous phyllites, massive to schistose greenstones and volcaniclastic rocks, argillite, chert, and scattered pod-like bodies of limestone. (Pls) massive and thin-bedded marble with interbedded calcareous phyllite.

Unconformity; questioned where uncertain.

U/D — Fault; U, upthrown side; D, downthrown side; dashed where approximately located.

60 — Strike and dip of bedding

Strike and dip of vertical bedding

40 — Strike and dip of foliation

Strike and dip of vertical or nearly vertical foliation

Intrusive Dike

Contact; dashed where approximately located

Topographic base from U.S.G.S. 15-minute quadrangle maps: Durkee, Huntington, Mineral, and Olds Ferry

EXPLANATION

Q — Quaternary deposits; alluvium, landslide debris, and terrace deposits.

Tb — Tertiary basalt; correlates with the Columbia River Basalt Group; basalt flows and minor volcaniclastic rocks.

Ji — Jurassic intrusive; gabbro and diorite.

Ŧmb — Upper Triassic Martin Bridge Formation; gray limestone and dolomite with minor amounts of shale.

Ŧu — Middle and Upper Triassic undifferentiated; marine volcaniclastic rocks, spilitic flows, and minor amounts of limestone.

Ŧi — Lower Triassic (?) intrusives; quartz diorite, albite granite, diorite, and gabbro.

? — Uncertain correlation; probably Permian and/or Triassic marine volcaniclastic rocks, spilite flows, shale, and limestone (blue). Includes those rocks in the small inlier below Brownlee Dam.

Fz — Foliated zone; cataclastic and mylonitized Paleozoic and Triassic(?) rocks. Includes Lower Triassic (?) mylonitized intrusives. These rocks are part of the Oxbow-Cuprum shear zone.

Pu — Permian undifferentiated; marine volcaniclastic rocks, spilite and keratophyre flows, minor amounts of limestone and argillite.

P (?) — Permian (?) or older Paleozoic; keratophyre flows and tuffs.

~?~ Unconformity; questioned where uncertain.

U/D Fault; U, upthrown side; D, downthrown side; dashed where approximately located.

Axes of folding; anticline, syncline.

60 Strike and dip of bedding

Strike and dip of vertical bedding

40 Strike and dip of foliation

Strike and dip of vertical or nearly vertical foliation

Significant fossils

Contact; dashed where approximately located

Topographic base from U.S.G.S. 15-minute quadrangle maps: Copperfield, Cuprum, Homestead, and He Devil.

