

# The Ore Bin



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Head Office: 1069 State Office Bldg., Portland, Oregon - 97201  
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## NOTES ON LATE TERTIARY FORAMINIFERA FROM OFF THE CENTRAL COAST OF OREGON

By

Gerald A. Fowler  
Department of Oceanography, Oregon State University

### Introduction

Since 1960 the Department of Oceanography at Oregon State University has been collecting rock samples from the continental shelf and slope off Oregon. Most of them were obtained from Stonewall and Heceta Banks during the completion of a doctoral research project by Maloney (1965). Information on sampling techniques, location data, and lithologic descriptions are given by Maloney and Byrne (1964) and Maloney (1965).

Foraminiferal faunas have been extracted from rocks taken at 34 stations. A study of these has revealed chronologically and paleoenvironmentally useful assemblages from 12 stations (Figure 1). The dominant or distinctive members of the faunas are reported and discussed here as a contribution to a better understanding of the geologic evolution of the Oregon continental margin. Knowledge of the faunas is particularly important, since most of them are not represented onshore in the state, and since they exist in a section actively being explored for petroleum.

### Age

Age determinations previously reported for rock samples off the central coast of Oregon range from late Miocene to perhaps Pleistocene (Byrne, 1962, 1963; Byrne and Maloney, 1965). Both mollusca and foraminifera were used in these determinations, some of which were made by the writer.

All but one of the samples examined contain foraminifera dated as Pliocene or younger. The one exception comes from station 113 at the northwest corner of Stonewall Bank (Figure 1). The siltstone from this locality contains a well-preserved assemblage (Table 1) that is completely different from any of the others studied. It is referred to the lower part of the Relizian Stage of the middle Miocene (Table 2) as defined for the California

