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Origin of the Black Sands
of the
Coast of Southwest Oregon

by
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Foreword

The "black sand" deposits of the Oregon coastal region have for a matter of 75 years received more or less attention from geologists, prospectors, miners and inventors of various devices for gravity mineral concentration. Throughout this time numerous mining enterprises were started on "black sand" deposits, mainly in localities south from Coos Bay to and beyond the California line. All of such projects tried to recover precious metals, and practically all of them were commercial failures because of the difficulty of separating finely divided metallic gold and platinum from the heavy "black sand" minerals. Not until very recently has any comprehensive effort been made to recover minerals of value other than the precious metals, gold and platinum.

In 1938, the newly organized Oregon Department of Geology and Mineral Industries recognized the potential value of the chromite in these sands and began to investigate the possibility of commercial utilization of the deposits. Electrostatic methods of separation were tried first, with encouraging results. The determination of available tonnage of the desired chromite was next attacked.

A Works Projects Administration exploratory campaign was carried out under Departmental sponsorship with the United States Geological Survey cooperating in supervision and moral support. Professor George W. Gleeson of Oregon State College assisted in the sampling and carried out valuable metallurgical work in connection with concentration problems.

The program of drilling and sampling indicated the presence of commercial black sand lenses capable of producing nearly 100,000 tons of chromite concentrate. This work furnished the evidence desired and led to extensive investigation by private groups.

The interest in these chrome occurrences has been heightened by war conditions and need for large supplies of chromite in the war program. The project nearest to actual production is that of the Krome Corporation, now building a 2,000-ton per day primary concentrator in the Coos Bay area. At the same time a finishing plant to raise the primary chromite concentrate to commercial grade is being built for the Federal Government with funds supplied by the Defense Plant Corporation.

The Department has long recognized that the actual progress in the development of these sands toward commercial utilization has gone well ahead of the scientific studies of the source and the manner of their deposition. Technicians of the U. S. Geological Survey have given valuable assistance to operators in the field and have done excellent mapping, but they have been obliged to postpone studies of origin in deference to immediate economic problems.

In the summer of 1942 the Department was fortunate in being able to arrange for a thorough study of the origin of the black sands by Dr. W. H. Twenhofel, Head of the Department of Geology, University of Wisconsin. The present paper, representing weeks of field work, is more than merely a report on the Oregon coastal geology—it is an exposition of the mechanics of coastal sedimentation; and the principles explained herein may be applied to natural concentrations of heavy minerals in coastal marine deposits in other parts of the world. Dr. Twenhofel, an authority on sedimentation, not only gives a scientific analysis of the abundant geologic data and field observations, but also makes general suggestions as to likely localities or conditions where black sand lenses may be found.

EARL K. NIXON, Director.

December 5, 1942.