PLATE 5

Q Quaternary deposits

Tb Tertiary basalt

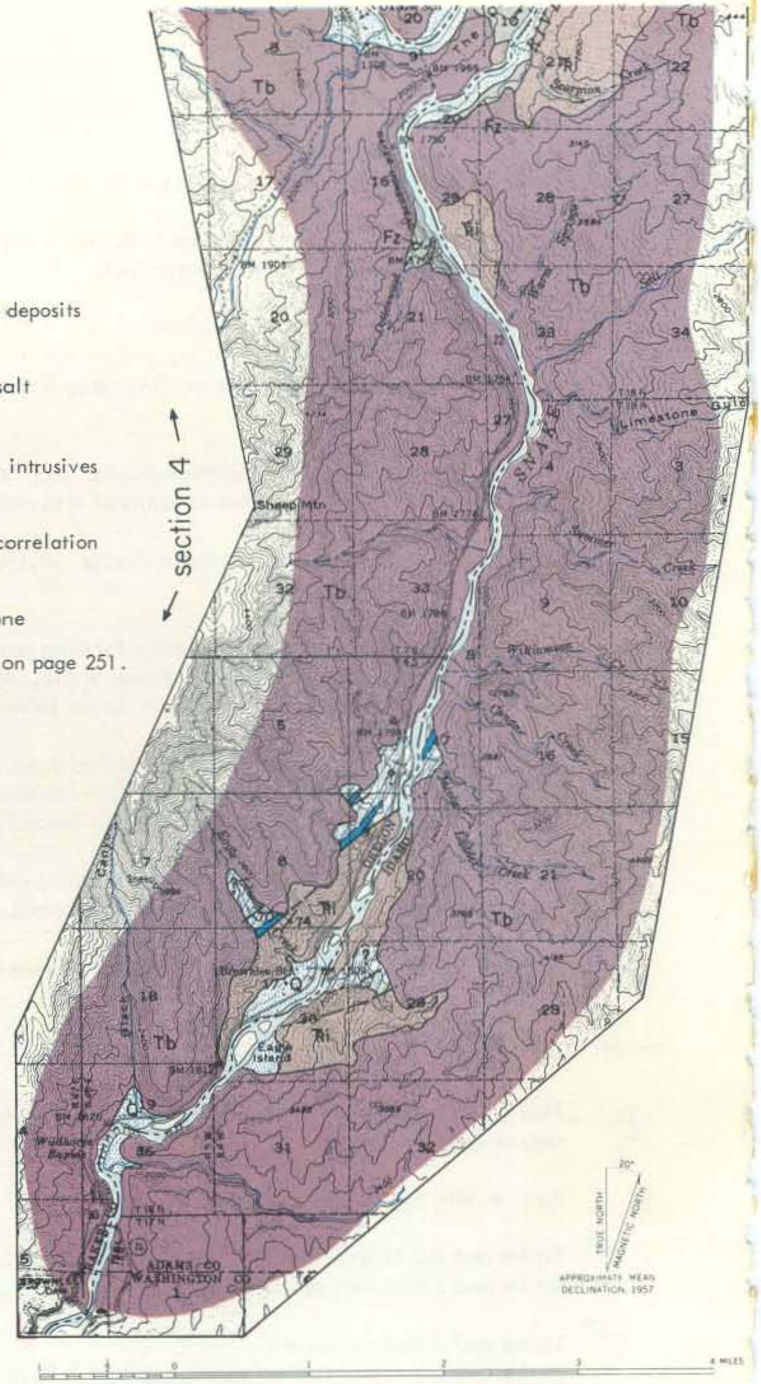
Ri Triassic (?) intrusives

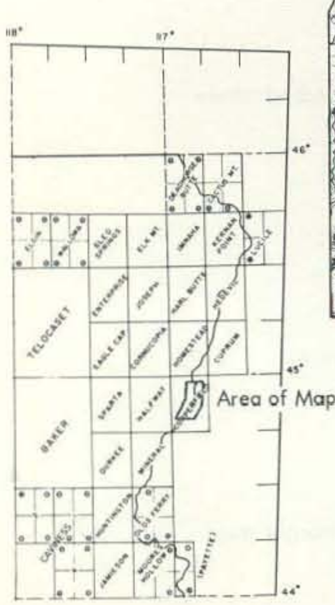
? Uncertain correlation

Fz Foliated zone

See explanation on page 251.