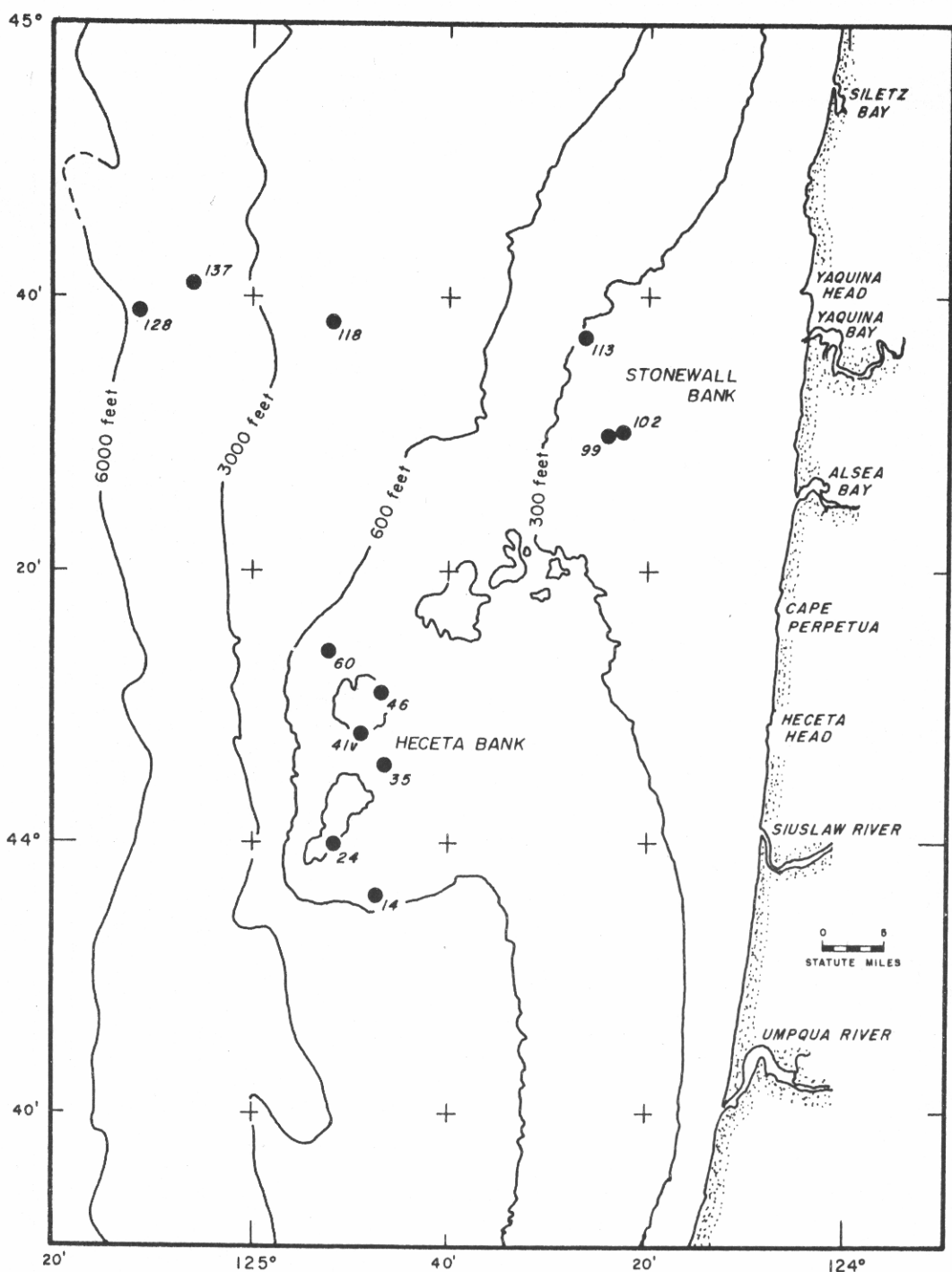


Figure 1. Simplified bathymetric map of the central Oregon continental margin showing locations of rock samples used in this study. The base is adapted from a map compiled by Byrne (1962).

TABLE 1. Relative abundance of dominant and distinctive benthic foraminifera from Oregon offshore rocks. Station numbers in parentheses are accession numbers of the OSU Department of Oceanography. (A = abundant, C = common, R = rare)

| SPECIES                                                        | STATION       |             |               |             |             |               |            |              |              |              |              |
|----------------------------------------------------------------|---------------|-------------|---------------|-------------|-------------|---------------|------------|--------------|--------------|--------------|--------------|
|                                                                | 14(6301-2-95) | 24(6209-21) | 35(6301-2-68) | 41(6209-17) | 46(6209-12) | 60(6301-2-24) | 99(6212-9) | 102(OC 0021) | 113(OC 0001) | 118(OC 0042) | 128(OC 0041) |
| <u>Baggina cf. B. californica</u> Cushman                      |               |             |               |             |             |               |            |              | C            |              |              |
| <u>Bolivina advena striatella</u> Cushman                      |               |             |               |             |             |               |            |              | C            |              |              |
| <u>Bolivina argentea</u> Cushman                               |               |             |               |             |             |               |            |              |              | A            |              |
| <u>Bolivina brevior</u> Cushman                                |               |             |               |             |             |               |            |              | C            |              |              |
| <u>Bolivina seminuda foraminata</u> R. E. and K. C. Stewart    |               |             |               |             | R           |               |            |              |              |              |              |
| <u>Bolivina seminuda seminuda</u> Cushman                      |               |             |               |             |             |               |            |              |              | C            |              |
| <u>Bolivina semiperforata</u> Martin                           |               |             |               |             | C           |               |            |              |              |              |              |
| <u>Bolivina spissa</u> Cushman                                 | C             | C           | C             | C           |             | C             |            |              |              |              |              |
| <u>Bolivina subadvena sulphurensis</u> Cushman and Adams       |               |             |               |             | R           |               |            |              |              | C            | C            |
| <u>Bulimina striata mexicana</u> Cushman                       |               |             |               |             |             |               |            |              |              |              | C            |
| <u>Bulimina subacuminata</u> Cushman and R. E. Stewart         |               | C           |               |             |             | C             |            |              |              |              |              |
| <u>Buliminella californica</u> Cushman                         |               |             |               |             |             |               |            |              | A            |              |              |
| <u>Buliminella exilis</u> (H. B. Brady)                        | A             |             |               |             | A           | C             |            |              |              | C            |              |
| <u>Cassidulina delicata</u> Cushman                            | A             |             | R             |             |             | A             |            |              |              | C            |              |
| <u>Cassidulina cf. C. modeloensis</u> Rankin                   |               |             |               |             |             |               |            |              | C            |              |              |
| <u>Cassidulina subglobosa</u> H. B. Brady                      |               |             | A             |             |             |               | C          |              |              |              |              |
| <u>Cassidulina cf. C. tumida</u> Natland                       |               |             |               |             | C           |               |            |              |              |              |              |
| <u>Cassidulinoides cornuta</u> (Cushman)                       |               |             |               |             |             | A             |            |              |              |              |              |
| <u>Cibicides mckannai</u> Galloway and Wissler                 |               |             |               |             |             |               |            |              |              |              | C            |
| <u>Epistominella carinata pacifica</u> (Cushman)               |               |             | C             | C           |             | C             |            | C            |              |              |              |
| <u>Epistominella carinata parva</u> (Cushman and Laiming)      |               |             |               |             |             |               |            |              | R            |              |              |
| <u>Epistominella carinata smithi</u> (R. E. and K. C. Stewart) |               |             | A             |             |             |               |            |              |              |              |              |
| <u>Loxostomum pseudobeyrichi</u> (Cushman)                     | C             |             |               |             | C           |               |            |              |              |              |              |
| <u>Nonion pompilioides</u> (Fichtel and Moll)                  |               |             |               |             |             |               |            |              |              |              | R            |
| <u>Nonionella costifera</u> (Cushman)                          |               |             |               |             |             |               |            |              | R            |              |              |
| <u>Plectofrondicularia advena</u> (Cushman)                    | C             |             |               |             |             |               |            |              |              |              |              |
| <u>Stilostomella adolphina</u> (d'Orbigny)                     |               |             |               |             |             | C             |            |              |              |              |              |
| <u>Stilostomella advena</u> (Cushman and Laiming)              |               |             |               |             |             | C             |            |              |              |              |              |
| <u>Uvigerina juncea</u> Cushman and Todd                       |               |             |               |             |             |               |            | A            |              |              |              |
| <u>Uvigerina peregrina hispidocostata</u> Cushman and Todd     |               |             | C             |             |             |               | A          |              |              |              | C            |
| <u>Uvigerina peregrina peregrina</u> Cushman                   | C             | C           | C             | A           | C           | C             |            |              |              | A            | A            |
| <u>Uvigerina cf. U. segundoensis</u> Cushman and Galliher      |               |             |               |             |             |               |            |              |              | R            | F            |
| <u>Uvigerina senticosa</u> Cushman                             |               |             |               |             |             |               |            |              |              |              | C            |
| <u>Uvigerinella californica ornata</u> Cushman                 |               |             |               |             |             |               |            | C            |              |              |              |

