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GEOMORPHOLOGY OF THE CONTINENTAL TERRACE OFF THE NORTHERN COAST OF OREGON

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Introduction

The continental terrace off the central and southern coast of Oregon has been described in two earlier papers published in The ORE BIN (Byrne, 1962, 1963). This paper presents a bathymetric chart and a description of the major submarine geomorphic features of the continental shelf and continental slope off the northern coast of Oregon, from 45°00'N to 46°30'N. In this northern area, the continental terrace is traversed by Astoria Submarine Canyon, and the lower portion of the continental slope is overlapped by Astoria Fan*, apparently a depositional apron consisting of sediment discharged from the mouth of Astoria Canyon (figure 1).

The bathymetric chart of the area (plate 1) is based on the unpublished soundings from 22 distinct surveys of the U.S. Coast and Geodetic Survey, with supplementary soundings made by the Department of Oceanography, Oregon State University. Three different contour intervals are used on the chart, which includes the continental shelf and the upper two-thirds of the continental slope (to a depth of 1,000 fathoms). For depths less than 100 fathoms, the sounding density varies from 7 to 200 soundings per square mile, and a contour interval of 10 fathoms is used. Between 100 and 1,000 fathoms, where the sounding density is one to five soundings per square mile, a 50-fathom contour interval is employed. Where soundings are less than one per square mile, below 1,000 fathoms, the contour interval is 100 fathoms. It is thought that these contour intervals adequately portray the major features of the continental slope, and also give a more detailed picture of the features of the continental shelf.

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* This feature was previously referred to as Astoria Cone, but in keeping with the list of terms for undersea features recently accepted by the U. S. Board of Geographic Names, the term "fan," rather than "cone," will be used henceforth.

Continental Shelf

As is true elsewhere off the Oregon coast, the continental shelf is narrower, steeper, and has its seaward edge in deeper water than is generally the case elsewhere around the world. For this northern area the shelf is widest south of the Columbia River, and has a maximum width of 30.3 nautical miles* at latitude 46°00'N. The shelf break, or outer edge of the shelf, trends essentially north-south in the area north of 45°50'N, but south of this latitude trends southeasterly, and consequently the shelf narrows to a minimum width of 13 miles off Cape Kiwanda. South of Cape Kiwanda there is a general increase in the width of the shelf, which is best seen on the chart for the area off the central coast of Oregon (Byrne, 1962).

The change in slope which marks the edge of the continental shelf (shelf break) occurs at about 80 fathoms north of Astoria Canyon, but generally increases in depth south of the canyon to 90 fathoms, and then to 100 fathoms in the southern part of the area. The slope of the shelf, determined from the shelf width and depth of shelf break, varies from 0°11' to 0°26'. For comparison, average values for the continental shelves of the world are: width, 40 nautical miles; depth of shelf break, 72 fathoms; average slope, 0°07' (Shepard, 1963, p. 257).

Although bottom notations made by the U.S. Coast and Geodetic Survey and samples collected by the Department of Oceanography indicate that the major portion of the continental shelf is covered by unconsolidated sediment, in several places outcrops of rock form shoals which rise above the general level of the shelf. These positive features, which are of interest to anyone concerned with the bedrock geology of the continental terrace, occur primarily near the edge of the shelf between latitudes 45°50'N and 46°00'N. In this area, a number of individual banks are delineated by the 80-fathom contour. This group of small hills is tentatively named "The Nehalem Banks." The largest of these is about 6 miles long, 2.5 miles wide, and 21 fathoms high. Bottom notations indicate that the material making up the banks is shale.

Another indication of rock exposed on the shelf occurs between the 70- and 80-fathom contours directly south of Astoria Canyon; the bottom notation on U. S. Coast and Geodetic Survey Chart 5902 indicates that the rock is shale. The Department of Oceanography collected a sample of this material from 75 fathoms of water at approximately 46°12.7'N,

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* A nautical mile equals approximately one minute of arc of a great circle (one minute of latitude); officially, 6,076.115 feet. In this report, distances are expressed in nautical miles.

