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EVIDENCE FOR POSSIBLE PLACER ACCUMULATIONS ON THE SOUTHERN OREGON CONTINENTAL SHELF

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Introduction

The oceans of the world cover nearly three-quarters of the earth's surface and constitute a virtually unlimited resource for the ever-increasing needs of mankind. Oceanographic research has made significant advances in the past 20 years and is the foundation on which man will explore and exploit the resources of the ocean. Although both seawater and the deposits beneath the seas contain minerals of economic importance, only a few of these resources have been exploited profitably.

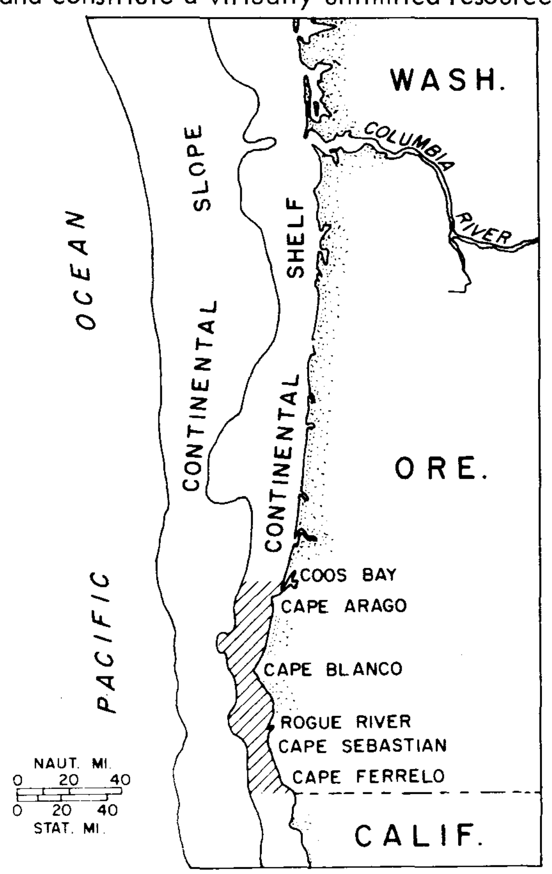


Figure 1. Location map. Lined area shows region of present investigation.

Exploration on submerged lands for petroleum products is already well established, but the search for hard-mineral deposits is just beginning. Since there are numerous profitable land-mining operations in the modern and raised beaches and alluvial deposits around the world for such valuable minerals and metals as gold, tin, rutile, and zircon, it is reasonable to assume that such deposits also exist on the adjacent continental shelf. Inasmuch as ocean mining technology is still in its infancy, the shallow submerged lands must be the first areas to be exploited.

In February 1967, the U.S. Geological Survey established a joint five-year study of the continental margin (continental shelf and slope) off Oregon with the Department of Oceanography, Oregon State University. This study is being conducted as a part of the Survey's Heavy Metals Program, which was developed in response to the increasing depletion of the supply of heavy metals, such as gold, platinum, silver, tin, and mercury.

One of the major objectives of the Heavy Metals Program in Oregon is to conduct a three-dimensional geologic-geophysical analysis of the continental margin. Such an analysis will permit an appraisal of the mineral and the energy resources on and beneath the sea floor and provide insight into the geological processes operating in the marine environment.

The continental shelf between Coos Bay, Oregon, and the Oregon-California border was selected for the initial phase of research and exploration for submerged mineral deposits (fig. 1). Beach placer deposits containing economic quantities of gold, platinum, and chromium occur onshore in southern Oregon and are a primary consideration in the selection of offshore exploration sites. Both stream and beach placers no doubt occur on the continental shelf off southern Oregon, but whether they are of commercial value is yet to be determined. This report is a preliminary synthesis of the results of the first year of research and exploration on the southern Oregon continental shelf, and it describes some of the probable areaswhere economic accumulations of heavy metals may occur.

The first year of exploration and research on the southern Oregon shelf has just been completed; it included both a reconnaissance and a detailed study of the area. Continuous seismic profiling was conducted on the shelf to determine the general structure, thickness of unconsolidated sediment, and nature of Pleistocene drainage. A reconnaissance magnetometer survey was made in selected areas to locate possible placer deposits. More than 300 surface and subsurface sediment samples were collected with grab samplers and short corers for analysis. Several hundred under-water photographs were taken on the continental shelf and upper slope to survey in detail portions of the sea floor. Rock dredges were also used to determine the nature and the composition of the rocks on the sea floor.

Geologic Setting

The geomorphology of the Oregon continental shelf and slope south of Coos Bay has been described in some detail by Byrne (1963). The shelf varies in width from about 9 to 17 nautical miles (17 to 31 km); its outer edge generally occurs at depths of from 90 to 100 fathoms (165 to 183 meters); and it has a slope which ranges from 0°18' to 0°40'. Off southern Oregon the shelf is narrower, deeper, and steeper than the world average shelf.

A prominent submarine bank on the outer shelf, Coquille Bank, disrupts

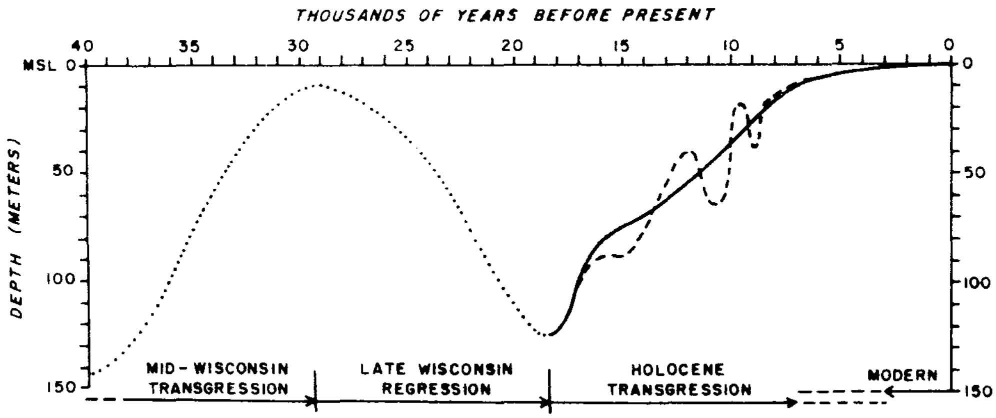


Figure 2. Late-Quaternary fluctuations of sea level (after Curray, 1965). Dotted curve is largely based on speculation. Solid curve based on selected published and unpublished radiocarbon dates. Dashed curve represents postulated fluctuations and shows probable complexity of Holocene Transgression.

the generally smooth surface of the shelf between the Coquille River and Cape Blanco. Although other rocks crop out elsewhere on the shelf, they are not as prominent as Coquille Bank. The outer edge of the shelf northwest of the mouth of the Rogue River is cut by the Rogue Submarine Valley which originates in about 70 fathoms (128 meters) of water.

The numerous eustatic sea-level fluctuations during the Quaternary, brought about by alternating periods of glaciation and deglaciation, have had a pronounced effect on the geomorphology and the sediments of the continental shelves of the world. Only from the past 20,000 years is there sufficient reliable information to postulate the times and the magnitudes of these fluctuations. The events that followed the Wisconsin glaciation (fig. 2) are described by Curray (1965). The stand of sea level, which is believed to mark the end of the late Wisconsin glaciation and the beginning of the Holocene Transgression, occurred between 20,000 and 17,000 years before the present (B.P.) and is represented by a present water depth of about 65 fathoms (120 meters). From 17,000 to 7000 years B.P., there followed a rather rapid transgression (Holocene Transgression) of the sea, with postulated minor regressions interrupting the general Holocene Transgression. The rate of the rise of sea level slowed from 7000 B. P. to the present; whether sea level has been stable or fluctuating during the past 3000 to 5000 years still is a moot question. If the postulated minor regressions occurred during the general Holocene Transgression (Curray, 1965), and there is some independent evidence that suggests this is the case (van Andel and Sachs, 1964), a number of submerged shorelines may be expected between the 65 fathom (120 meter) depth contour and the present-day shoreline. The water depth in which these submerged shorelines may occur today depends upon the tectonic stability of the continental margin. Deformation of the emergent