Table 2. Estimated paleodepths and ages of the foraminiferal faunas reported on table 1 and approximate amounts of uplift of the Oregon Continental Margin. Depths are in feet.

| Station | Present Depth | Paleodepth | Approximate Uplift | Age                       |
|---------|---------------|------------|--------------------|---------------------------|
| 102     | 150           | 350        | 200                | ?                         |
| 99      | 180           | 3500       | 3300               | Pliocene                  |
| 113     | 270           | 1000       | 700                | Middle Miocene (Relizian) |
| 46      | 288           | 3000       | 2700               | Pliocene (? Early)        |
| 24      | 300           | 2500       | 2200               | Pliocene                  |
| 41      | 300           | 3500       | 3200               | Pliocene                  |
| 35      | 378           | 2500       | 2100               | Pliocene                  |
| 60      | 396           | 2500       | 2100               | Pliocene (? Early)        |
| 14      | 456           | 2500       | 2000               | Pliocene                  |
| 118     | 1800          | 3000       | 1200               | Pliocene (? Early)        |
| 137     | 2160          | 3500       | 1300               | Pliocene (? Early)        |
| 128     | 5250          | 9000       | 3800               | ?                         |

section (Kleinpell, 1938). Definitive foraminifera include Baggina cf. B. californica, Bolivina advena striatella, Buliminella californica, and Uvigerinella californica ornata. The only reported occurrence of Relizian foraminifera from onshore Oregon is in strata of the Astoria Formation in the southern part of the Astoria Embayment (Snively, Rau, and Wagner, 1964). Foraminiferal assemblages almost identical to the one reported here are present at several localities in the Grays Harbor area of western Washington (Rau, 1948; Fowler, 1965). The fauna occurs very high in the Astoria Formation as defined in that area.

Most foraminiferal species from assemblages considered to be Pliocene or younger are still living off Oregon. Others are living in somewhat warmer water as far south as Central America (Smith, 1964). Very few, if any, are extinct. This situation makes an age assessment somewhat difficult. Since the faunas came from firm rocks exposed on the shelf and slope, and since they represent environments much deeper than present depths at the sampling sites, at least a pre-Wisconsin and probably a pre-Pleistocene age is indicated.

Detailed foraminiferal biostratigraphic analyses of complete Pliocene sections have been made for the southern California area (Natland, 1953 and 1957; Ingle, 1962). Nevertheless, it is often impossible to place isolated foraminiferal faunas correctly into the established frameworks, because apparent stratigraphic differences are due to shifting biologic depth facies and not to evolution. In the Oregon offshore area, not even a physical stratigraphic framework is available for positioning isolated samples. One must, therefore, attempt to use the California zonations. Such long-

range comparisons are at best subjective and must be used carefully. The presence of such species as Bolivina seminuda foraminata, Bolivina semi-perforata, and Bolivina subadvena sulphurensis is reasonable assurance that many of the samples are Pliocene, but it is premature to try to affix lower, middle, or upper designations. However, some of the Oregon faunas have marked similarities to lower Pliocene Repettian faunas of the Los Angeles and Capistrano areas in Southern California (Martin, 1952; White, 1956). The nearest equivalent foraminiferal faunas in the Northwest are from the Quinault Formation of western Washington (Cushman, Stewart, and Stewart, 1949; Fowler, 1965) and the Wildcat Series of northern California (Cushman, Stewart and Stewart, 1930).

Faunal assemblages comparable to those from the late Miocene Montezano Formation of western Washington (Fowler, 1965) have not been recognized in the Oregon offshore area by this investigator. This suggests a possible stratigraphic break between the middle Miocene and Pliocene in this area.