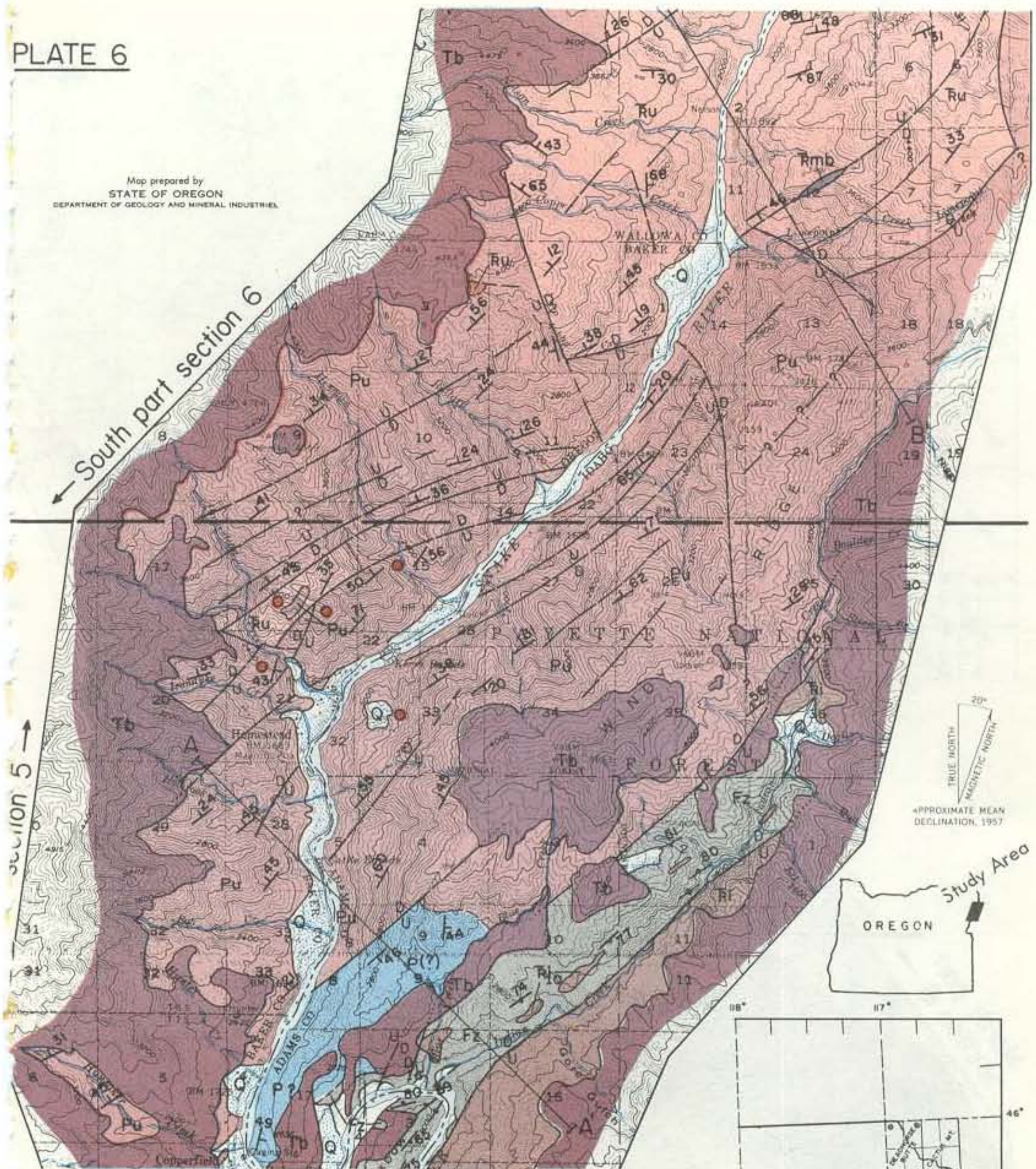
← section 4 →

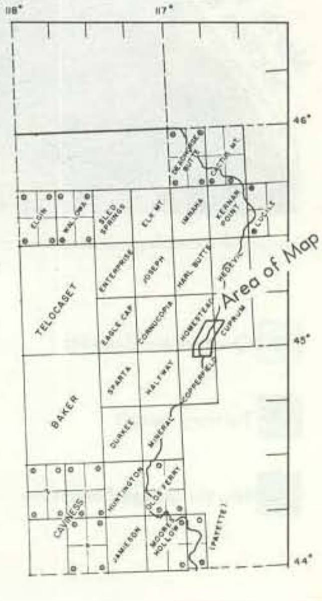




Distance between bottom of PLATE 5 and top of PLATE 4, 8.5 river mile gap. Only Tb is exposed.