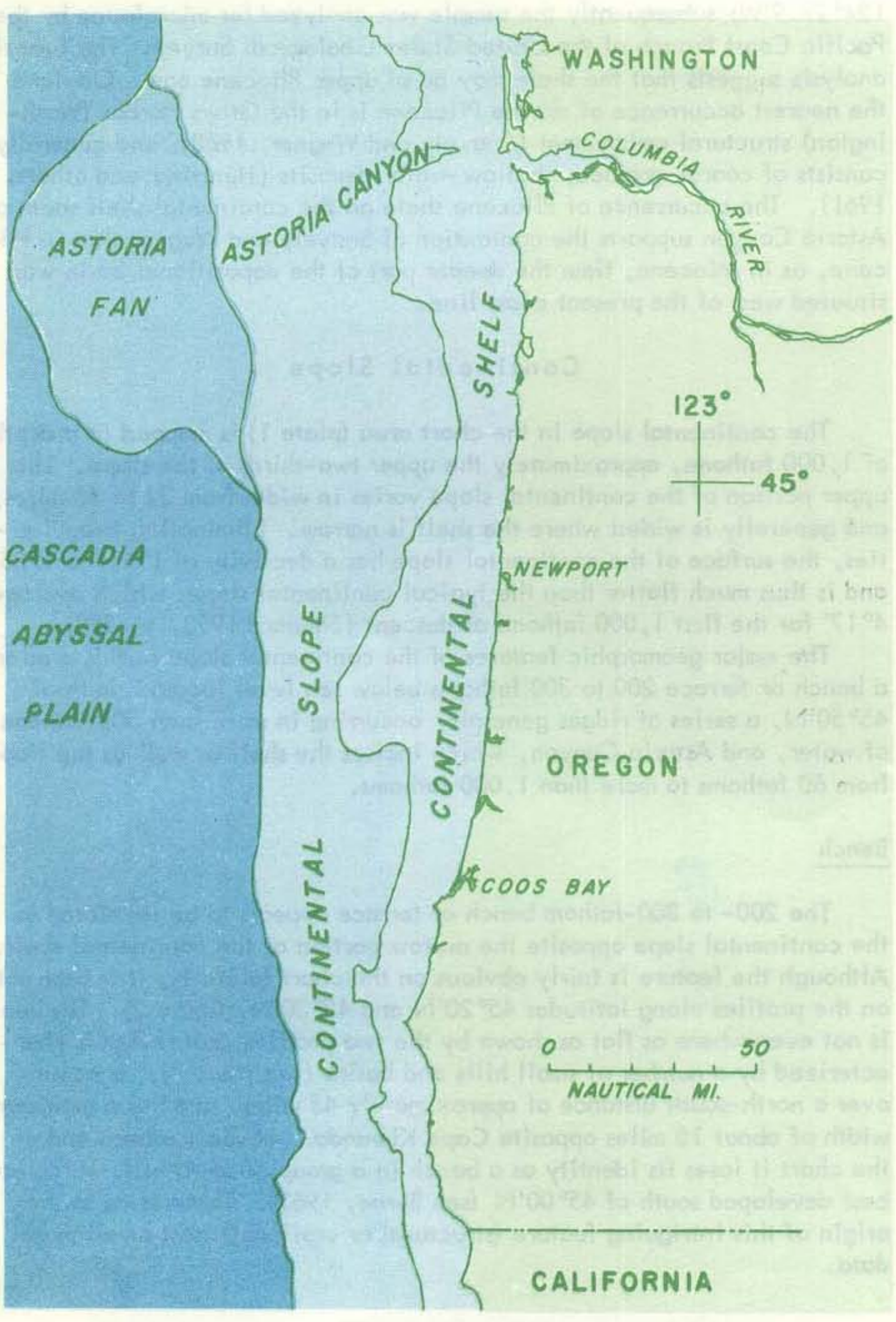

Figure 1. Index map of the submarine geomorphic features off the coast of Oregon.

124° 29.9'W; subsequently the sample was analyzed for microfauna by the Pacific Coast Branch of the United States Geological Survey. The faunal analysis suggests that the shale may be of upper Pliocene age. On land the nearest occurrence of marine Pliocene is in the Grays Harbor (Washington) structural embayment (Snavely and Wagner, 1963), and generally consists of coarse-grained, shallow-water deposits (Huntting and others, 1961). The occurrence of Pliocene shale on the continental shelf south of Astoria Canyon supports the contention of Snavely and Wagner that in Pliocene, as in Miocene, time the deeper part of the depositional basin was situated west of the present coast line.

Continental Slope

The continental slope in the chart area (plate 1) is mapped to a depth of 1,000 fathoms, approximately the upper two-thirds of the slope. This upper portion of the continental slope varies in width from 32 to 43 miles, and generally is widest where the shelf is narrow. Eliminating irregularities, the surface of the continental slope has a declivity of 1°11' to 1°35', and is thus much flatter than the typical continental slope, which averages 4°17' for the first 1,000 fathoms of descent (Shepard 1963, p. 298).

The major geomorphic features of the continental slope in this area are a bench or terrace 200 to 300 fathoms below sea level located south of 45°50'N, a series of ridges generally occurring in more than 500 fathoms of water, and Astoria Canyon, which incises the shelf as well as the slope from 60 fathoms to more than 1,000 fathoms.

Bench

The 200- to 300-fathom bench or terrace appears to be restricted to the continental slope opposite the narrow portion of the continental shelf. Although the feature is fairly obvious on the chart (plate 1), it is best noted on the profiles along latitudes 45°20'N and 45°30'N (figure 2). The bench is not everywhere as flat as shown by the two profiles, but rather is characterized by a number of small hills and basins (see plate 1). It occurs over a north-south distance of approximately 45 miles, and has a maximum width of about 15 miles opposite Cape Kiwanda. At the southern end of the chart it loses its identity as a bench in a group of small hills which are best developed south of 45°00'N (see Byrne, 1962). Theories as to the origin of this intriguing feature (structural or erosional) must await more data.