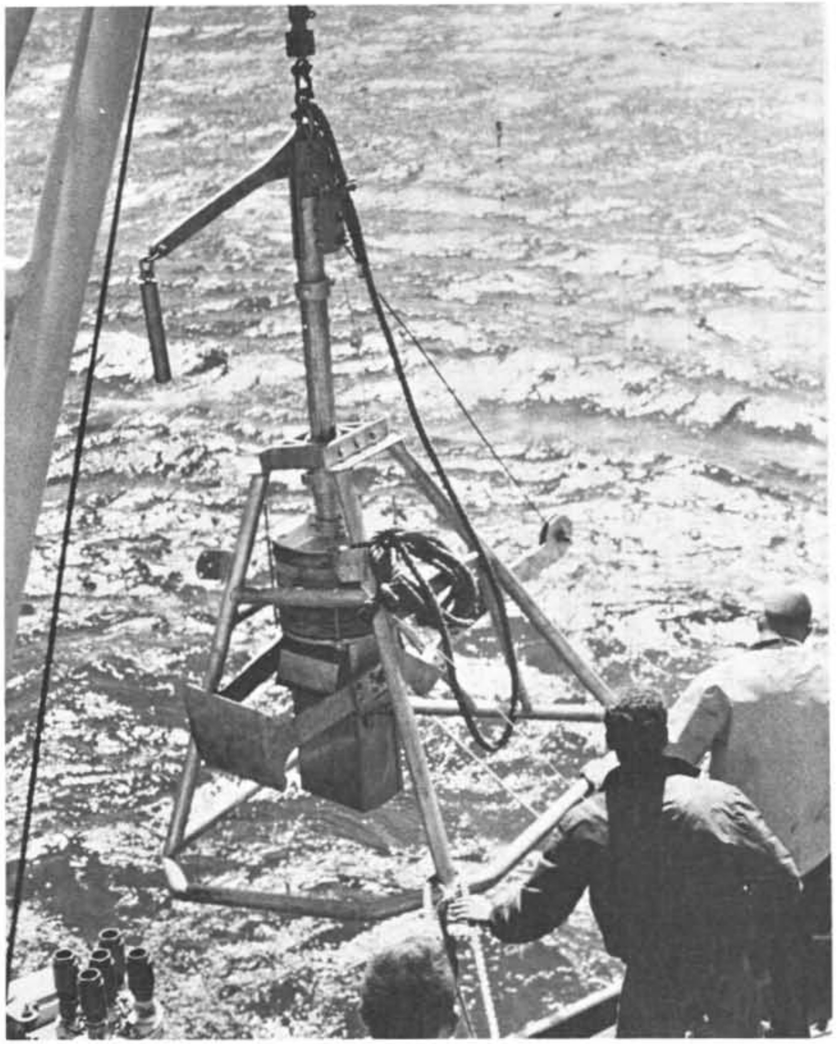
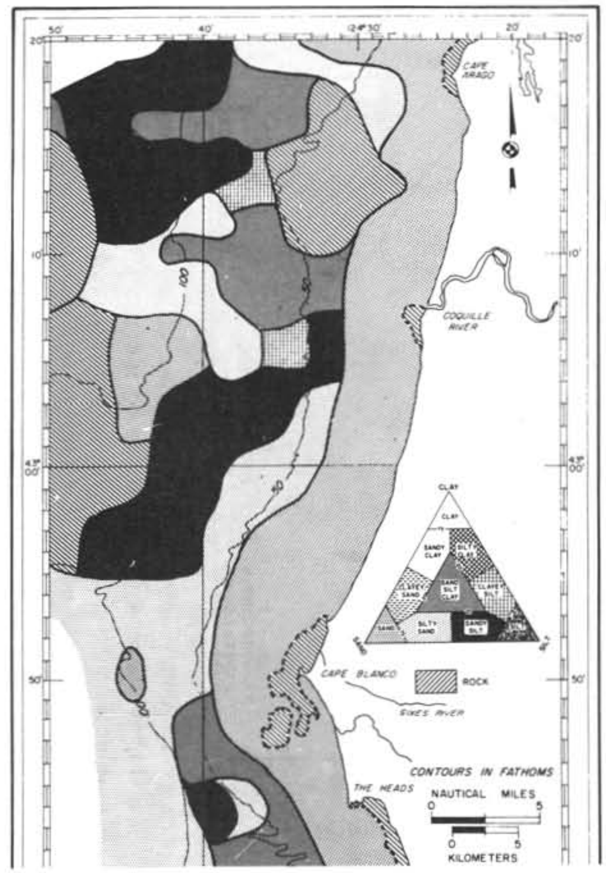


Figure 3. Box corer. After the corer has penetrated the sediment, the large knife cuts through the sediment closing off the bottom of the rectangular box.



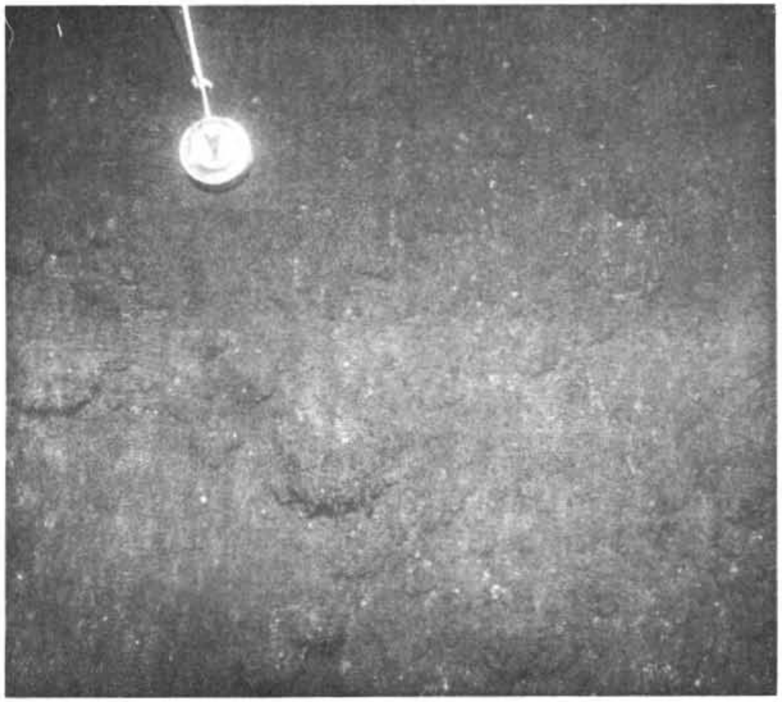


Figure 5. Gravel deposit on inner continental shelf. Water depth 33 fathoms (60 meters). Location 43° 11.5' N and 124° 29.5' W.

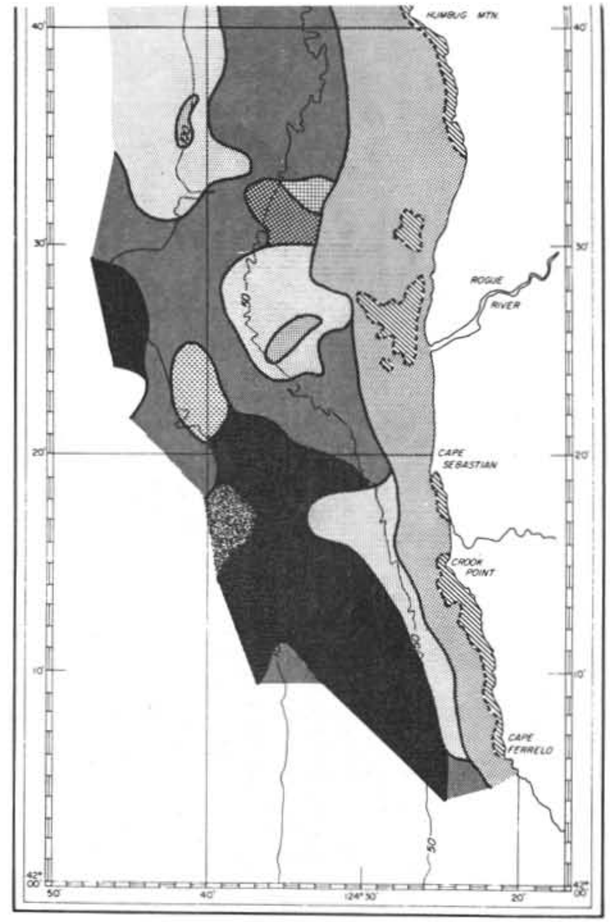


Figure 4. Distribution of surface sediment types. Sediment classification according to Shepard (1954).

terraces onshore, such as the Elk River terrace on Cape Blanco (Baldwin, 1945), indicate that at least minor tectonic instability exists along the southern Oregon coast. The shorelines that formed off southern Oregon may not occur at the same water depths that would be expected on a more stable continental shelf.