PLATE 6

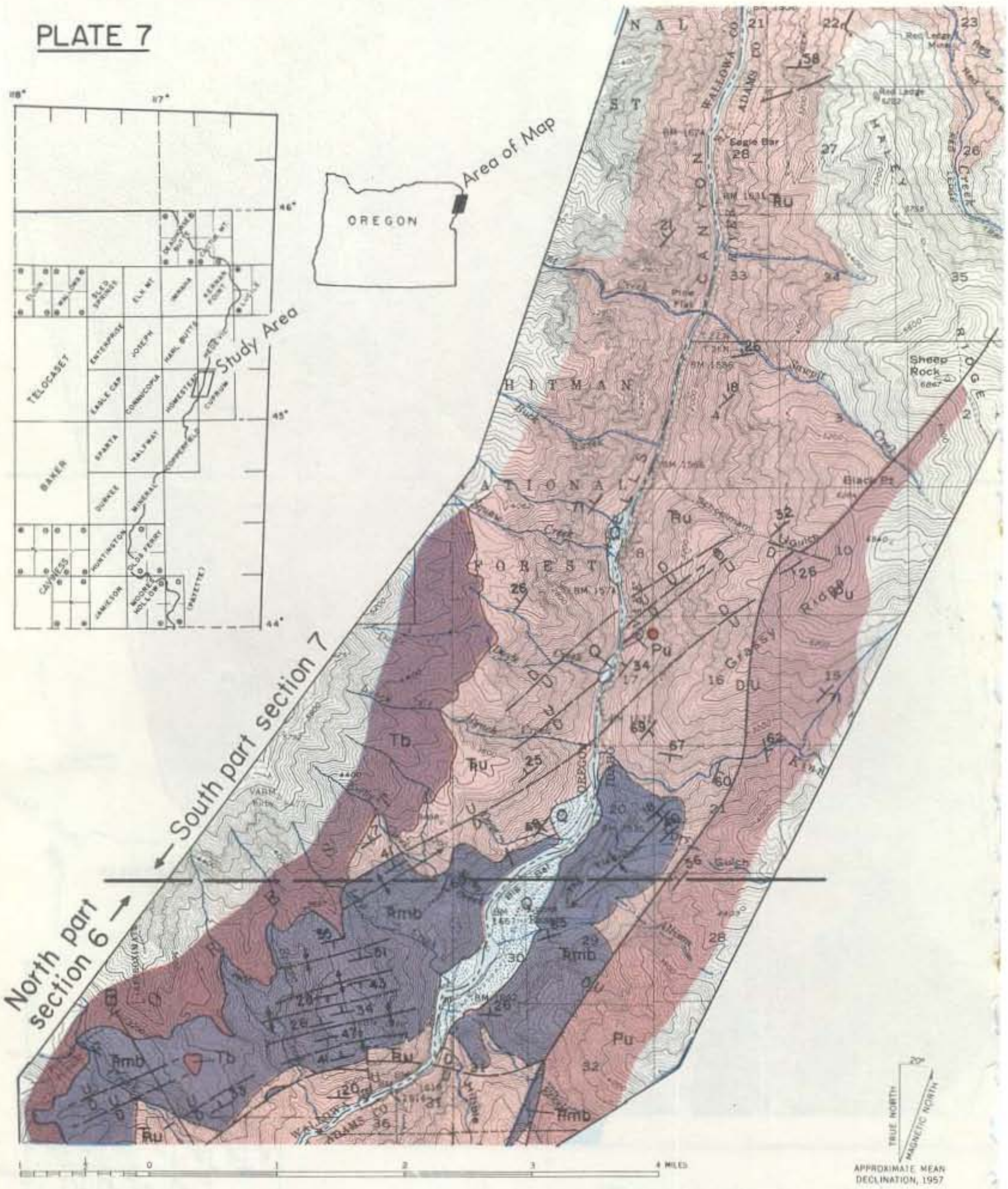




See explanation on page 251.

Q Quaternary deposits	Ri Triassic (?) intrusives
Tb Tertiary basalt	Fz Foliated zone
Rmb Martin Bridge Formation	Pu Permian undifferentiated
Ru M-U Triassic undifferentiated	P(?) Permian (?) or older

PLATE 7



Q Quaternary deposits

Tb Tertiary basalt

Ŧmb Martin Bridge Formation

Ŧu M-U Triassic undifferentiated

Pu Permian undifferentiated

See explanation on page 251.