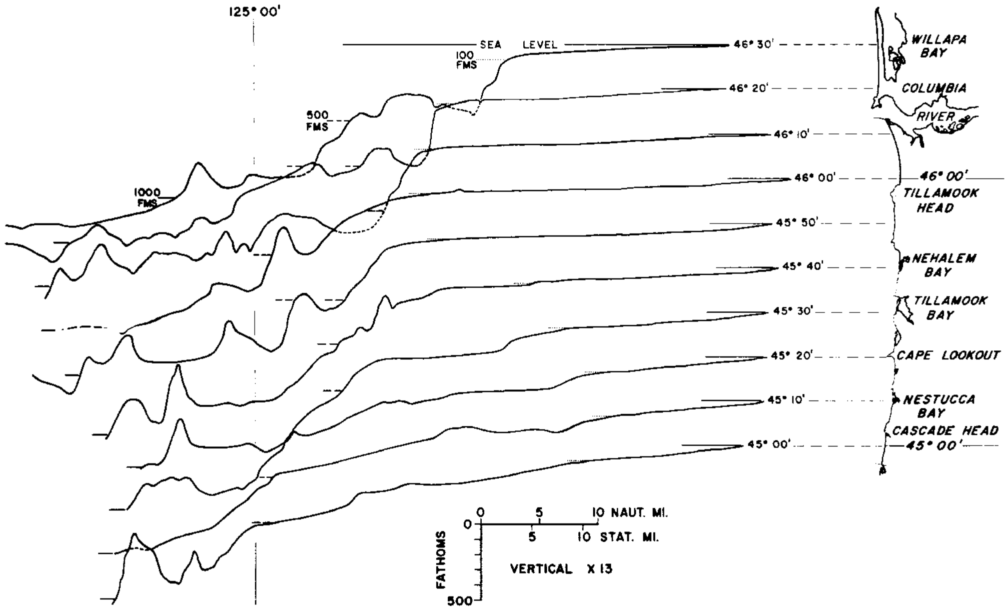

Figure 2. Profiles of the continental terrace from 45°00'N to 46°30'N.

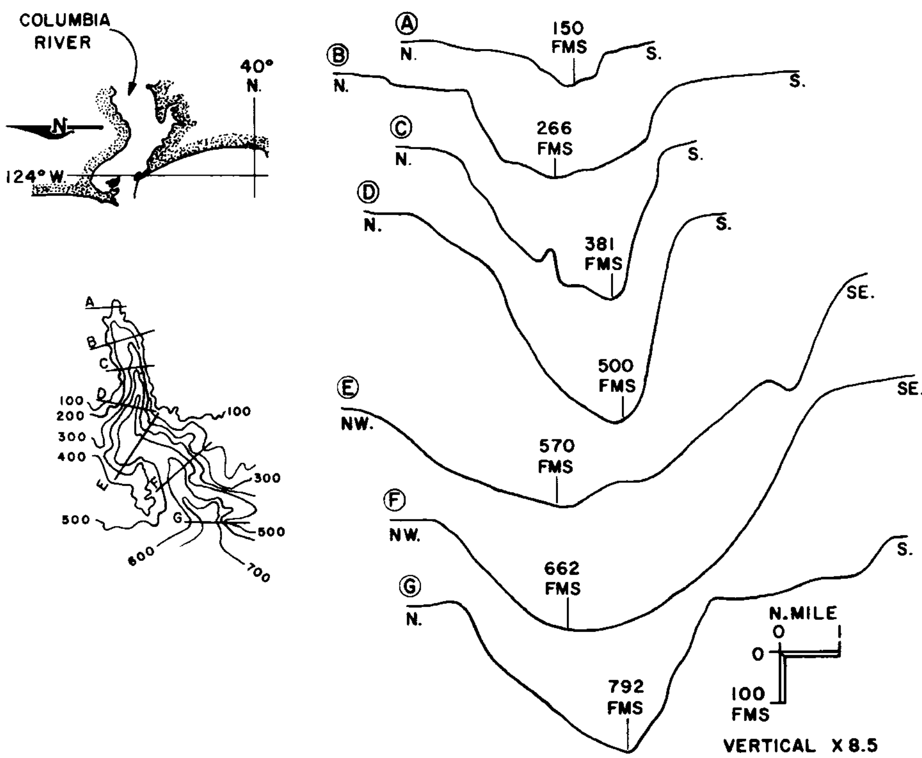

Figure 3. Transverse profiles of the upper portion of Astoria Canyon.

Ridges

At depths generally greater than 500 fathoms, the continental slope is characterized by a series of ridges and intervening troughs and basins. The ridges, which are 5 to 40 miles long, appear to be oriented primarily north-northwest, and because of the more or less uniform alignment, are considered to be structural features. They exhibit up to 376 fathoms of relief on the landward sides and up to 627 fathoms of relief on the seaward sides, but average about half those values. A measurement of the landward and seaward slopes indicates that the ridges are slightly steeper on the seaward flanks; the landward slopes are in most places 8 to 11 degrees, the seaward ones, 12 to 16 degrees. Possibly genetically related to the ridges is a series of scarps trending north-northeast along the south side of Astoria Canyon between 124° 40'W and 125° 00'W. The ridges and scarps appear to be developed along two linear trends at an angle to each other of 30 to 50 degrees. This angular relationship further suggests that the geomorphic features on this portion of the continental slope may be of structural origin.

Astoria Canyon

Astoria Canyon heads in about 60 fathoms of water approximately 10 miles west of the mouth of the Columbia River. The canyon is mildly sinuous and exhibits an overall orientation to the west-southwest. The general relationship between the sinuosity of the canyon and the scarps mentioned above presents the possibility that the course of the canyon is structurally controlled. The axis of the canyon can be traced fairly continuously to 800 fathoms, but the low sounding density makes the exact position of the canyon below that depth questionable. A distinct possibility exists that the axis of the canyon turns to the north between two elongate ridges, and that Astoria Canyon is a tributary of the canyon to the north. However, the position of the apex of Astoria Fan implies that the course of the canyon shown on the chart is the correct one.