Planktonic (floating) foraminifera are among the most reliable organisms for interregional correlations of Mesozoic and Cenozoic strata (Bandy, 1964). However, little is known of planktonic zonations in cool temperate areas, particularly in the Northwest. All of the Oregon offshore samples contain planktonic foraminifera, but only Globigerina pachyderma (Ehrenberg) is considered, at this time, to have any stratigraphic value. Bandy (1960) has demonstrated for the southern California section a dominance of right-coiling forms of this species in the lower and upper Pliocene and the Recent, and left-coiling specimens in the middle Pliocene and Pleistocene. This information has helped to affix possible narrow limitations on the Pliocene determinations of some of the Oregon samples (Table 2).

### Paleobathymetry

Knowledge of the distribution and ecology of modern foraminifera has expanded greatly in the last 20 years (Phleger, 1960). Studies of modern benthic (bottom dwelling) foraminifera have made known a regular succession of distinctive assemblages from shallow to deep water. This knowledge is being used by paleontologists to make paleoenvironmental interpretations that markedly advance our understanding of geologic history (Bandy and Arnal, 1960; Bandy and Kolpack, 1963).

Although exact ages are difficult to determine for the Oregon offshore faunas, very definite conclusions can be drawn on the paleobathymetry by comparing fossil species with modern ones. All of the faunas examined were deposited at water depths of 350 feet or greater, and most originated at upper middle slope depths of 2,500 to 3,500 feet (Table 2). Abundant specimens of Uvigerina juncea in sample 102 are diagnostic of outer shelf depths of about 350 feet, the shoalest reported in this paper. Modern homeomorphs

of the extinct middle Miocene species characterize upper slope depths of about 1,000 feet. Depths of 2,500 to 3,000 feet are represented by large numbers of typical specimens of Bolivina spissa, Buliminella exilis, Cassidulina delicata, Epistominella carinata smithi, Loxostomum pseudobeyrichi, and Uvigerina peregrina peregrina. Significant numbers of Uvigerina peregrina hispidocostata at stations 41, 99, and 137 indicate depths of approximately 3,500 feet. A Nonion pompilioides - Uvigerina senticosa paleobathymetric assemblage from station 128 lived at a depth of 9,000 feet or greater, the deepest recognized in the offshore area.

Of particular note is the marked difference in paleodepths of 3,500 and 350 feet between two adjacent stations on Stonewall Bank, 99 and 102 respectively. These may represent two formational units separated by an unconformity or fault.

The inferred paleodepths are considerably greater than the present depths at the sample stations. Amounts of uplift indicated range from 200 to more than 3,500 feet (Table 2). No trends in the rate of uplift of the Oregon continental margin are apparent in the data. This is largely because there is no assurance that samples from the same geologic horizon are being compared.

### Summary and Conclusions

On the basis of foraminiferal evidence, rocks from the Oregon offshore area are considered to be younger than most of those cropping out along the Oregon coast. All but one of them have been dated as Pliocene or younger. The one exception is dated as middle Miocene and probably represents a late phase in the development of the Astoria Formation. The other samples come from unnamed stratigraphic units that are not known to be exposed onshore.

All of the faunas were deposited at water depths greater than those existing at the collecting sites. The differences range from 200 to more than 3,500 feet. These differences are interpreted as expressions of the amount of uplift of the Oregon continental margin. Some areas have probably been elevated more than 3,500 feet since the middle Pliocene. Previous estimates of perhaps as much as 5,000 feet of uplift (Maloney and Byrne, 1965; Byrne, Maloney, and Fowler, 1965) were based upon incomplete faunal analyses.

### Acknowledgments

This study was carried out under contract with the Office of Naval Research, contract Nonr 1286(10). Samples were collected aboard the R/V ACONA. Neil J. Maloney processed the samples and prepared faunal slides. Thanks are extended to John V. Byrne and Susan J. Borden for critical and editorial reading of the manuscript.

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## SOUTHEASTERN MALHEUR COUNTY MAPPED

"Reconnaissance Geologic Map of the West Half of the Jordan Valley Quadrangle, Malheur County, Oregon," by G. W. Walker and C. A. Reppenning, has been issued by the U.S. Geological Survey as Miscellaneous Geological Investigations Map I-457. It may be obtained from the Geological Survey, Federal Center, Denver, Colorado 80225, for 75 cents.

The map area lies in the southeastern corner of Oregon in a region not previously mapped geologically. Idaho and Nevada are its eastern and southern boundaries, and long. 118° and lat. 43° are its western and northern boundaries. U.S. Highway 95 traverses the map area from the northeast corner near Jordan Valley to the Nevada line near McDermitt. The scale of the map is approximately 1 inch = 4 miles.