Beaches may have formed during these periods of sea-level oscillation or even during earlier oscillations if sea level stabilized for a long enough period of time. Each time sea level was lowered, the coastal streams cut channels across the continental shelf to the shoreline of that time. Both the beaches and the stream deposits were submerged during the final rise of sea level. We might expect to find placer accumulations in both the beach and the stream deposits, provided that the proper conditions for concentration existed in the offshore region where there is an adjacent continental source of valuable minerals.

Sampling and Treatment of Samples

The location of the sampling stations and the positioning for the magnetometer and continuous seismic profiling surveys were determined with the aid of radar fixes on distinctive coastal features or on land-based radar transponders. The navigational accuracy is believed to be better than ± 0.25 nautical mile (0.5 km) up to 5 miles (9 km) offshore.

Surface sediments were collected on a two-mile grid from Coos Bay to Cape Blanco in 1964 and 1965, with additional samples collected in the vicinity of Cape Blanco and between Coquille River and Cape Arago in the summer of 1967. Samples collected on the two-mile grid were analyzed by Runge (1966). Surface sediments south of Cape Blanco were sampled along profiles with additional samples taken in selected areas. Where a more detailed sediment survey was desired, a one-mile grid of stations was occupied. Such a closely spaced grid was used off Cape Blanco and between Cape Sebastian and Cape Ferrelo.

A variety of sampling equipment was used to obtain the surface and subsurface sediments from the continental shelf; these devices include a Smith-McIntyre grab, Shipek sampler, box-corer, and piston corer. The Shipek sampler and the grab sampler were used primarily to obtain homogeneous sediments from the sandy areas on the shelf in water depths shallower than 50 fathoms (92 meters). A total of 157 samples was collected on both R/V YAQUINA and R/V CRIPPLE CREEK (U.S. Bureau of Mines vessel under charter to Oregon State University) cruises. The box-corer used in the sampling program is similar to the one described by Bouma and Marshall (1964), with a few minor modifications (fig. 3). This type of sampler takes an essentially undisturbed sample, even in sandy bottoms, and has a capacity of 0.1 m^3. The box corer is used to obtain large samples up to 45 cm in length; the cores then can be subsampled onboard ship or in the laboratory. Fifty-two box cores were taken on the continental shelf, largely in the vicinity of Cape Blanco and the Rogue River, and several piston cores ranging up to 4 meters in length also were collected on the shelf.

All unconsolidated sediment samples, including subsamples, were analyzed for sediment texture and heavy mineral content; selected samples were analyzed for their authigenic mineral content. The textural parameters have been determined for approximately 311 surface and subsurface samples on the southern Oregon continental shelf. Particle settling techniques were used to analyze all sediment samples for their textural properties. The sand fraction (>0.062 mm) was analyzed with the Emery (1938) settling tube, while the fine fraction (<0.062 mm) was analyzed by a soil hydrometer. The results of these two analyses were then combined for each sample to complete the textural analysis. Only the sand-silt-clay percentages, according to the nomenclature of Shepard (1954) are presented here.

Heavy mineral analyses were made on 173 surface and 71 subsurface samples. The heavy mineral separation was made with tetrabromoethane (specific gravity 2.96); only the sand fraction of the sediment was used.

The magnetic content of the sand fraction of selected samples was determined by passing a horseshoe magnet over the sediments. The magnetic minerals consist chiefly of the opaque mineral magnetite, minor amounts of ilmenite, and non-opaque minerals with magnetic inclusions. The magnet was passed over the samples several times until the number of non-opaque minerals with magnetic inclusions exceeded the number of opaque magnetic minerals in the magnetic fraction. The total magnetic content of the sediment samples was then computed on a weight basis.

Sediments

Areal distribution of sediment types

The surface sediment distribution pattern on the southern Oregon continental shelf is quite varied and irregular (fig. 4). The sand zone, which generally consists of detrital quartz, feldspar, and ferromagnesian minerals, extends from the shoreline out to a water depth of approximately 40 fathoms (73 meters) along most of the shelf. The width of the sand zone varies with the width of the shelf in this area. For example, the shelf is narrow south of the Rogue River and the sand zone also narrows to the south. Much of the inner shelf sand is probably relict transgressive material deposited during the last rise in sea level (Runge, 1966). These sands are extensively reworked by benthonic organisms and lack internal structures. Deposition of modern sands, those sands which are in equilibrium with the present environment, is confined largely to the water depths shallower than 10 fathoms (18 meters). Sediments immediately seaward of the sand zone generally consist of either silty sand or sand-silt-clay. Seaward of these two sediment types, sandy silt or clayey silt are most common. Deposits of gravel (fig. 5), sand, and silty sand occur on the outer continental shelf and are surrounded by or partially covered with the modern fine-grained silts and clays derived from local coastal rivers. The sandy sediments on the outer shelf appear to be mostly relict sediments which are out of equilibrium with their present environment. They consist of either detrital quartz and feldspar or the authigenic mineral glauconite, or both. Glauconite is confined to the continental slope and generally is absent in water depths shallower than 100 fathoms (183 meters), except in the vicinity of Coos Bay and the Coquille River, where it occurs in waters as shallow as 60 fathoms (110 meters).

Rocks crop out in numerous areas on the continental shelf, particularly between Cape Arago and Cape Blanco. Most of these areas are associated with anticlinal structures and may have a thin veneer or pockets of unconsolidated sediment covering portions of the rocky surfaces. Bottom photographs taken over these rocky areas show a general lack of sediment, which indicates that shelf currents tend to sweep these surfaces clean of sediments, except on topographic lows.

The nature of the sediments at depth generally is known only in the upper few tens of centimeters; a limited number of piston cores provide information in the upper two to four meters. Sediments containing approximately 100 percent sand generally are confined to the inner shelf in water depths shallower than 25 fathoms (46 meters). However, cores taken on the outer continental shelf also may have a high detrital sand content. In general, there is an increase in the percentage of sand with depth in the cores. Reversals in sand content are notedin a few cores and may reflect the minor regressive cycles suggested by Curray (1965) for the Holocene Transgression which started about 17,000 years ago.

The unconsolidated sediment distribution and thickness on the continental shelf was determined from data obtained from a 5000-joule EG and G sparker system. Sparker records show that there is usually only a thin veneer of sediment less than 15 meters thick over the majority of the shelf which lies between Cape Blanco and Cape Arago. However, small isolated pockets of unconsolidated sediment probably occur in the rocky areas on this part of the shelf. Between Cape Blanco and Cape Ferrelo the unconsolidated deposits range in thickness from less than 15 meters to more than 35 meters, but average only about 20 meters in thickness.

Heavy mineral concentrations

Several well-defined heavy mineral concentrations occur in the surface sediments on the continental shelf off southern Oregon (fig. 6). The heavy mineral percentages range from 1 to more than 40 percent of the total sand fraction. The most extensive and most prominent heavy mineral zones occur in the vicinity of the Rogue River. This large surface concentration is 20 miles (37 km) long and extends 10 miles (19 km) north and 10 miles (19 km) south of the river mouth and apparently extends from the shoreline