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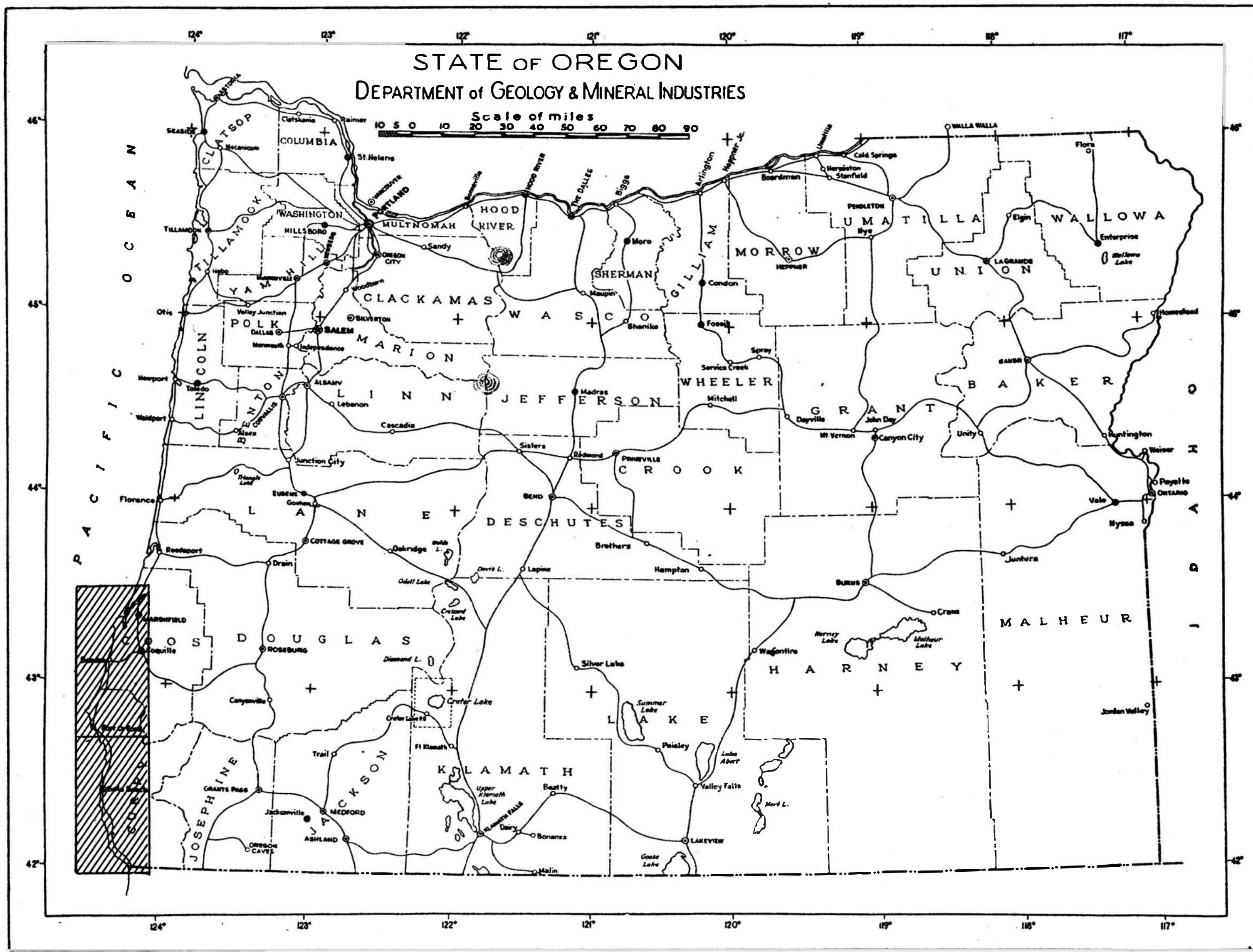

INDEX MAP OF THE STATE, SHOWING LOCATION OF AREA STUDIED

ORIGIN OF THE BLACK SANDS OF THE COAST OF SOUTHWEST OREGON

by

W. H. TWENHOFEL

Abstract

Black sand deposits along the coast of southwest Oregon have been mined for nearly a century and have been studied for almost 50 years. The presence of chromite, a strategic mineral, in these sands has renewed interest in the deposits, previously mined only for gold and platinum. The sands occur on the present beaches, and above sea level beneath the surfaces of various marine terraces which are found at elevations ranging from 35 to 1500 feet. The black sands are composed of dark minerals (such as magnetite, chromite, and ilmenite) and others, which, because of their relatively high specific gravity and resistance to weathering, have also been preserved and concentrated by the waves of past and present seas.

The rocks of the coastal region of southwest Oregon range in age from Paleozoic to recent, but those of importance as source rocks of the black sands are the basic and ultrabasic igneous rocks of pre-Tertiary (Mesozoic) age which occupy large areas in the Klamath Mountains, particularly in the drainage basins of the Rogue and Illinois Rivers in Oregon and in the Smith and Klamath Rivers of northern California.