This part of the state is underlain by terrestrial volcanic and sedimentary rocks ranging in age from Miocene to Recent. Vertebrate faunas of Miocene, Pliocene, and Pleistocene age are the basis for dating much of the sedimentary strata and fossil localities are listed. At least 20 geologic units are shown on the map by colors and patterns and are described in the map legend. Although no formational names are given to these geologic units, some are correlated with known formations in other areas.

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## OCEAN CURRENT OBSERVATIONS FROM OFFSHORE DRILLING PLATFORMS

By

W. V. Burt and S. Borden

Department of Oceanography, Oregon State University

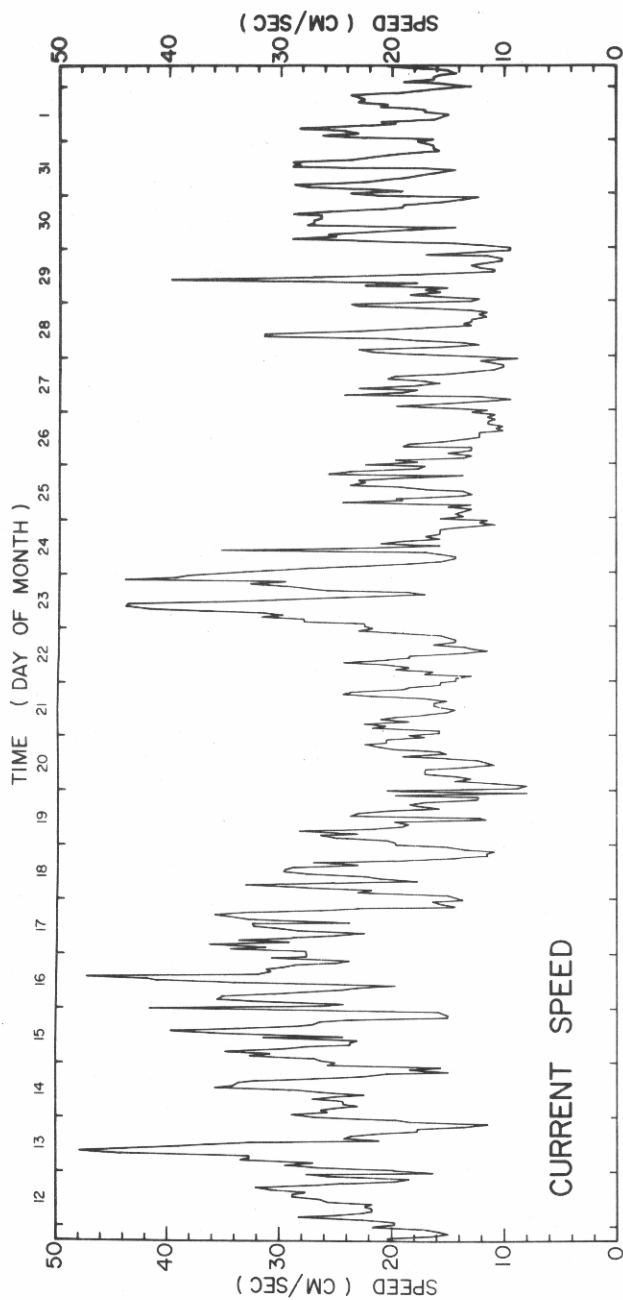
In early May of 1965, the Department of Oceanography at Oregon State University began a program of detailed current measurement in conjunction with the offshore oil exploration on the continental shelf off the Oregon coast. For several years, we have been surveying the currents in this area, and in the area farther seaward, but only in a general way. Only the surface currents had been measured in any detail, and those only by using floating devices such as drift bottles and drogues. The relative water motions below the surface had been inferred indirectly from observations of the temperature and salinity of the water. But on the continental shelf, where we know the currents should be quite variable, we had few direct observations to support our theoretical studies. We were, then, eager to take advantage of the opportunity to use the drilling platforms and the logistical support their operations could provide us in studying the current structure in more detail.

We made arrangements to use two of the drilling platforms operating offshore in the Newport area: WODECO III\*, leased jointly by Union Oil Co., Standard Oil Co. of California, and others; and BLUE WATER, operated by Shell Oil Co. All of our work to date has been done either on or near the WODECO III, first located about 20 miles northwest of Newport, and later on Stonewall Bank about 18 miles west of Waldport.

The project is designed to provide information about the currents and their causes and effects, as well as data for statistical studies. Eventually, we hope to have enough data on the currents and their driving forces to be able to make predictions about what can be expected to occur in this area in the future.

Currents were measured in four different ways: (1) with a fixed array of current meters suspended from a taut wire between an anchor and a sub-surface buoy located about a mile from the WODECO III, (2) with a "yo-yo" instrument system that was lowered from the deck of the WODECO III, (3) by optically tracking floating devices in the area near the WODECO III, and (4) indirectly, as inferred from temperature and salinity of the water in the area. By using all these methods, we will be able to view the current structure in a variety of ways, and thus examine it in more detail than had been possible in the past.