Where the canyon is incised into the continental shelf, its boundaries are definite; in deeper water, the precise limits of the canyon may become confused by the ridge system. In the area of the outer shelf, the canyon is one to four miles wide, and has 300 to 400 fathoms of relief (figure 3). The slope along the axis varies irregularly from 0° 27' to 2° 34', but generally is one to two degrees. In its upper reaches, the canyon is steeper on the south side than on the north side. Measurements made from the original survey sheets indicate slopes of 5 to 35 degrees for the south wall, and slopes of 4 to 8 degrees for the north wall. Precision depth records made by the Department of Oceanography suggest that slumping occurs along the north wall, and may contribute material which ultimately is carried down the canyon to Astoria Fan.

Although the question of the origin of submarine canyons is a long way from being completely solved at the present time, many marine geologists feel that the upper or shallow portions of the canyons may have been initiated by subaerial erosion during a lower stand of the sea, probably during the Pleistocene, and that the movement of material down the canyon in response to gravity has served to erode the canyons into deeper water and to keep the existing canyons essentially clear of great quantities of sedimentary debris. The presence of sand in long cores taken from Astoria Fan is evidence that Astoria Canyon does serve as an avenue for the movement of fairly coarse material from shallow to deep water. The exact relationship of the Columbia River to Astoria Canyon is yet to be learned.

Acknowledgments

The writer is indebted to the Pacific Coast Branch of the United States Geological Survey for the faunal analysis of the rock sample. This study was carried out under contract with the Office of Naval Research, Contract Nonr 1286(02) Project NR 083-102.

References

Byrne, J. V., 1962, Geomorphology of the continental terrace off the central coast of Oregon: The ORE BIN, vol. 24, no. 5, p. 65-74.

__________, 1963, Geomorphology of the Oregon continental terrace south of Coos Bay: The ORE BIN, vol. 25, no. 9, p. 149-157.

Huntting, M. T., Bennett, W. A. G., Livingston, V. E., and Moen, W. S., 1961, Geologic map of Washington: State of Wash. Dept. of Conserv., Div. of Mines and Geol.

Shepard, F. P., 1963, Submarine geology (second edition): Harper and Row, New York, 557 p.

Snavely, P.D., Jr., and Wagner, H.C., 1963, Tertiary geologic history of western Oregon and Washington: State of Wash. Dept. of Conserv., Div. of Mines and Geol., Rept. of Invest No. 22, 25 p.

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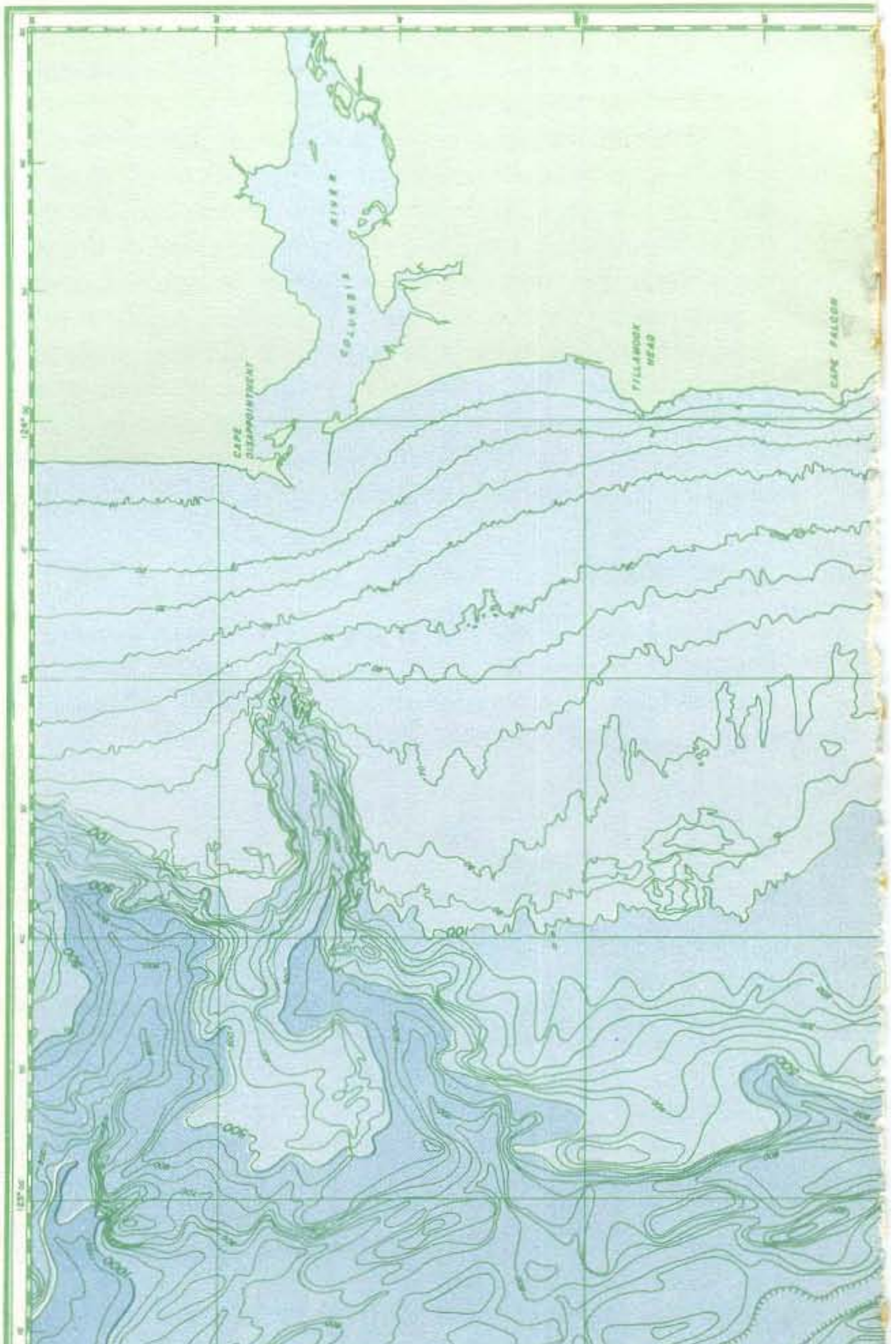
CAPE DISAPPOINTMENT
COLUMBIA RIVER
TILLAMOOK HEAD
CAPE FALCON