Black sand deposits are found on the present beaches and in the deposits beneath the elevated coastal plains as follows: beneath terraces present between 30 and 100 feet above sea level; terraces between 150 and 170 feet; terraces between 300 and 350 feet; other higher beach terrace deposits are known which apparently do not contain black sands in important concentrations. The individual black sand lenses range in thickness from a few inches to tens of feet and are usually overlain by a considerable thickness of more or less barren sands of aqueous and presumably marine deposition. They frequently pass into gravel at the base, and lie upon or close to bedrock. Often more than one layer of black sand appears in a deposit, and the chromite content decreases outward from the black sand lenses into the adjacent gray or yellow sands. Nearly always they are located a quarter of a mile, or perhaps more, from the shore-lines which existed when the terraces under which they lie were formed.

Deposition of beach and offshore sediments in any locality is dependent upon five factors, namely: strength of waves and currents and their impingements on a coast; shoreline configuration both at the beach and in shallow water below sea level; relations of sea level to the land; and specific gravity and dimensions of the sedimentary particles. A study of the features of the various black sand deposits in the light of the above five conditions of deposition indicates that they must have been deposited during submergence of the coastline (or rise of sea level) in embayments where the longshore currents and the force of the incoming waves were sufficient to bring in the black sands. These were concentrated by means of the selective action of the outgoing currents, which, being less powerful than the onshore waves, carried out the lighter and finer materials.

Due to the prevailing southwesterly winds, these sand concentrations took place just south of promontories or at the north side of the embayments. As the sea rose, the location of the black sand concentrations changed with the changing position of the promontories and embayments, and the deposits were submerged below sea level and buried beneath considerable thicknesses of marine sands and muds.

As the land again rose or the sea level dropped, there were at least six periods during which the sea level remained stationary long enough for sea cliffs and terraces to be cut in the sands and muds which had been deposited in connection with the black sands. In places cliffs and terraces were also cut into the underlying bedrock. In places the overburden was nearly stripped from the buried black sand deposits; in places the black sands may have been completely eroded away; elsewhere the black sands may still remain deeply buried. The present terraces were cut by the retreating sea and most black sand deposits are older and have no genetic connection with them.