\* Western Offshore Drilling & Exploration Co. Barge No. 3

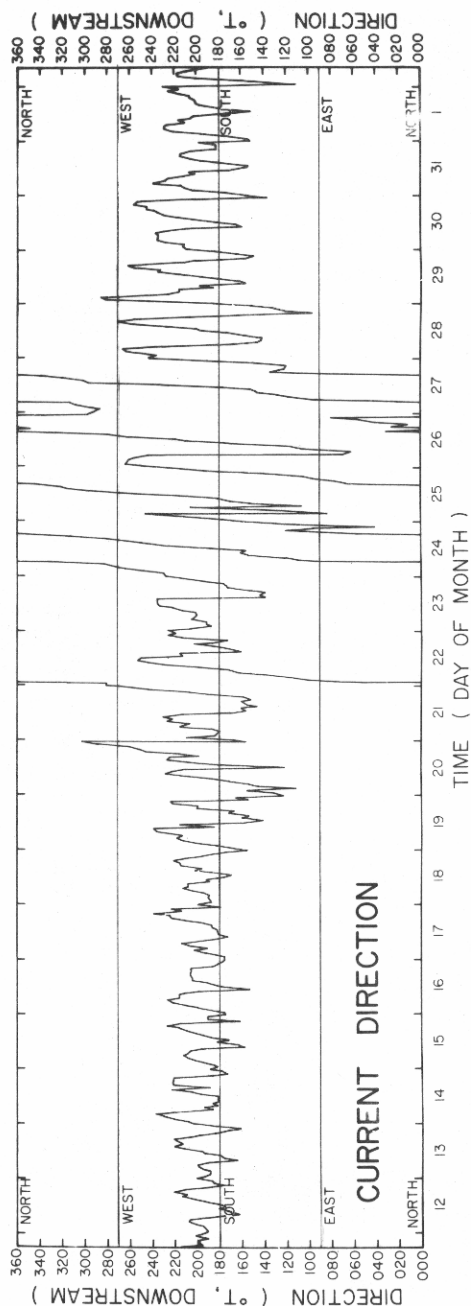


CURRENT SPEED AT A DEPTH OF 20 METERS

JULY 11 TO AUGUST 2, 1965

44° 51.5' N. 124° 15.2' W

( NINE MILES WEST-NORTHWEST OF DEPOE BAY )



CURRENT DIRECTION AT A DEPTH OF 20 METERS

JULY 11 TO AUGUST 2, 1965

44° 51.5' N, 124° 15.2' W

( NINE MILES WEST-NORTHWEST OF DEPOE BAY )

Preliminary analyses of the data taken last summer show that the currents are highly variable, and also quite strong. The accompanying figures show the current speed and direction at a single point 20 meters below the sea surface at the drilling location about 20 miles northwest of Newport. The data shown were taken continuously between July 11 and August 2, 1965. Current speeds ranged from 9 to 48 cm/sec, or from about 0.1 to 1.0 knots (1 knot equals about 50 cm/sec). Current speeds changed as much as 30 cm/sec within one day. The current generally set toward the south-southwest, but sometimes rotated through a complete clockwise circle (as on July 27).

Much of this variability can be attributed to the tides. When our observations have been fully analyzed through the use of computers, we should be able to predict this tidal variability with some accuracy. Other variations observed are apparently related to the winds, but just how they are related, we do not yet know. Continued series of observations of these currents, accompanied by regular meteorological observations both at sea and on the nearby shore, will provide a much stronger foundation for future predictions.

The detailed studies begun this summer form an important part of our comprehensive program, which encompasses the area from the coast to more than 200 miles off shore. The information gained from this project is a vital link in our chain of information on changes in oceanographic variables between our coastline and the open sea. Our findings from these efforts should be very useful to those who wish to exploit the rich area off our coast, not only for prediction of what they can expect to find there, but in forecasting the difficulties they might encounter in achieving their goals.

#### Acknowledgments

Financial support for this program has been furnished by NSF Grant GP 4472 and ONR Contract Nonr 1 286(10), NR 083-102. The generous assistance of the crews of WODECO III and BIG TIDE, Standard Oil Co., and California Research is gratefully acknowledged. Without their support, this program could not exist.