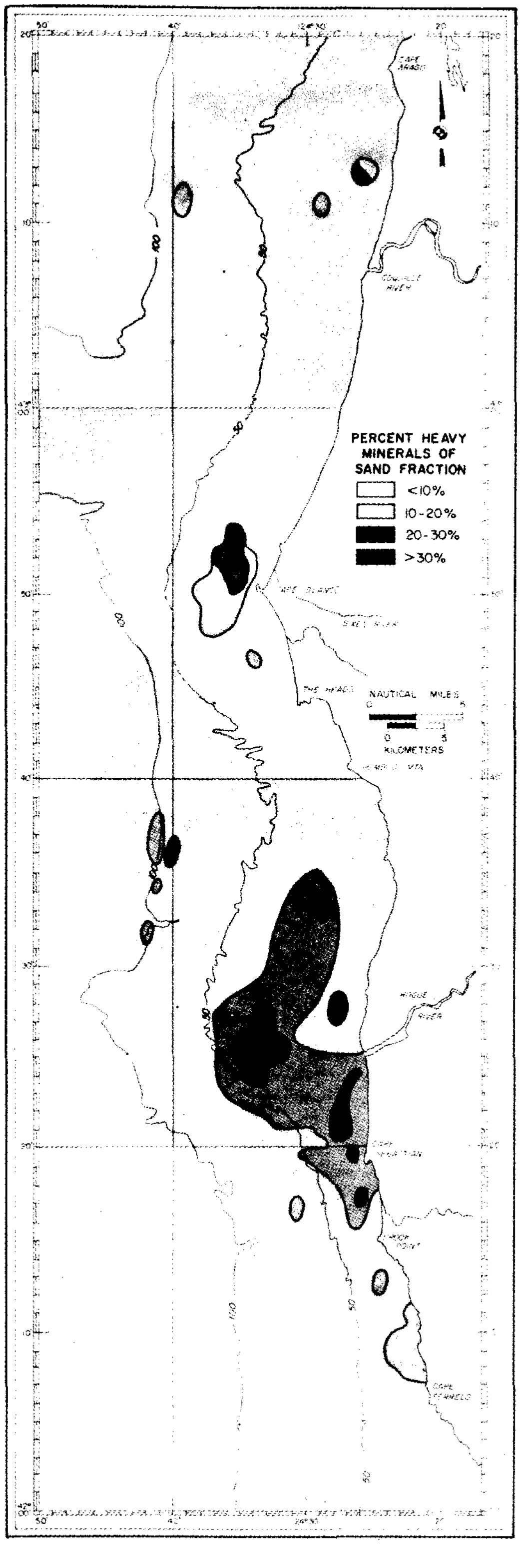


Figure 6. Heavy mineral concentrations in surface sediments.

out to a depth of 50 fathoms (90 meters). It is not known whether the tongue-shaped body of heavy minerals, which lies north of the mouth of the Rogue River, has a shoreward extension; the Rogue Reef just north of the river mouth has limited the sampling in this area. Richer heavy mineral concentrations, 20 to 30 percent, occur within this large surface deposit. One of these concentrations is located due west of the mouth of the Rogue River in water depths ranging between 30 and 45 fathoms (55 to 82 meters); it has been confirmed by repeated sampling. Another heavy mineral concentration of similar magnitude is located immediately south of the Rogue River in 3 to 25 fathoms (6 to 46 meters). This linear concentration bends towards the river mouth, indicating that the Rogue River is indeed the major source of heavy minerals. Isolated patches of surface heavy mineral concentrates occur to the south of the one just described, between Cape Sebastian and Crook Point, and are located in similar water depths.

Somewhat smaller heavy mineral surface concentrations occur between Crook Point and Cape Ferrelo and may extend from the shoreline out to approximately 32 fathoms (60 meters). These concentrations do not exceed 20 percent heavy minerals by weight.

A less extensive but higher concentration of heavy minerals lies off Cape Blanco and the Sixes River. This concentration is approximately 7 miles (13 km) long and 3 miles (6 km) wide; it is found in water depths ranging between 10 and 30 fathoms (18 and 55 meters). The concentration ranges up to 33 percent in heavy minerals.

An exceptionally high heavy mineral concentration (43 percent at the surface) was found at 81 fathoms (150 meters) midway between Cape Blanco and the Rogue River (42° 35.9', 124° 41.0'). The area was sampled with a piston corer and has the highest percentage of heavy minerals found to date in the surface sediments off southern Oregon. Other surface samples taken in this area frequently contain more than 20 percent heavy minerals.

Surface samples taken between Cape Arago and the Coquille River have failed to reveal any large or extensive heavy mineral concentrations on the inner part of the continental shelf. The region to the west of the small-sized concentration at approximately 10 to 20 fathoms (18 to 36 meters) is extremely rocky and probably has only a thin veneer of sediment. If high concentrations are present in this area, they probably occur in isolated patches or pockets.

The subsurface concentrations of heavy minerals, with few exceptions, are similar to those observed in the surface sediments (fig. 7). All of the subsurface samples analyzed for their heavy mineral content contain more than 75 percent sand-size material. Piston core 6708-43 (81 fathoms) has 56 percent heavy minerals a few centimeters below the surface. This is the highest concentration of heavy minerals found to date in cores or at the surface. All sediments sampled in this core produced more than 40 percent heavy minerals. At approximately the same water depth, core 6708-44 displays a marked increase in heavy minerals (more than 30 percent) near the bottom of the core.

With the exception of the two cores just described, the highest heavy mineral content found in the cores off southern Oregon to date occurs in the vicinity of the Rogue and the Sixes Rivers. A number of cores in these areas show a slight decrease in heavy mineral content with depth, while others increase or remain constant.

Magnetic content of sands

Virtually all of the placer deposits in southern Oregon contain an appreciable quantity of black sand, which commonly consists of chromite, ilmenite, and magnetite. Magnetite content varies from one placer to another in the land deposits, but it is generally present in sufficient quantity to produce a substantial magnetic attraction, which can be detected with a magnetometer. In the vicinity of the Rogue River, the magnetite:chromite ratio is about 10:1 and the magnetite:ilmenite ratio about 10:1 (Griggs, 1945).

The magnetic content (chiefly magnetite with some ilmenite and nonopaque minerals with magnetic inclusions) of the sand fraction of the unconsolidated sediments was determined in a number of box cores, piston cores and surface samples (fig. 8). In general, the percentages of magnetic material in the surface and subsurface samples is highest south of the Rogue River and significantly decreases northward to the vicinity of the Coquille River. Near the Rogue River the magnetic content of all sediments averages about 10 percent; near Cape Blanco the average magnetic content is 5 percent; and off the Coquille River magnetic contents average about 1 percent. Data from previous studies (Day and Richards, 1906) show that the percentage of magnetite in the beaches and elevated marine terraces decreases markedly from the Oregon-California border. The offshore content of magnetite and other magnetic minerals coincides with the trends of the onshore deposits.

The highest percentage of magnetic material (up to 18 percent) found in the sediments occurs throughout piston core 6708-43 and at the base of box core 6708-44; both cores were taken on the outer continental shelf at 82 and 81 fathoms (150 and 148 meters), respectively. Other sediments high in magnetic material occur in the large surface concentration of heavy minerals west and north of the Rogue River (fig. 6).

In the cores the magnetic content is generally the same in the subsurface as it is at the surface or varies slightly with depth. In the vicinity of the Rogue River, with a few exceptions, there is a general increase in magnetics with depth, but in the vicinity of Cape Blanco there seems to be a slight decrease with depth. No specific trends were noted in the only core examined off the Coquille River.