Map prepared by
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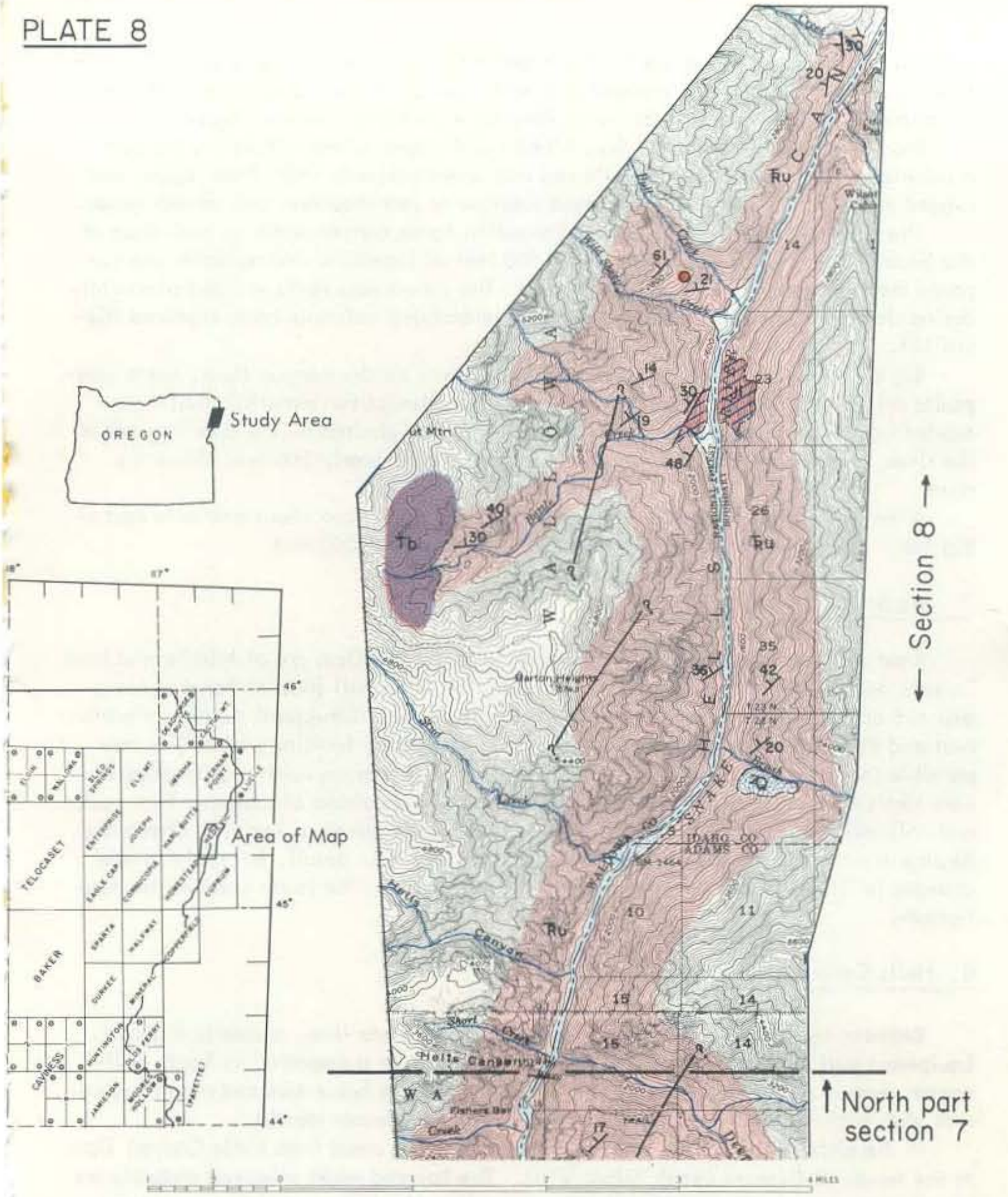
PLATE 8



Q Quaternary deposits

Tb Tertiary basalt

Ji Jurassic intrusive

Ru M-U Triassic undifferentiated

Map prepared by STATE OF OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

ee explanation on page 251.

half a mile northeast of the mouth of Limepoint Creek, a fault slice of Upper Triassic (Martin Bridge) limestone is exposed as a white peak. A fault slice in Eckels Creek is composed of limestone and separates Permian from Triassic strata (figure 17).

From Limepoint Peak to Big Bar, Middle and Upper Triassic rocks are exposed in a complex anticline. Upper Triassic red and green volcanic rocks form jagged and rugged outcrops. Middle Triassic strata weather to low shoulders and smooth slopes.

The Upper Triassic Martin Bridge Formation forms canyon walls on both sides of the Snake River at Big Bar. More than 1700 feet of limestone and dolomite are exposed along the south side of Kinney Creek. The calcareous rocks yielded plastically during deformation, but the more competent underlying volcanic rocks ruptured (figure 18).

Big Bar (figure 19), a major topographic feature on the canyon floor, has a composite origin. River-bar gravels interfinger with alluvial fan materials that were eroded from the canyon wall. A landslide, which originated on the opposite side of the river, capped the bar and formed a hill that stands nearly 200 feet above the river.

A major fault separates Permian and Upper Triassic strata about one mile east of Big Bar. Apparent stratigraphic separation is at least 10,000 feet.