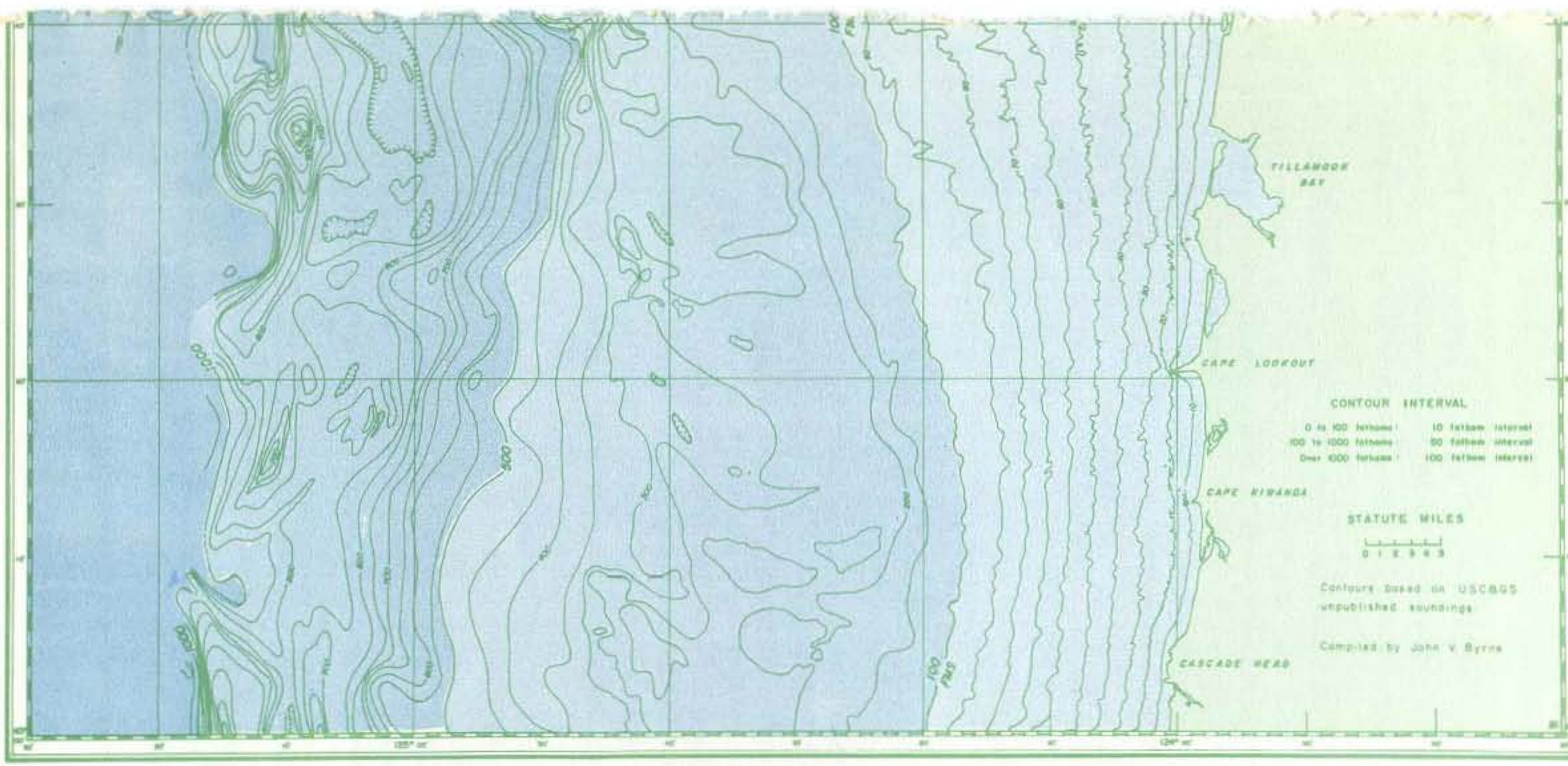

Plate 1. Bathymetric chart of the continental terrace off the northern coast of Oregon, 45°00'N to 46°30'N.