Heavy metal analyses

A number of surface sediment samples have been analyzed for their gold

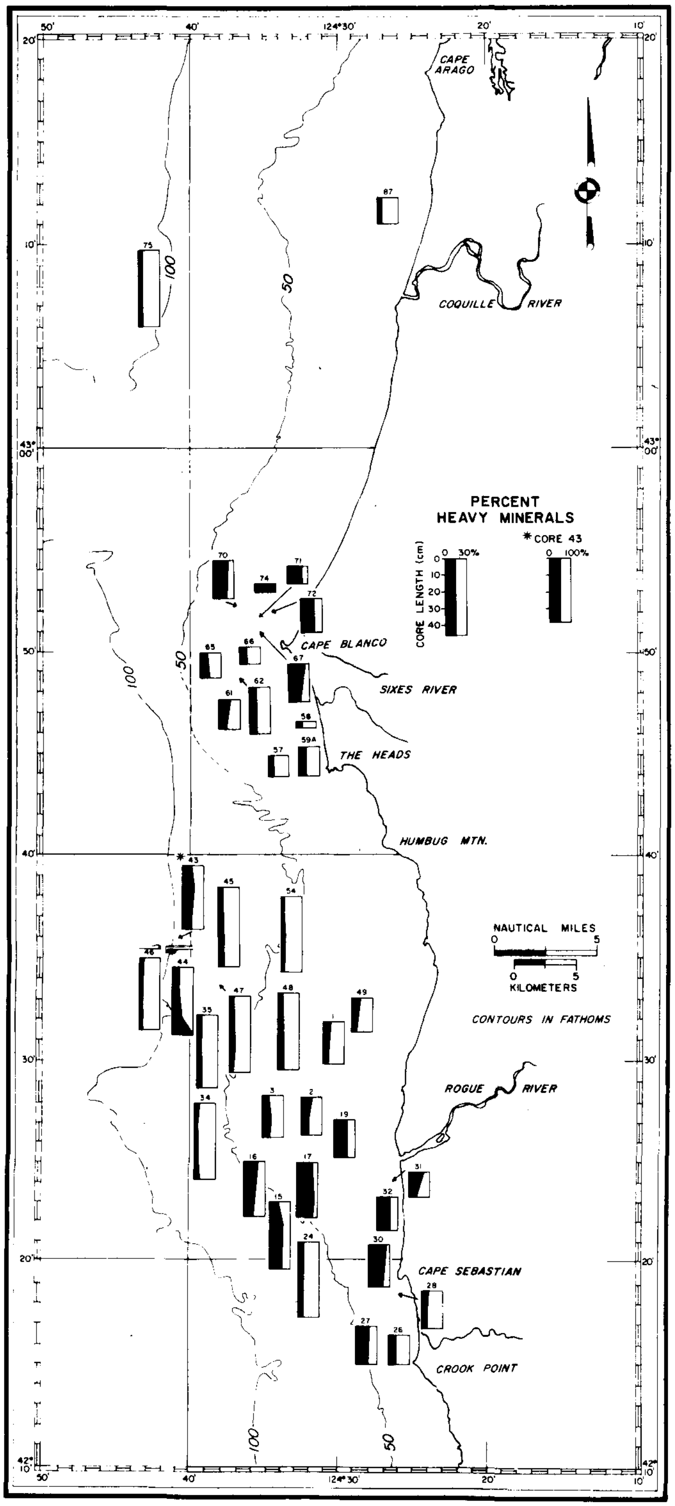


Figure 7. Distribution of heavy minerals in box cores. Sample number or arrow indicates core location. Note that the concentration scale in all cores ranges from 0-30%, except core 43 which is 0-100%.

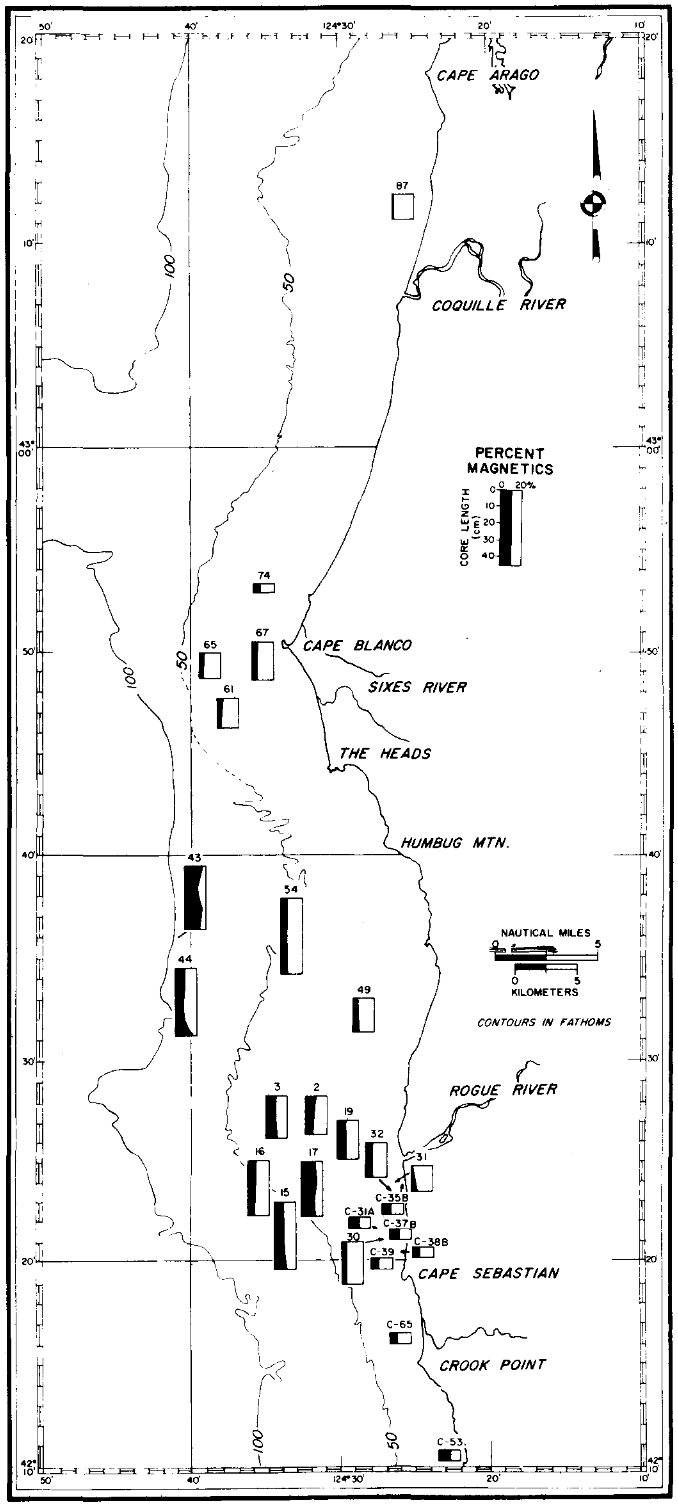


Figure 8. Distribution of magnetic materials in box cores. Sample number or arrow indicates core location.

content by the U.S. Geological Survey. The results of the analyses are summarized in a separate report (Clifton, 1968).

Magnetometer Survey

A reconnaissance magnetometer survey was made off the Rogue, Sixes, and Coquille Rivers where the surface and the subsurface concentrations of heavy minerals, and sediment texture, suggested the existence of possible placer accumulations. Approximately 72 nautical miles of magnetometer track lines were run off these rivers (fig. 9).

The total intensity magnetic field was measured with a ship-towed proton precession magnetometer which has an instrumental accuracy of $\pm$ 5 gammas. Our magnetograms were compared with the magnetograms from Tucson, Ariz., to determine the effect of magnetic storms. No storms were noted on any of our records.

Magnetic anomalies

Several prominent magnetic anomalies (A through H) were discovered in the magnetic survey (figs., 10, 11, 12; refer to fig. 9 for the locations of the anomalies on the shelf). These anomalies range in magnitude from 10 to 300 gammas. They are narrow and steep sided, which suggests that the source is very shallow and rather narrow in dimension. These anomalies could be small intrusive or extrusive bodies, or magnetite-bearing black sand deposits.

The largest anomalies occur in the vicinity of the Rogue River. Peaks of anomalies A, E, and F occur at water depths of 45, 37, and 40 fathoms (83, 70, and 73 meters), respectively (fig. 10). Another prominent anomaly, B, is located at a depth of 20 fathoms (37 meters). A group of large, narrow anomalies was observed immediately south of the entrance of the Rogue River in about 10 fathoms (18 meters) of water (fig. 11, C). The most prominent anomalies observed anywhere occur directly off the entrance of the Rogue River, along an imaginary line projected seaward from the general trend of the river mouth onshore (fig. 11, D). Each anomaly peak falls on this line, which was traversed at a number of different points.

Two less prominent magnetic anomalies (G and H) occur in the vicinity of the Sixes River and Cape Blanco (fig. 12). The anomalies occur as doublets along each profile and are located between 16 and 25 fathoms (29 and 46 meters) on two different east-west magnetometer tracks spaced approximately 2 miles (4 km) apart.

Magnetic anomalies also were observed off the Coquille River area but are less definitive and are not discussed here.

Analysis of magnetic data

An attempt has been made to determine the dimensions and the magnetic

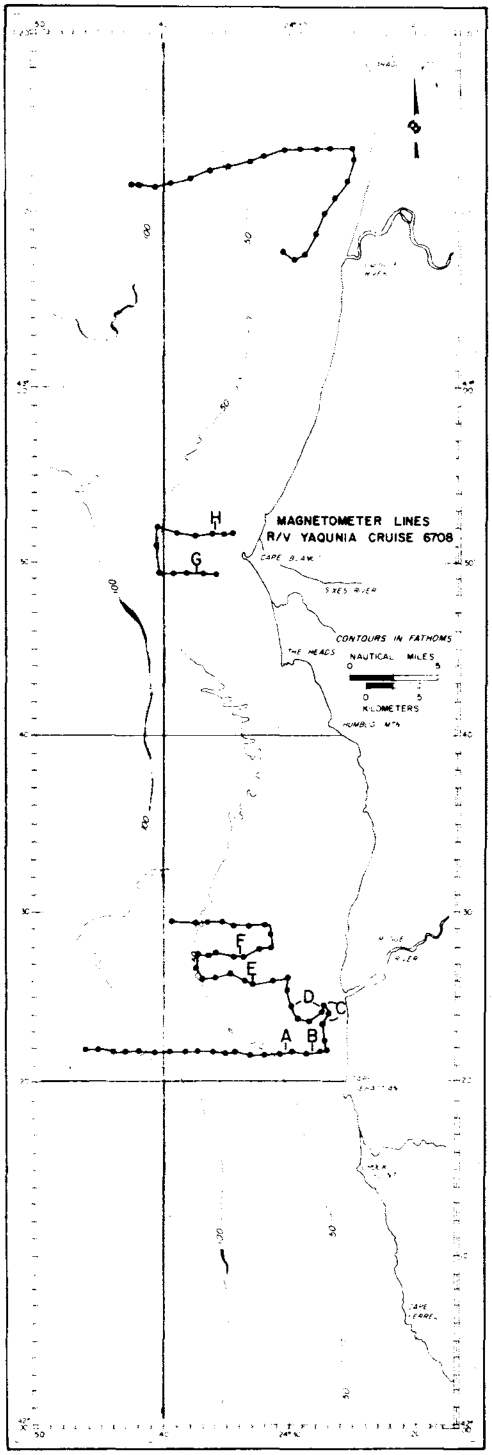


Figure 9. Magnetometer survey profiles. Letters indicate locations of magnetic anomalies. (See figures 10, 11, and 12.)