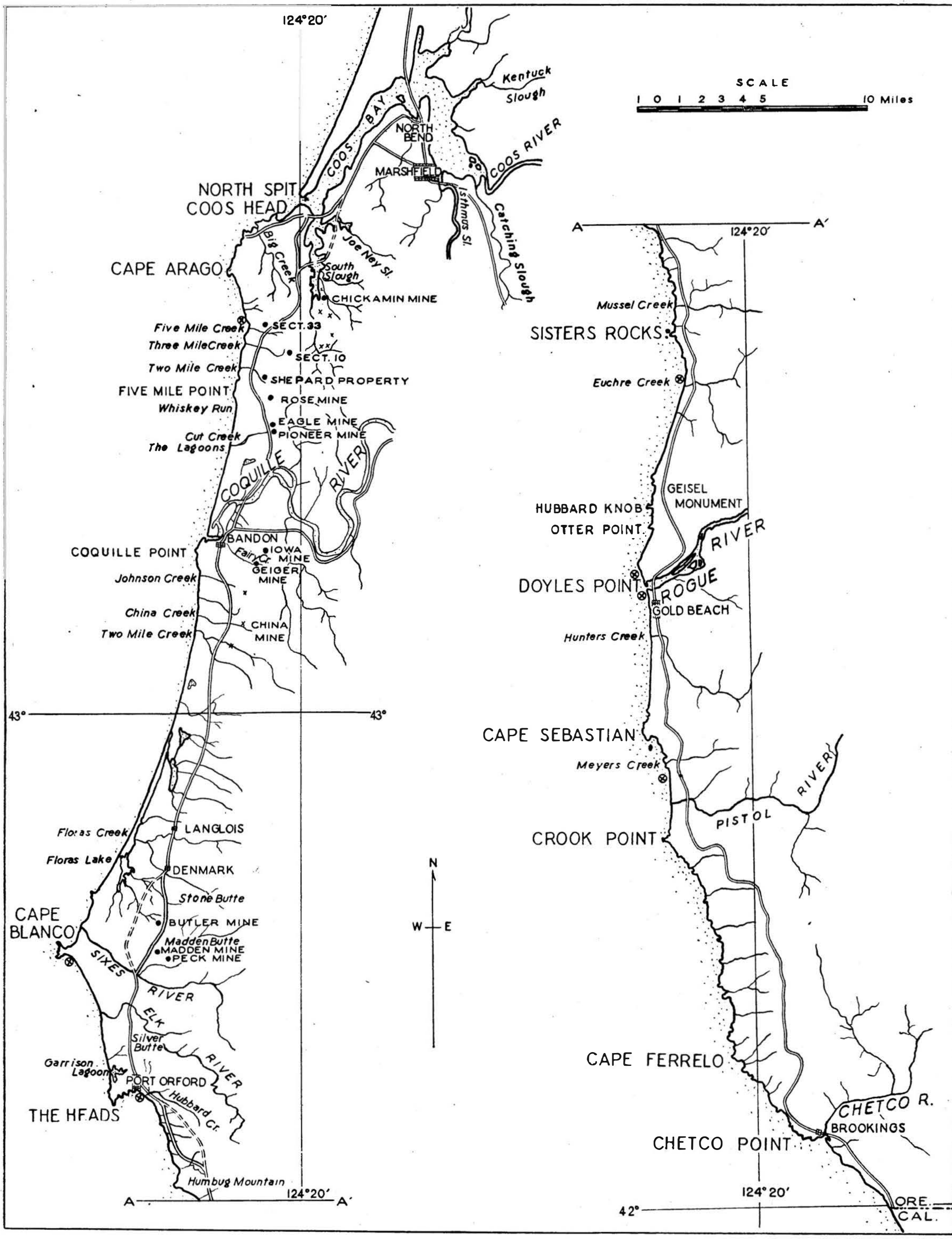

Figure 1. Map of the coast of southwest Oregon. Drawn after a map by Pardee (9) and from chart 5802 of the U. S. Coast and Geodetic Survey. The mark (x) denotes places on the coast where the distribution of the black sands has been studied and where the concentrations may be adequate for commercial extraction. The coast south of the Pistol River has not been studied by the author.

Introduction

The black sands of the coast of southwest Oregon have attracted the attention of miners and geologists for nearly a century and the occurrences have been noted and described in many papers. These sands were described by Diller (4, 6) in the Port Orford and Coos Bay folios of the United States Geological Survey and they have been considered in some of his other papers. They formed the subject of a Bureau of Mines Technical Paper written by Horner (8) and they were given consideration by Day and Richards (3) in a paper on the "Useful Minerals in the Black Sands of the Pacific Slope." Data bearing on the occurrence of gold, platinum, and other minerals in the black sands were published by Pardee (9). Other papers giving consideration to the black sands are listed in the bibliography.

The black sands of the present beaches of southwest Oregon and the adjacent coast of California attracted the attention of prospectors as early as 1852 in which year and later they were worked for gold and to some extent for platinum. The black sands included in the Pleistocene sediments beneath the elevated marine terraces* on the coast were discovered to contain gold in 1870 and a number of placer mines in these deposits have been worked for gold and platinum. Other minerals went into the tailings. Reports are current in southwest Oregon of the extraction of several millions of dollars of gold and platinum from some of the old workings. Others state that most of the mines were losing ventures. Most workings have been abandoned several times and later reopened on renewal of hope or interest. At the date of writing, none of the old mines is being worked for either gold or platinum.

The urgent need for chromium in connection with the war effort has stimulated interest in the black sands of the Oregon coast, as some of the particles to which the color is due are composed of chromite. Ilmenite and magnetite are also responsible for some of the blackness. Several large organizations and some small ones have acquired land holdings and have conducted much exploration. Chromium is now the desired substance instead of the gold, platinum and rarer metals of earlier years.

* i.e. "below ground surface in the bench-like old sea terraces."