U.S.G.S. BEGINS ROCK ANALYSIS PROGRAM

Four igneous rocks have been collected in Oregon by geologists of the U.S. Geological Survey for use as standards of chemical composition. The Geological Survey plans to make these rocks available as analyzed samples for worldwide distribution.

The Oregon rocks will be carefully ground and split, and portions analyzed by a number of selected laboratories throughout the world. The analytical work will include measurements of major constituents by wet chemical methods, x-ray spectrometry, or other applicable techniques, and trace element measurements by many techniques including emission spectroscopy. Mineralogical studies of the rocks also will be made.

Samples of the analyzed rocks will be available to research institutions and universities. The present trend to instrumental methods of analysis makes comparison materials of this kind very important, and it is anticipated that these analyzed rocks from Oregon will be referred to repeatedly in the literature in comparing results and indicating the accuracy of analytical data.

The following are the rocks collected from Oregon for the standards program:

1. Flow rock, probably andesite, collected by George W. Walker from the east wall of Guano Valley, Lake County, Oregon. A dense greenish-gray, commonly mottled, locally flow-jointed rock that occurs on the flanks of a small, andesitic, strato volcano of probable middle or late Miocene age.
2. Rhyo-dacite, collected by George W. Walker about 10 miles NE of Lake Abert, Lake County, Oregon, from a mass that is probably a part of an exogenous dome or related flow of late Miocene (?) age.
3. Columbia River Basalt, collected by Aaron C. Waters from the upper part of a flow exposed in a quarry, Cooper Falls, Bridal Veil quadrangle, Oregon.
4. Nephelene syenite, collected by Parke D. Snavely, Jr., and Norman MacLeod from Table Mountain Sill, Georgia-Pacific Quarry on Table Mountain, Tidewater quadrangle, Oregon.

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NOTICE

New and renewal subscriptions to The ORE BIN will be $1.00 per year, effective January 1, 1964. Available back issues will be 10 cents each.

NEW OIL AND GAS SERIES PROMULGATED

"Petroleum Geology of the Western Snake River Basin, Oregon-Idaho" by V. C. Newton, Jr., and R. E. Corcoran, Oil and Gas Investigations No. 1 published by this department, is now available at its three offices. The postpaid price is $2.50.

The 64-page volume contains three maps and two subsurface sections, 30 well logs, seven gas analyses, porosity and permeability data from six wells, and 47 references to earlier publications and graduate theses. The Western Snake River Basin was chosen for the first of this new series, because a large amount of subsurface information is available and the possibilities for developing commercial gas production appear encouraging.

The Western Snake River Basin is part of a much larger area usually referred to as the "Snake River Plain," a broad, relatively flat plain forming a belt across southern Idaho and extending into southeastern Oregon. The western portion, which has an area of about 2,000 square miles and an average elevation of about 2,300 feet, is roughly triangular in shape, with the base south of Boise and Nampa in Idaho and the apex north of Vale and Ontario in Oregon.

The first exploration for petroleum in the region began in 1902, and sporadic but unsuccessful drilling has continued to the present time. The major incentive for these activities was the fact that varying quantities of gas were encountered in many of the test wells. None of these drillings have produced commercial amounts for sustained periods, but several shallow wells provide gas for a few ranches.

The basin is underlain by a nonmarine section of sediments and lavas at least 5,000 feet thick ranging in age from middle or late Miocene to Pleistocene. The high mountains that surround the area on three sides are composed of slightly metamorphosed Permian to Jurassic sediments and volcanics and Jurassic-Cretaceous plutonic rocks of the Idaho batholith.

The major structural feature of the basin is a broad downwarp of Pliocene and younger formations bounded on both sides by fault blocks of older rock. The best possibilities for entrapment of oil or gas appear to be in updip pinch-outs of sand horizons in the Pliocene section.

The similarity in rock types and depositional environment of the Western Snake River Basin to other well-known nonmarine basins in the world that now produce commercial amounts of oil and gas indicate that conditions suitable for the formation of hydrocarbons apparently existed in this region during late Miocene and early Pliocene time. The constantly increasing demand for gas in the Pacific Northwest and its nearness to the El Paso - Four Corners pipeline make the basin an attractive area for exploration.