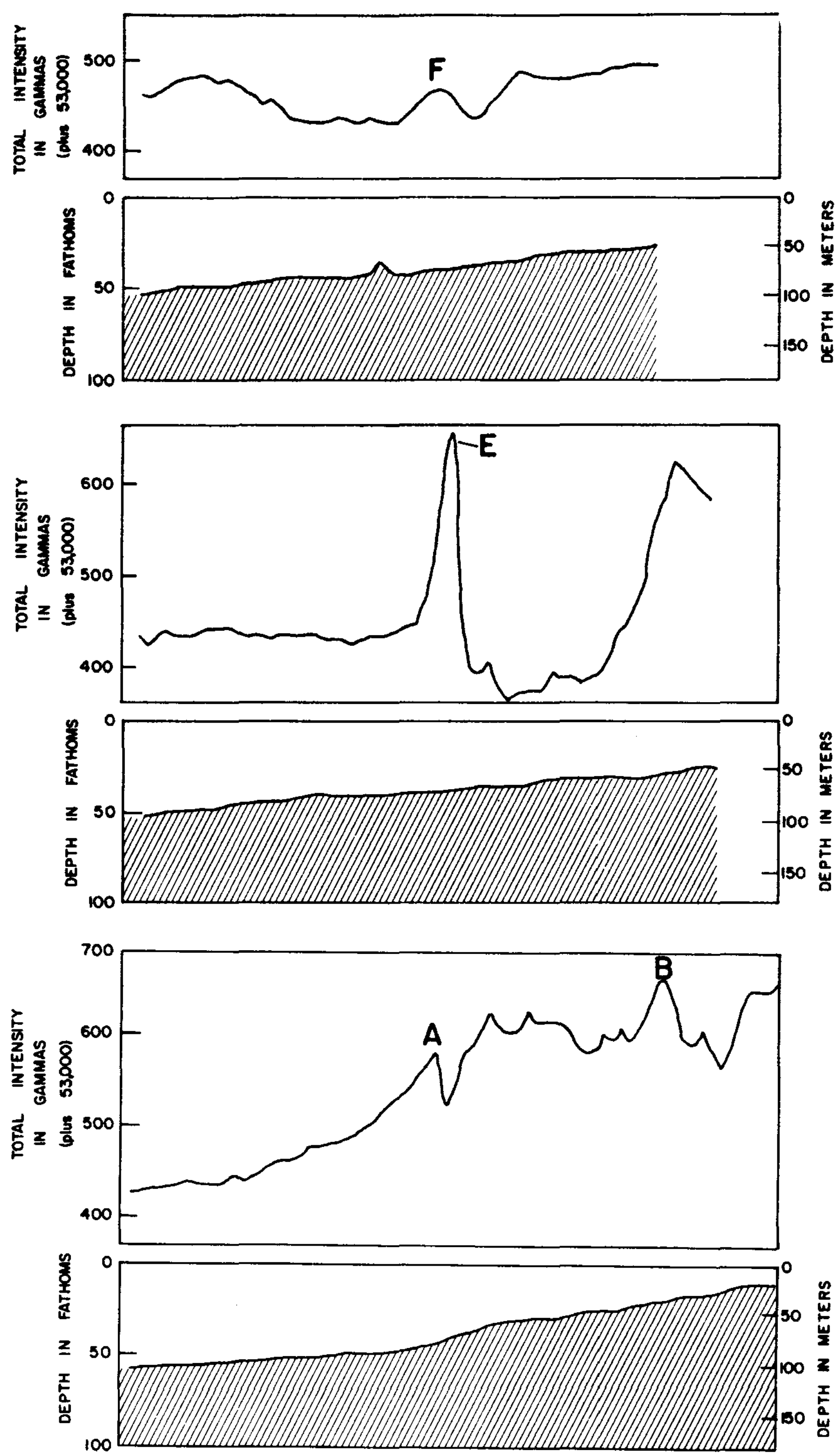


Figure 10. Total magnetic intensity values and bathymetry along three east-west profiles off the Rogue River. Letters indicate magnetic anomalies. (See figure 9 for location.)

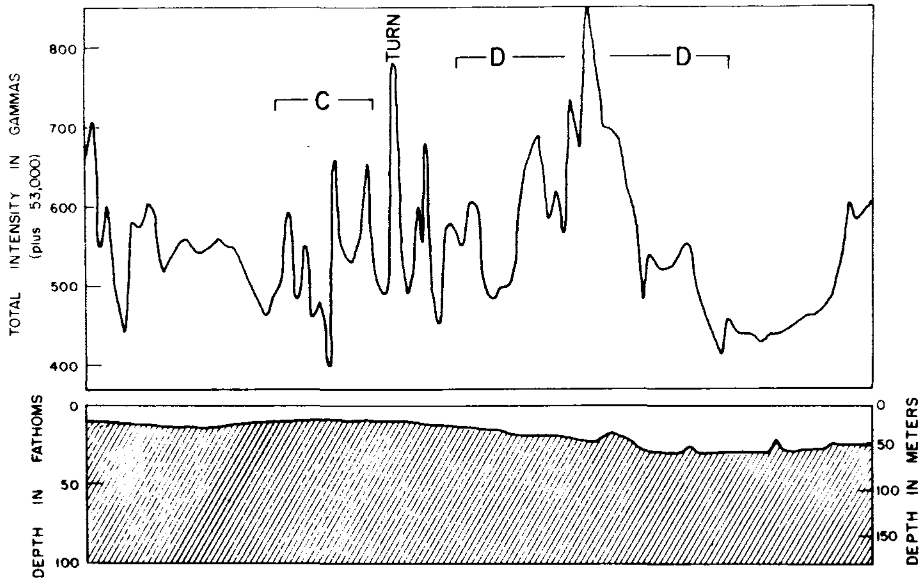


Figure 11. Total magnetic intensity values and bathymetry immediately south of the Rogue River (left-hand side) and off mouth of Rogue (right-hand side). TURN indicates separation between profiles. Letters indicate magnetic anomalies. (See figure 9 for location).

susceptibility of the bodies causing the magnetic anomalies E (Rogue River), and G (Sixes River) on the continental shelf. A number of hypothetical models were constructed with the aid of a computer to simulate the magnetic anomalies observed at these two locations.

The assumption is made that the magnetic anomalies are produced by magnetite-bearing placers with dimensions and a magnetic susceptibility similar to the black sand deposits in the modern beaches and the elevated marine terraces explored and exploited on land. Pardee (1934) and Griggs (1945) give a detailed explanation of the physical characteristics of these deposits. An additional assumption is made that the anomalies are produced by submerged beach placers which parallel the general trend of the present-day shoreline. Only the width and the thickness of the body can be considered because the anomalies are but single profiles across the source.