7. Big Bar to Hells Canyon Dam

Most of the rocks between Big Bar and Hells Canyon Dam are of Middle and Late Triassic age (plates VII and VIII). One exception is a small slice of Permian rocks exposed across the river from the mouth of Doyle Creek. Structural trends are northeast and beds dip to the northwest. Repetition of beds by faulting probably is responsible for the apparent thickness of the strata. The canyon continues to deepen near Hells Canyon Dam (figures 20 and 21). Rugged shoulders of volcanic flow rocks and volcaniclastic rocks cast long shadows in the early mornings and late afternoons. Stratigraphic relationships of these rocks are not known in detail, but rapid lateral changes in lithology are common and thick dikes that cut the strata confuse the stratigraphy.

8. Hells Canyon Dam to Granite Creek

Between Hells Canyon Dam and the Washington State line, access is difficult. Equipment and supplies required by field parties must be transported by boat, helicopter, horse, or backpack. The legwork of mapping is hazardous and requires unusual physical stamina in the high temperatures of the summer months.

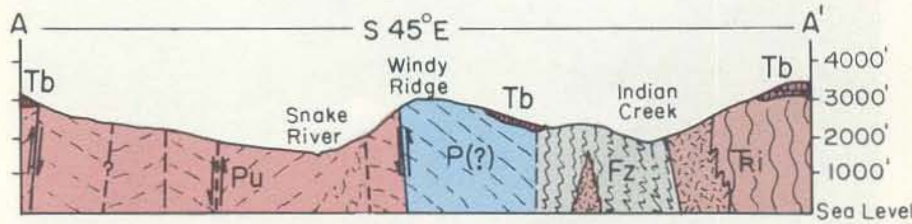
In the summer of 1967, a brief reconnaissance was made from Hells Canyon Dam to the mouth of Granite Creek (plate VIII). The layered rocks observed probably are Late Triassic in age (figures 22 and 23). A small gabbroic intrusive is exposed near the canyon floor at Battle Creek.

Future Program

No geologic maps of the canyon from Granite Creek to the Washington State line have been published. This segment, as the aerial photographs (figures 24 and 25) clearly show, includes the most rugged and inaccessible part of Hells Canyon. As noted in the Introduction, future field studies are planned that will continue the mapping to the Oregon-Washington boundary. This section is expected to reveal

Figure 13. The Oxbow of the Snake River. Erosion along northeast-trending shear zones and foliations resulted in a 180° bend in the river.

GENERALIZED GEOLOGIC SECTION



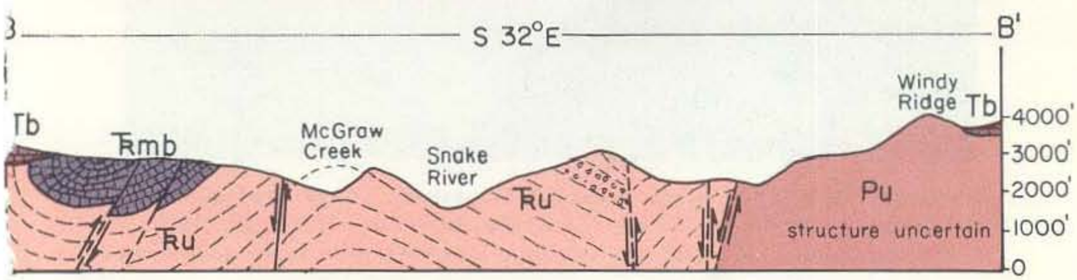


Figure 14. Nearly vertical, northeast-trending schists, mylonites, and gneissic mylonites of the Oxbow-Cuprum shear zone. This outcrop is at river level, about 100 yards east of the mouth of Indian Creek.

Figure 15. Permian and Triassic rocks near Homestead, Oregon are capped by Miocene basalt flows. The Iron Dyke mine, active during the early 1900's, is left of center. The Wallowa Mountains form the skyline in the background.

Figure 16. Outcrop characteristics of Permian rocks between Ballard and Ashby Creeks, Oregon. More than 1500 feet of northwest-dipping strata are exposed along the north side of Ballard Creek (left center of photograph). Road is the Kleinschmidt Grade.