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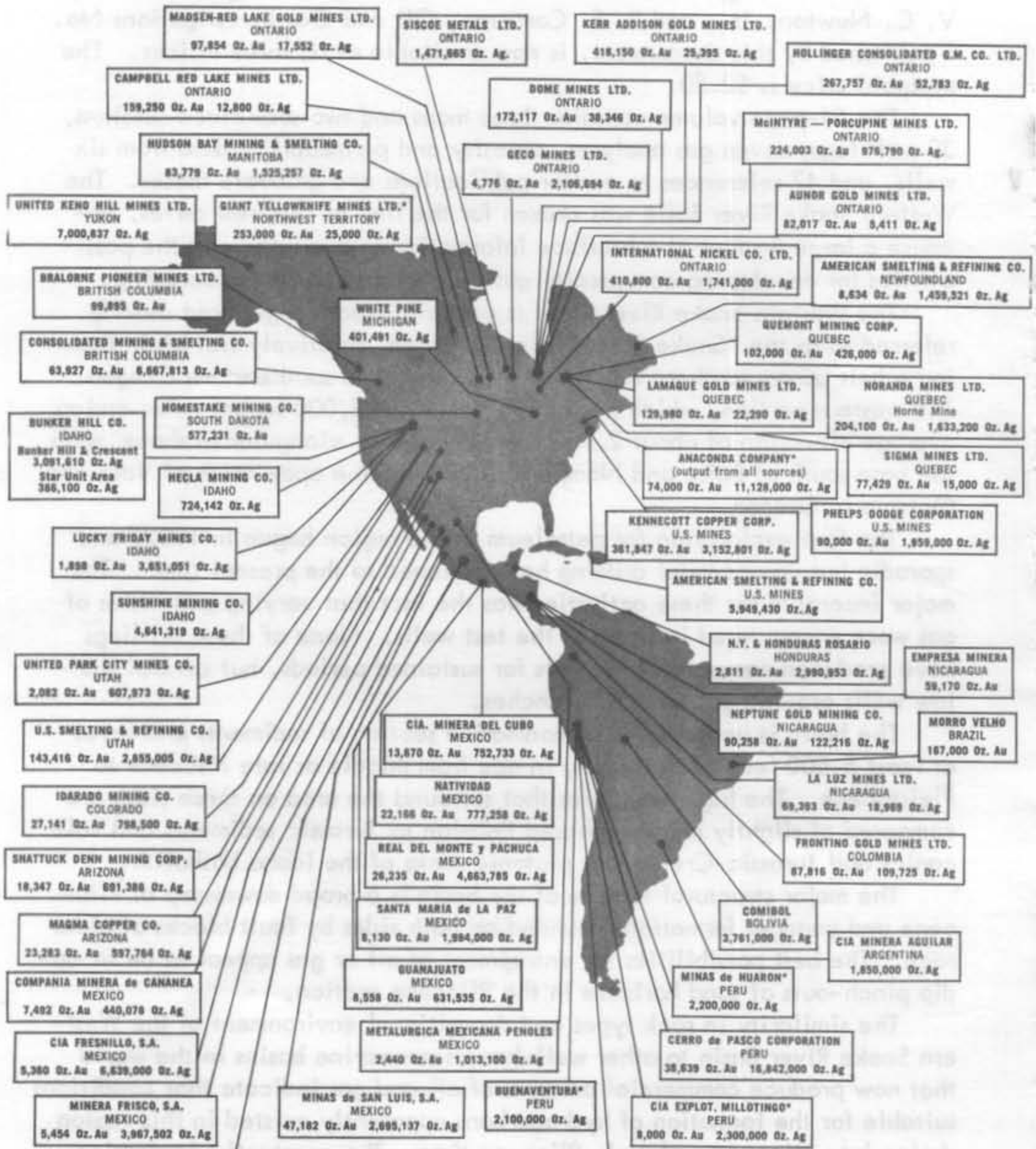
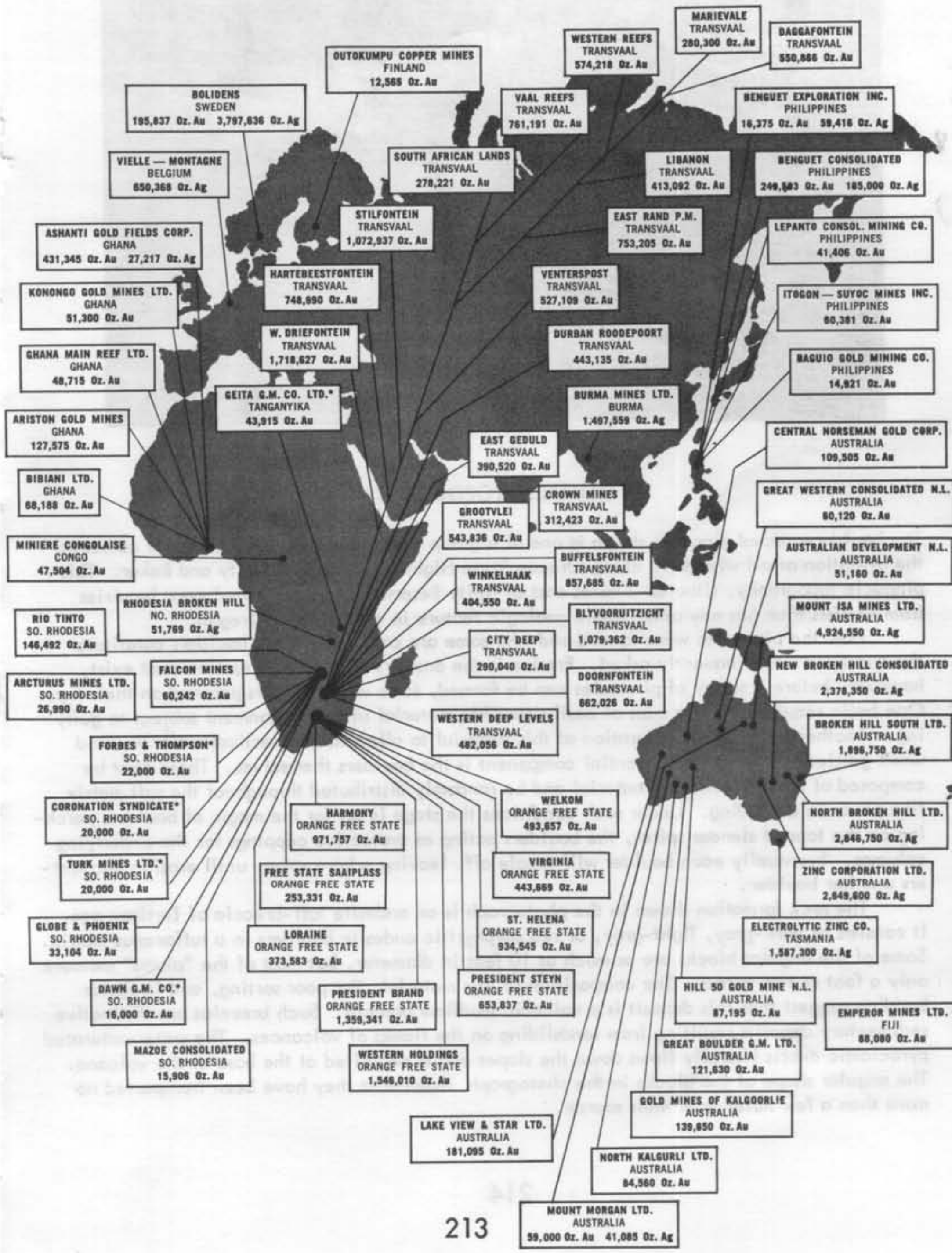
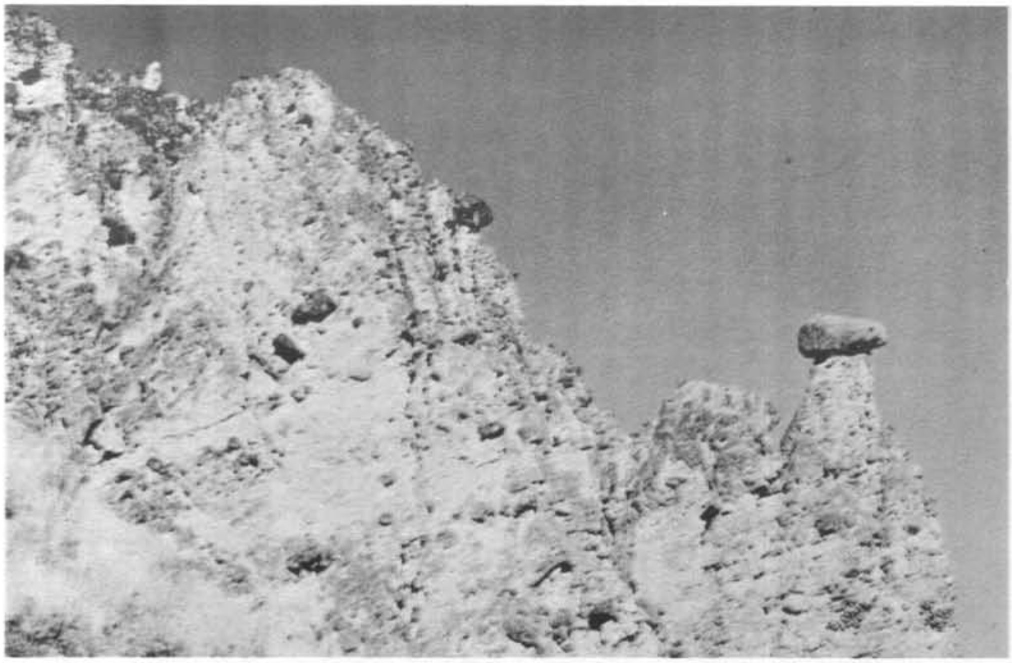
PRINCIPAL GOLD AND SILVER