The territory upon which this report is based extends from Coos Bay to Pistol River, but only reconnaissance examination was made by the writer of the districts south of Gold Beath (See maps of figure 1). The coastal sands were examined at numerous points between Gold Beach and Coos Bay and any extents of the coast which seemed favorable to the concentration of the minerals of the black sands were examined in detail. All old workings in black sands beneath the elevated marine terraces were studied in detail.

This study was made in the late summer of 1942 and was made possible through the interest in the black sands of Mr. Earl K. Nixon, director of the Department of Geology and Mineral Industries of the State of Oregon. The writer is extremely grateful to Mr. Nixon for the opportunity to make the study. Mr. Nixon also spent several days with the writer in the field at the beginning of the study, and toward the end of the field work assistance was rendered by Mr. John Eliot Allen and Mr. Ray C. Treasher, both members of the staff of the Department. The writer is indebted to Mr. O. Paul Lance of the Krome Corporation and Mr. Edward Nelson of the Humphreys Gold Dredging Company for the opportunity to study the results of drilling by their companies. Mr. Allan Griggs of the United States Geological Survey assisted in the finding of the old mines east of Bandon and made the writer acquainted with his discovery of black sands in the sea cliff south of the mouth of Two Mile Creek. He also accompanied the writer in the examination of the sands in the channels of Sixes and Rogue Rivers.

This paper gives the results of the field studies of the black sands. It is contemplated that a later paper will be presented which will give results of the laboratory studies of the black and associated sands.

Location of the Black Sands

Contrary to the opinion of those who have not seen the black sands, they have only limited distribution on the present beaches. There are far more areas of beach without black sands than with them. The long stretch of beach from the north side of Cape Blanco to Bandon contains few black sands and even the minerals which compose large parts of the black sands are not common. There are few concentrations of chromite in sands north of Cape Arago. There are some occurrences of black sands between Cape Arago and the mouth of Coquille River, but the places where black sands are not present are very much more numerous than those places where they are present. There are few black sands, perhaps none, from the mouth of Elk River to the north side of the peninsula at Port Orford and none seems to be present on the beach from the south side of the bay at Port Orford to the peninsula of the Geisel monument. The map of figure 1 shows places on the present beach where there are important concentrations of the minerals of the black sands.

The black sands which have been discovered above present sea level beneath the marine terraces which border the coast of southwest Oregon have in the past been assumed to occur in connection with the beaches corresponding to the terraces and to have been concentrated on these beaches when the terraces were formed. Reasons are given on later pages for dissenting from this view. Distribution of the black sands in the sediments beneath the marine terraces is limited and there are very many more places without black sands than with them.

Mineral Composition of the Black Sands

The black sands are composed of ilmenite, magnetite, chromite, quartz, garnet, olivine, epidote, zircon, feldspar, hornblende, rare particles of gold and platinum group metals together with a few other particles of minerals and rocks. The grains are generally of medium to small sand and silt dimensions and most are excellently rounded. The proportions of the different minerals vary from place to place and from bed to bed. Quartz is usually the most common mineral, both in the black sands and in the light-colored sands which compose most of the beaches. Garnet is extremely abundant in some beds and places. Olivine is also occasionally common. Ilmenite, magnetite, and chromite, the minerals responsible for the blackness, also vary in their proportions from place to place. Some occurrences carry little chromite and much ilmenite and magnetite. In other occurrences the reverse is the case. Some gray sands may carry considerable chromite, ilmenite and magnetite, whereas other gray sands carry few particles of these minerals and owe their color to numerous dark rock particles of sand dimension. Mineral relations are about the same in the sands beneath the elevated marine terraces as they are in the sands of the present beaches. The rounding, sorting and mineral composition of the sands of the beaches and those beneath the raised marine terraces are in marked contrast to the sands of the rivers which empty into the sea over the area studied. The river sands are rounded slightly or not at all, are poorly sorted, and have a different mineral composition. The black sands are mostly composed of mono-mineral particles, but about the mouth of the Rogue River there are particles composed of more than one mineral.