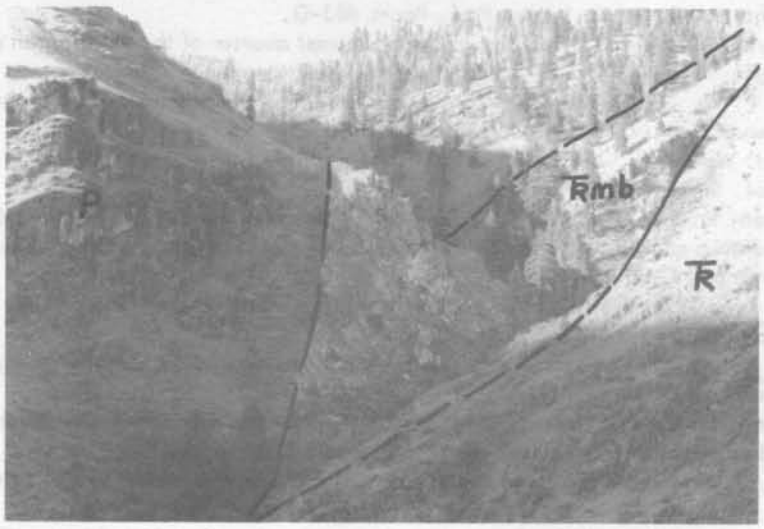


Figure 17. Martin Bridge Formation as a fault slice between Permian rocks (on the left) and Middle(?) Triassic rocks (on the right) in Eckels Creek, Idaho. Inked lines trace faults.

valuable stratigraphic and structural data necessary for understanding the geology of the whole canyon. The information obtained will be a major contribution to the geology of northeastern Oregon and western Idaho.

Upon completion of the work in the entire canyon, the Department plans to issue a publication consisting of a series of strip maps, accompanied by an explanation that will be of interest to the vacationer who comes to view the spectacular canyon of the Snake River.

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Figure 18. Folded Martin Bridge limestone near Big Bar. Flat surfaces between streams signify an old erosion surface. Quartzite boulders of unknown source and age are scattered over the surface in the upper left corner. Miocene basalt caps the limestone.

Figure 19. Big Bar, Idaho. The topographic high was formed by landslide debris. River gravels in Big Bar are more than 100 feet thick in some places.

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DEEP MINES OF THE WORLD

Man has been digging into the earth in the search for minerals since the Stone Age. In recent years the development of new mining techniques and equipment has made it possible to mine to depths never before considered. In the following table are listed some of the very deep mines in the world:

Mine	Country	Depth below surface
East Rand Proprietary Mines (1)	South Africa	11,246 feet
City Deep (1)	South Africa	10,645
Champion Reef (2)	India	10,000
Crown Mines (1)	South Africa	9,848
Western Deep Levels (1)	South Africa	9,804
Durban Deep (1)	South Africa	9,560
Morro Velko (2)	Brazil	8,501
Star (2)	Idaho, U.S.A.	7,100
Magma (2)	Arizona, U.S.A.	5,600
Anaconda Mountain (2)	Montana, U.S.A.	5,280
Homestake (2)	South Dakota, U.S.A.	5,000

(1) Data supplied by Information Service of South Africa.

(2) Written communication, Dr. Walter Hibbard, Director, U.S. Bureau Mines.

One of the big problems in very deep mines is heat. Elaborate refrigerating systems have been employed to bring the temperatures at the working faces down to acceptable levels. The cost of driving tunnels and sinking shafts to great depths is also a limiting factor. In deep mines the pressure of overlying rock is often great enough to shatter the tunnel walls; thus, concrete and steel reinforcement is commonly employed in permanent working and haulage areas. U.S. Bureau of Mines authorities report that the ultimate limit at which mining could be carried on in the South African deep mines would be about 12,500 feet below the surface.

* * * * *

Figure 20. Upper Triassic rocks exposed in 32 Point Creek near Hells Canyon Dam.

Figure 21. Hells Canyon Dam. Chiseled into the Upper Triassic volcanic rocks, the 400-foot dam is dwarfed by the rugged canyon walls.

Figure 22. Rugged outcrops of Upper Triassic strata near Stud Creek. A probable fault extends from bottom to top. The Snake River is 3000 feet below the bench in the top-center of the photograph.

Figure 23. Upper (?) Triassic rocks exposed near Wild Sheep and Bull Creeks, Oregon. A stratigraphic section, several thousand feet thick, can be measured in this area. The relief is about 5500 feet.

Figure 24. Aerial view looking east across Snake River Canyon from Lookout Mountain in Oregon to Seven Devils Mountains in Idaho.


BERNARD CR.
WATERSPOUT CR.
SNAKE RIVER
SADDLE CR.

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