Map shows 1962 gold and silver producers selected on basis of their economic importance to the areas in which they are located (Courtesy of American Cyanamid Co., New York).

PRODUCERS OF THE WORLD IN 1962





PINNACLE TOPOGRAPHY

The boulder-capped pinnacle shown is one of a group of picturesque rock spires that command the attention of all who drive along Oregon State Highway 7 between Unity and Baker. This pinnacle topography, situated 2 miles east of Unity Reservoir, has generated more inquiries from tourists than has any other single geologic feature in northeastern Oregon.

How the pinnacles were formed and why some are capped by large boulders constitute the questions most frequently asked. Erosion is the answer. A special situation must exist, however, before a swarm of pinnacles can be formed, some with boulders perched on their tops. One basic requirement is a mass of easily erodible material in an environment subject to gullying. Another is sufficient induration of this material to allow nearly vertical walls to stand when gullied. Finally, the essential component is the boulders themselves. These must be composed of erosion-resistant material and be randomly distributed throughout the soft matrix like plums in a pudding. Under such conditions the stage is set for the magic of boulders perching on the tops of slender spires, the boulders acting as protective cappings for the underlying columns. Eventually each boulder will topple off, leaving a bare spire until erosion encounters another boulder.

The rock formation shown in the photograph is an andesite tuff-breccia of Tertiary age. It consists of dark-gray, light-gray, or red porphyritic andesite boulders in a tuffaceous matrix. Some of the angular blocks are as much as 10 feet in diameter, but most of the "plums" measure only a foot or two across. The composition of this material, the poor sorting, and irregular bedding suggest that this deposit is a volcanic mudflow breccia. Such breccias are distinctive sedimentary deposits resulting from landsliding on the flanks of volcanoes. The water-saturated pyroclastic debris literally flows down the slopes and is deposited at the base of the volcano. The angular shape of the blocks in the photograph shows that they have been transported no more than a few miles from their source.

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