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#### REPORTS RELEASED BY GEOLOGICAL SURVEY

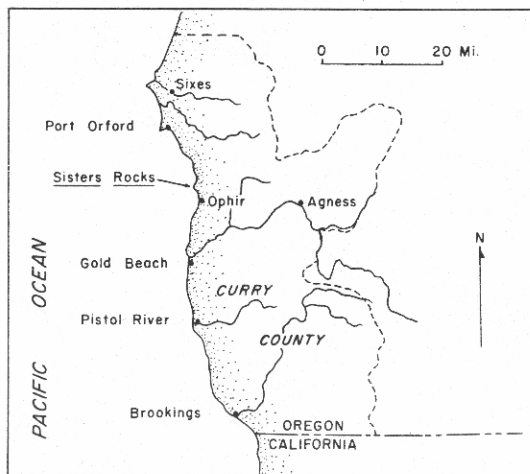
Two reports of economic interest to Oregon have been published by the U.S. Geological Survey. One is concerned with energy sources in areas of recent volcanism, and the other with potential power production from the Nehalem River. Circular 519, "Geothermal energy," may be obtained free from the Geological Survey, Washington D.C. 20242. Water-Supply Paper 1610-C, "Water power resources in Nehalem River Basin, Oregon, with sections on geology of sites," sells for \$1.25 by the Superintendent of Documents, Government Printing Office, Washington D. C. 20402.

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# LATE JURASSIC ICHTHYOSAUR FROM SISTERS ROCKS COASTAL SOUTHWESTERN OREGON

By

John G. Koch\* and Charles L. Camp\*\*



## Introduction

Ichthyosaur teeth and jaw fragments collected at Sisters Rocks (Figure 1) in 1961 by N. V. Peterson<sup>1/</sup> were given to J. G. Koch for use in his thesis studies. The remains have since been described in detail (Camp and Koch, 1966) and donated to the University of California, Berkeley, Museum of Paleontology (Loc. No. V6169, Spec. No. U.C. Mus. Pal. 65.304), where other Pacific Coast ichthyosaur fossils are kept.

Figure 1. Index map of southwestern Oregon.

## Ichthyosaur Morphology, Habitat, and Evolution

Ichthyosaurs were Mesozoic reptiles that lived in the sea. They had numerous fish-like attributes and grossly resembled porpoises (Figure 2). The elongated head bore large eyes and consisted primarily of narrow, beaked jaws with many pointed teeth. Unlike other marine reptiles, they lacked a distinct neck; and the streamlined body tapered into a large tail fin -- the main propulsive organ. Their limbs were modified into two sets of paddle-like paired fins, and a dorsal fin served as a keel. Most of the complete specimens have a length of less than 10 feet, although the skull of an

\* Standard Oil Co. of California, Western Operations, Inc., Ventura, Calif.

\*\* Department of Paleontology, University of California, Berkeley.

<sup>1/</sup> Geologist, State of Oregon Dept. of Geology and Mineral Industries.

Early Jurassic ichthyosaur (Leptopterygius) from Europe is 7 feet long, indicating a total body length of nearly 45 feet. Some specimens from the Triassic of California, Nevada, and Oregon are more than 60 feet long.

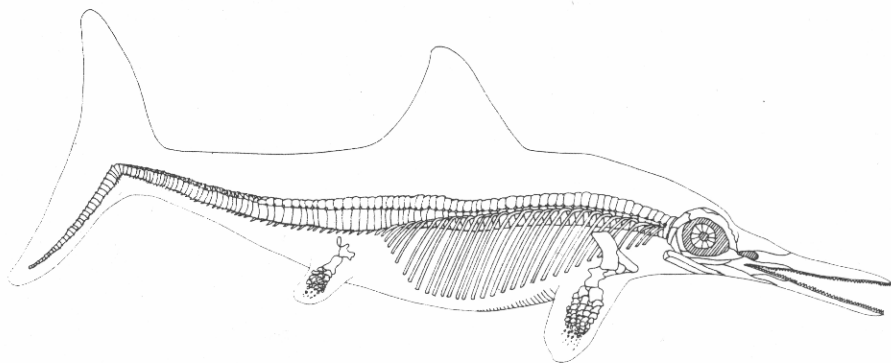


Figure 2. A Jurassic ichthyosaur, greatly reduced. (Redrawn from Romer, "Vertebrate Paleontology.")

Other marine reptiles also existed during the Mesozoic. Their occurrence was a significant reversal in the evolution of life, for shortly after reptiles evolved from amphibians during the late Paleozoic some reptilian stocks became adapted to the aquatic environments.

The oldest known member of the aquatic reptiles was the long-necked Early Permian Mesosaurus, which lived in bays, lagoons, and possibly in fresh water. It has been cited as the ichthyosaur's ancestor, which, because of anatomical dissimilarities, is very doubtful. The ichthyosaurs apparently originated during the Triassic, flourished during the Jurassic, and became extinct by the end of the Cretaceous.

### Oregon Specimen

The coastal Oregon, Sisters Rocks ichthyosaur remains were found as an isolated, fist-sized, crushed mass in a mudstone intercalated with thinly bedded, graded, graywacke sandstones. Elsewhere, identical rocks of the Otter Point Formation contain latest Jurassic, Tithonian (Portlandian - Purbeckian) ammonoids and the pelecypod Buchia piochii (Gabb).