Stratigraphy of the Coastal Region

The rocks of the coastal region of southwest Oregon were described by Diller (6, 4) in the Port Orford and Coos Bay folios. It is not unlikely that further study of the stratigraphic section will lead to some modification. A partial stratigraphic section of the sedimentary rocks is as follows:

Recent	Stream alluvium and the deposits on the present beaches.
Pleistocene	Gravels, sands, silts, and clays beneath the raised terraces. Silts and clays are not common.
	Unconformity
Tertiary	Miocene **Empire formation.** Sandstones and siltstones of light to dark colors. Probably of marine origin.
	Unconformity
	Eocene **Arago series.** **Coaledo formation.** Sandstones, siltstones, claystones, and coal. Continental origin. **Pulaski formation.** Sandstones, siltstones, and claystones. Possibly of continental origin.
	Unconformity
Cretaceous	**Myrtle formation.** Conglomerates, sandstones, siltstones, and claystones, all more or less metamorphosed.

In addition to the above tabulated sedimentary rocks, there are bodies of chert and silicious shale of possible Cretaceous age. The chert has colors ranging from gray to blue.

There are also extensive areas underlain by metamorphic and igneous rocks. These consist of blue and gray amphibolite and some mica schists which are doubtfully assigned to the Cretaceous, intrusions of gabbro, and flows and dikes of basalt and dacite porphyry. Bodies of serpentine of considerable extent were derived from alteration of ultrabasic igneous rocks. The ages of some of the igneous rocks remain to be established, but as the ages are not pertinent to the problem of the black sands, no attempt at age determination was made by the writer.

There was a deformative movement between the deposition of the Eocene sediments and those previously deposited. Thus the Eocene strata rest upon the eroded edges of the Cretaceous and older rocks. There was also deformation between the Eocene and the Miocene and thus the Empire formation has angular relationships with the Eocene and older rocks. Another deformative movement took place after the Miocene and before the Pliocene. Some strata in the coastal cliffs at Cape Blanco have been considered to be of Pliocene age and these are unconformable on underlying rocks. The Pleistocene sands of the raised marine terraces are unconformable on all rocks upon which they lie.

It is thought that the Pleistocene sands were largely deposited during a submergence of the land which brought sea level 1500 feet above its present position, and possibly in small part while the land was emerging to a position above present sea level. Sands were also deposited during the Pleistocene and Recent small submergence. The extent of the last rise is unknown, but the drowned or submerged lower courses of some of the streams, particularly over the north end of the coast studied, show that it has been considerable. Subsidence of the coast may be continuing.

Sources of the Minerals of the Black Sands

The minerals of the black sands were derived from pre-Pleistocene rocks. Basic and ultrabasic igneous rocks or their altered equivalents constitute the original sources of the ilmenite, magnetite, chromite, olivine and the platinum group minerals. The gold was probably derived from quartz veins.

Ilmenite and magnetite could readily have been derived from the gabbro, basalt, and the dacite porphyry, and the epidote from the greenstones. Magnetite, chromite, and the platinum minerals could have come from the serpentine or from the ultrabasic rocks from which the serpentine was derived. The olivine could also have originated from these rocks. The quartz veins in the Myrtle formation could have furnished the gold. The other minerals are common in all sands and it is not necessary to seek for definite sources for them.

As the rocks contributing the various black and associated minerals are apparently pre-Tertiary in age, it may be expected that Tertiary strata might contain minerals like those of the black sands and thus could serve as a secondary parent for them. However, both magnetite and ilmenite readily decompose and would not be likely to survive a second cycle of rock destruction. It is hence assumed that very little magnetite and ilmenite were derived from the sedimentary Tertiary rocks. Chromite, if it did not contain ferrous iron in its molecule, might survive a second cycle of decomposition and thus the Tertiary sedimentary rocks may be a source for this mineral. Gold and the minerals of the platinum group are not readily destroyed and they may also have been derived in part from the Tertiary sedimentary rocks. It is thus considered probable that the magnetite and ilmenite were almost entirely derived from the original parent igneous rocks. The chromite is assumed to have come for the most part directly from the ultrabasic rocks, but some may have been derived from the Tertiary sedimentary rocks. In general, it is thought that the Tertiary sedimentary rocks were very small contributors of the minerals of the black sands. They probably contributed extensively to the quartz and garnet sands.