The steep-sided, large magnetic anomaly observed off the Rogue River (fig. 10, E) could be produced by two placer bodies each 10 meters thick and 25 meters wide and spaced 45 meters apart (fig. 13). Depth to source calculations indicate that the tops of the bodies are approximately 75 meters below sea level or close to the sediment-water interface. A magnetic content of from 12.6 to 20.9 percent in body no. 1 and 7.5 to 12.4 percent in body no. 2 is sufficient to produce the magnetic susceptibility required to construct the anomaly E. The magnetic content measured in the surface and the subsurface sediments off the Rogue River, where the anomaly was

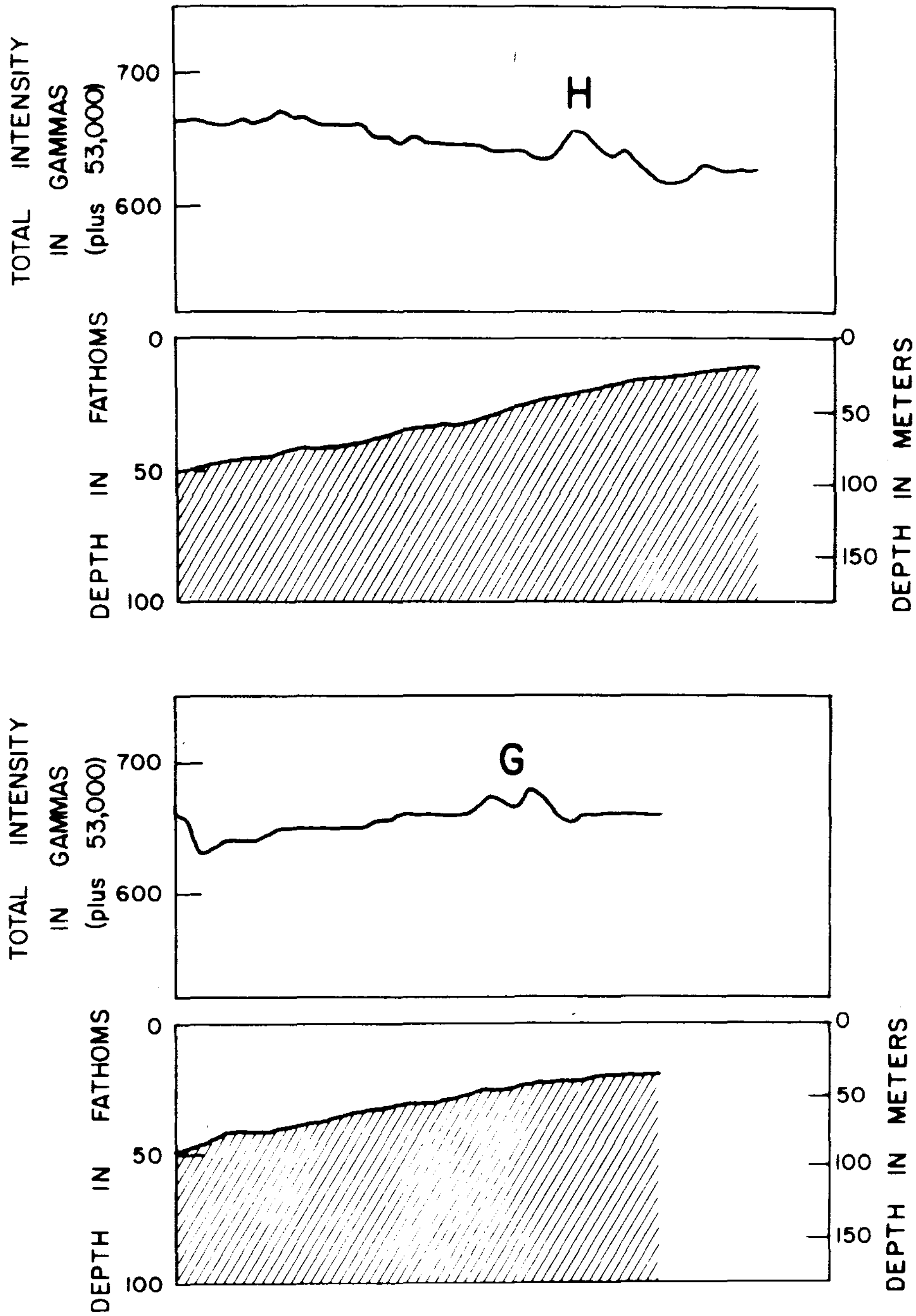


Figure 12. Total magnetic intensity values and bathymetry along two east-west profiles off Cape Blanco. Letters indicate magnetic anomalies. (See figure 9 for location.)

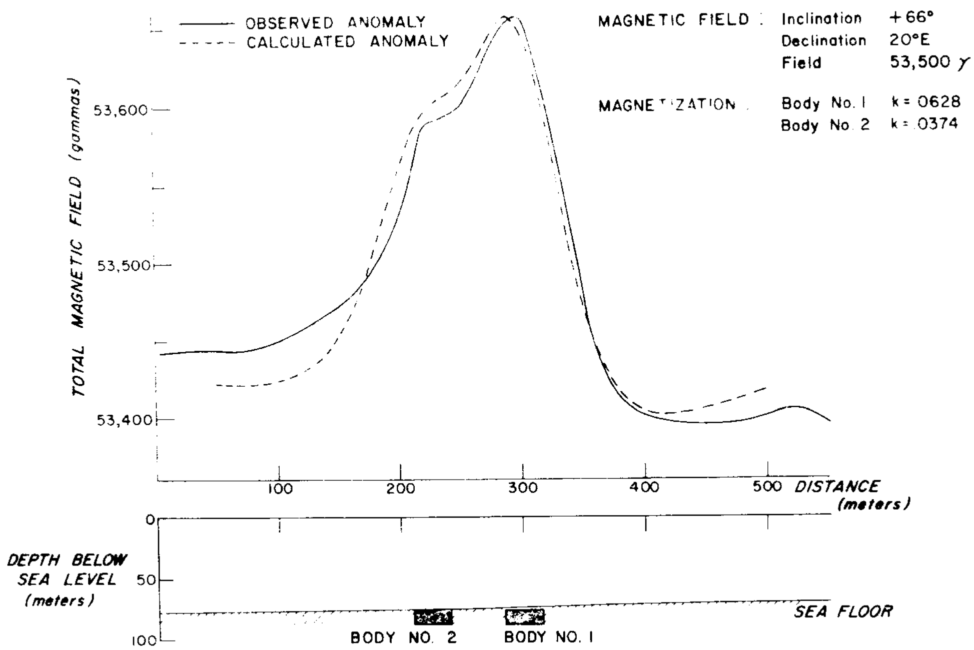


Figure 13. Calculated anomaly for simple model of magnetic anomaly E (Rogue River). (See figure 10 for complete profile.)

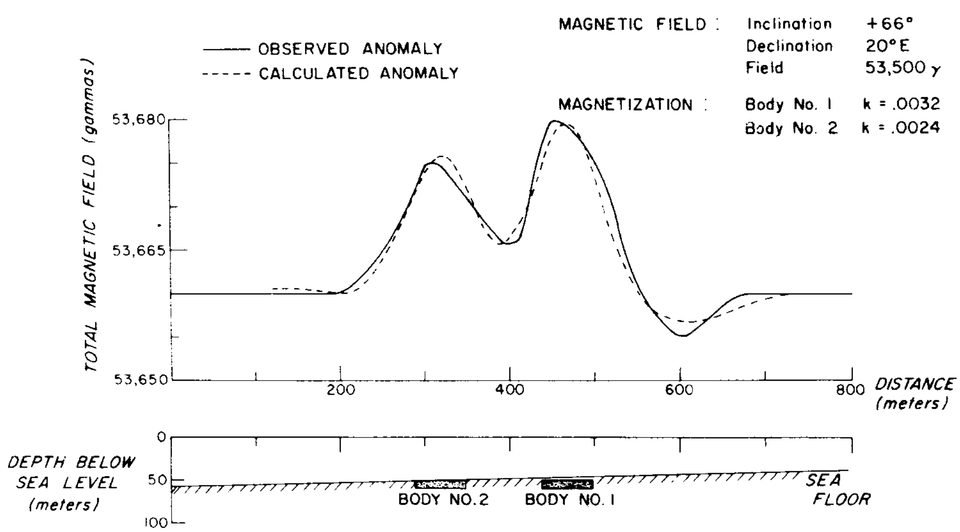


Figure 14. Calculated anomaly for simple model of magnetic anomaly G (Cape Blanco). (See figure 12 for complete profile.)

observed, is as high as 15 percent and averages about 10 percent (fig. 8). The total thickness of unconsolidated sediment in this area is approximately 21 meters.

The closely spaced double magnetic anomalies observed off Cape Blanco (fig. 12, G) can be produced by two magnetic bodies 10 meters thick and 60 meters wide with a magnetic content of 0.6 to 1.1 percent (body no. 1) and 0.45 to 0.83 percent (body no. 2) (fig. 14). These estimates are minimum magnetic percentages since the model uses large source bodies. The magnetic content of the sands off Cape Blanco averages about 5 percent (fig. 8). Depth to source calculations indicate that the tops of the anomalies are 50 meters below sea level or close to the sediment-water interface. The unconsolidated sediment cover is approximately 12 meters thick in the area where the anomaly was observed.