The Otter Point Formation at Sisters Rocks and several other places includes radiolarian cherts, volcanic flows and breccias, and many graded beds (Koch, 1966). It evidently is a eugeosynclinal deposit.

The dark, reddish-brown jaw pieces, a very small portion of the original rostrum, bear several well-preserved teeth (Figure 3). These are conical and fluted, and, within their hollow bases, they contain a brown powder that may be decayed cement. The largest tooth is about 36 mm long and 14 mm wide at its base. The jaw fragments range up to 8 cm in length and include opposing upper and lower dentitions with distorted occlusion.

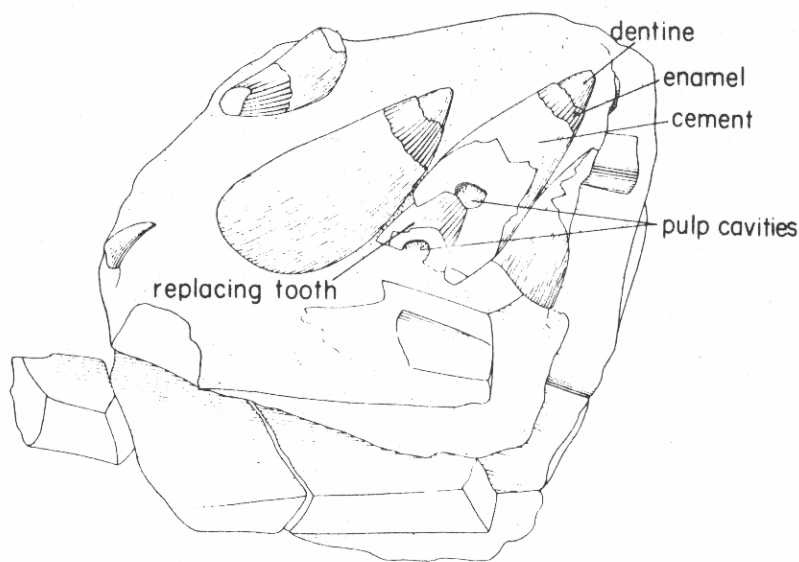


Figure 3. Crushed rostrum viewed from right side (X 1). Large lower teeth are opposed by a small upper tooth.

### Other Ichthyosaur Specimens

Ichthyosaur remains have been collected at only a few places along the Pacific Coast, including the Sisters Rocks locale. Most of the specimens are very incomplete, although some Triassic skeletons are as well preserved as ichthyosaurs from the High Plains and Rocky Mountains of the United States and from the Jurassic of Solnhofen, West Germany. Cervical vertebrae were obtained from the medial Cretaceous (Albian?) of Wheeler County (Mitchell quadrangle, NE $\frac{1}{4}$  sec. 23, T. 11 S., R. 21 E.), Oregon (Merriam and Gilmore, 1928), whereas the Jurassic fossils from California and Oregon consist only of jaw fragments and teeth. The Jurassic ichthyosaur remains from California were found in probable Franciscan Formation radiolarian chert cobbles among Quaternary gravels along Corral Hollow Creek and Del Puerto Canyon on the eastern side of the Diablo Range. Evidently the Pacific Coast medial and late Mesozoic environments, characterized by nearly continuous tectonism and rapid, typically mass-flow sedimentation, were unfavorable for ichthyosaur preservation.

### Identification and Stratigraphic Significance

Dr. C. L. Camp identified the coastal Oregon specimen as Ichthyosaurus californicus and those from coastal California as I. franciscanus and I. californicus (Camp, 1942; Camp and Koch, 1966). Both species are of

probable Late Jurassic age. The Oregon ichthyosaur is definitely Tithonian (latest Jurassic) in age, based on other fossils from the Otter Point Formation. But those from California were tentatively dated as Tithonian by comparison with specimens from Germany, although Taliaferro (1943, p. 195) cited them as firm evidence of such an age for the Franciscan Formation.

I. californicus does not permit detailed temporal correlation of the Franciscan Formation with the lithologically similar Otter Point Formation of coastal southwestern Oregon, but it does support other fossil evidence of a Tithonian age for at least part of the Franciscan. However, there is considerable evidence that the widespread Franciscan complex of the California Coast Ranges represents a long span of time, ranging from Late Jurassic into the Late Cretaceous (Bailey and others, 1964).

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A large collection of high-grade copper ores and native copper from Arizona has been donated to the Department by Mr. F. W. Libbey, mining engineer and former director of the Department. Many of the specimens are bonanza-type ores from famous old Arizona mines that were major producers early in the century. In addition to the copper minerals, the collection includes rich tungsten, silver, and gold ores from Arizona mines, and free gold from Cripple Creek, Colo. A portion of the collection is on exhibit at the Department's Portland office.

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Professor John V. Byrne  
 Department of Oceanography  
 Oregon State University  
 Corvallis, Oregon 97331

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