Magnetic anomalies were also observed between the Coquille River and Cape Arago, but they are not as large nor as definitive as those observed to the south. The lower magnetic content in the sands (less than 2 percent) in this area may be too small to produce well-defined anomalies that can be detected by a magnetometer with a ± 5 gamma accuracy.

Although the models of the observed magnetic anomalies give us some indication of the general dimensions and the magnetic susceptibility of the anomaly source, it is reasonable to assume that the entire body is probably not a homogeneous placer with an even distribution of magnetite. Pardee (1934, p. 5) states that "the backshore of the present beach and the ancient beach at an altitude of about 170 feet have been the most productive. The pay streak generally ranges from a few feet to 200 or 300 feet in width, is 3 or 4 feet thick in the middle, and tapers towards the edges. It consists largely of alternating layers of black and gray sand with more or less cobbles, boulders, and driftwood and in the ancient beach, is mostly covered with a barren sand 'overburden' 20 to 60 feet thick." It is most likely that the submerged placers will have similar physical and compositional characteristics and that the anomalies observed are an average of several thin, magnetite-rich superimposed layers of varying thicknesses.

Discussion of Results

Several lines of evidence, magnetics, and heavy mineral content, suggest that magnetite-bearing placer deposits may exist on the continental shelf off southern Oregon. Both stream and beach placers may be present, although buried stream channels have not as yet been defined and the existence of stream placers is suggested only by magnetometer data.

Surface and subsurface concentrations of heavy minerals in the marine sands are distinctly related to major streams, such as the Rogue River and Sixes River, which have sources of economic minerals in their drainage basins. Most of the largest and richest concentrations, with a few exceptions, are found from 1 to 7 miles (2 to 13 km) seaward of the present-day river mouths and in waters as deep as 50 fathoms (92 meters). An even higher concentration of heavy minerals is found on the outer edge of the continental shelf between the Rogue River and Cape Blanco in 80 to 100 fathoms (146 to 185 meters).

Modern beach sand generally is not transported offshore much below surf base (Dietz, 1963) or wave-induced surge (Vernon, 1966) or to water depths greater than about 10 fathoms (18 meters), except where submarine canyons intersect the littoral zone such as those which occur off southern California (Emery, 1960). Furthermore, Kulm and Byrne (1966) have shown that Oregon estuaries tend to trap sand within their estuarine systems. Only the suspended or silt-clay load of the rivers is carried seaward and deposited either on the central part of the shelf or on the continental slope as a mud facies; there appears to be a general lack of deposition on the outer continental shelf as pointed out by Curray (1965). The sands on the southern Oregon shelf that lie between the 10-fathom (18-meter) contour and the beginning of the central shelf mud facies at 40 fathoms (73 meters) are presumably relict Holocene Transgressive sands deposited during the last rise of sea level. These sands and their associated heavy mineral concentrations are apparently relict materials which are out of equilibrium with their present environment. Although these sands may be reworked periodically by shelf bottom currents, the persistence of the heavy mineral concentrations at depth in the cores and the association of these concentrations with their continental sources indicate that these zones have not been formed by the present environmental conditions. The isolation of the heavy mineral zone off Cape Blanco from the present shoreline also suggests that these deposits are not in equilibrium with their present surroundings; the same reasoning applies to the heavy mineral zones that occur 12 miles (22 km) from shore and in 80 fathoms (146 meters) of water. The relict deposits on the inner shelf probably were formed in a beach environment during one of the postulated regressions which interrupted the general Holocene Transgression. Several stillstands of the sea would be necessary during this complex period to concentrate the placers in the beaches.

The surface and near-surface concentrations of heavy minerals by themselves are not sufficient evidence to suggest that placer accumulations are nearby. However, the large magnetic anomalies associated with these deposits suggest that the concentrations may be black sand deposits with vertical and horizontal dimensions similar to the adjacent land placers. Some or all of the observed magnetic anomalies could be caused by intrusive or extrusive bodies in the earth's crust; however, the steepness and the shape of a number of the anomalies generally are not typical of these features and depth to source calculations indicate that the anomaly source is at or near the sea floor. Although igneous rocks are capable of producing some of the anomalies in the vicinity of the Rogue River, such rocks are not known in the vicinity of Cape Blanco. A regional magnetics survey of the southern Oregon shelf (Emilia and others, 1968) shows that there are no positive anomalies in the Rogue River and Cape Blanco areas; however, this survey was restricted to water depths greater than 40 fathoms (73 meters).

The only way to determine whether or not magnetic anomalies are placers of commercial importance is to sample them in depth by drilling and coring. Before such an exploratory drilling program is attempted, a more detailed magnetometer survey will be made of the magnetic anomalies to determine their orientation and lateral continuity. In addition, a high resolution seismic survey will be made in the areas of the anomalies and heavy mineral concentrations to detect sand and gravel deposits which might be associated with former shorelines or fluvial deposits.

Conclusions

1. Preliminary geological and geophysical data suggest that magnetite-bearing placer deposits may exist on the southern Oregon continental shelf.

2. Several well-defined surface and near-surface heavy mineral concentrations (ranging up to 56 percent of the total sand sample) have been discovered on the shelf in water depths ranging between 10 fathoms (18 meters) and 100 fathoms (183 meters). These concentrations are believed to be relict deposits formed in an environment different from that which exists in the area where these deposits occur today. Heavy mineral concentrations of similar magnitude are found in the modern-day beaches and in the older elevated marine terraces in southern Oregon. The offshore concentrations are located off the mouths of the Rogue River and Sixes River, which have sources of heavy metals in their drainages.

3. Associated with the offshore heavy mineral concentrations are high percentages of magnetic constituents, chiefly magnetite. There is a marked decrease in the percentage of magnetic constituents from the Oregon-California border to the vicinity of the Coquille River.

4. Large magnetic anomalies are associated with the surface and near-surface heavy mineral concentrations. Simulated model studies of these anomalies show that submerged placer deposits with the dimensions and the magnetic content of the onshore placers could give rise to the observed anomalies.

5. There appears to be some correlation of the heavy mineral concentrations and their associated large magnetic anomalies with the minor regressions that are postulated by Curray (1965) to have interrupted the general Holocene Transgression. If stillstands of the sea did occur and if there was sufficient time for a beach to develop, placer accumulations may be expected at depths ranging between 65 and 10 fathoms (120 and 18 meters). Because of the tectonic instability of the southern Oregon continental margin, no correlation of submerged shorelines in this area can be made with those in more stable areas without further investigation.

6. Further geophysical investigation is needed to determine the orientation and the lateral continuity of the probable placer deposits on the

southern Oregon continental shelf. A detailed magnetometer survey and a high-resolution seismic survey are necessary before the probable deposits are drilled and cored.

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<u>Editor's note:</u> As the foregoing paper went to press, the U.S. Geological Survey simultaneously published its Circular No. 587, entitled "Gold distribution in surface sediments on the continental shelf off southern Oregon: a preliminary report." This circular, written by H. E. Clifton, is obtainable free of charge from the U.S. Geological Survey, Washington, D.C. 20242. The publication describes the gold distribution on the shelf as it relates to the possible placer deposits described by Kulm, Heinrichs, Buehrig, and Chambers and thus complements their paper. These studies have resulted from a joint research program between the U.S. Geological Survey and the Department of Oceanography, Oregon State University, under contract. They have been conducted as part of the Geological Survey's Heavy Metals program, for the purpose of exploring the potential for economic concentrations of black sand on the continental shelf off southern Oregon. These two papers, combined, summarize the tentative conclusions reached as a result of the first year of this joint study.

GOLD AND SILVER IN OREGON PUBLISHED

The long-awaited, but timely, volume "Gold and Silver in Oregon" has been published by the Department as Bulletin 61. The 337-page publication represents 5 years of compilation by the authors, Howard C. Brooks and Len Ramp, geologists with the Department. Their sources of information consisted of an enormous collection of unpublished and published data, together with their own first-hand knowledge of the subject.

The bulletin describes the history, production, mineralization and geologic occurrence of gold and silver in the state. In all, some 500 lode and placer mines and prospects are discussed. Bulletin 61 is for sale by the Department at its Portland, Baker, and Grants Pass offices, for $5.00.

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