Granted that the inferences just made are correct, it is pertinent to inquire which of the streams of the part of the coast studied may have been important contributors of the minerals of the black sands to the present beaches and the deposits of black sands beneath the raised marine terraces. It is considered certain that the larger streams existed when the latter deposits were made. Named in order from south to north for the territory studied, the large streams are the Rogue, Elk, Sixes, Coquille, and Coos Rivers.

The Rogue River and its chief tributary, the Illinois River, drain large areas underlain by gabbro, basalt, peridotite, and serpentine and are thus in a position to acquire and make contributions of the minerals of these rocks to the coastal sediments of the present, and these streams must have been in like position to make contributions to the coastal sediments of the past. The sands about its mouth carry particles which are composed of more than one mineral, indicating that these particles are not far from original sources. The river also flows over extensive areas underlain by the Myrtle and other formations which contain quartz veins from which it could obtain gold. The river sands contain the minerals of the black sands.

The Elk River flows through extensive exposures of gabbro and basalt and its headwaters extend into a large area underlain by serpentine. Much of its course lies over the Myrtle formation. The river is thus in a position to acquire the minerals of the black sands and contribute them to the coastal sediments.

The Sixes River drains small areas underlain by gabbro, basalt, and serpentine, but large areas underlain by the Myrtle formation. It is in a position to acquire gold, but little ilmenite, magnetite, and chromite. Its contributions to the black sands ought never to have been large.

The Coquille River flows for much of its course over Tertiary sedimentary rocks and to some extent over basalt and serpentine. It does not seem at any time to have been in a position to make large contributions of the minerals of the black sands of the coastal sediments.

The Coos River flows almost entirely over Tertiary sedimentary rocks. The sands in the present channel of the stream are almost entirely quartz and feldspar and it is considered very unlikely that significant contributions of black minerals were ever made by the Coos River to the coastal black sands.

It is thus suggested that, so far as contributions of minerals of the black sands from primary parental sources are concerned, the Rogue and Elk Rivers could have contributed ilmenite, magnetite, chromite, and gold; the Sixes and Coquille Rivers ilmenite, magnetite, a little gold, and perhaps a little chromite; and the Coos River has contributed essentially nothing in the way of black minerals to the coastal sediments.

The data at hand thus suggest that within the area studied only the Rogue and Elk Rivers are in position to make or to have made significant contributions of the minerals of the black sands to the present or past coastal sediments. There are other rivers south of the area studied which must have been important contributors of the minerals of the black sands and these minerals may then have been moved north by the coastal currents. Among these streams are the Pistol River on the south margin of the area studied, the Chetco River which flows into the sea just north of the boundary of Oregon and California, the Smith River of northern California, and farther south in California, the Klamath River. The areas drained by the coastal rivers of northern California and southern Oregon which are underlain by ultrabasic rocks have been assembled by Mr. John Eliot Allen of the Department of Geology and Mineral Industries of the State of Oregon. These are as follows:

Coquille River, south fork	. 10	square miles
Floras Creek	 7	" "
Sixes River	 6	" "
Rogue River	. . . . . 380±	" "
Hunters Creek	 43	" "
Pistol River	 26	" "
Chetco River	 37	" "
Smith River	. . . . . 400±	" "
Klamath River	. . . . . 500±	" "

These data indicate that the Rogue, Smith and Klamath rivers were and probably are important contributors to the black sands of the coastal areas studied and that in all probability the sands of the coast of southwest Oregon have moved northward from the mouths of the rivers. In addition, there are parts of the northern coast of California where the coastal rocks are ultrabasic and wave erosion must have released minerals like those of the black sands from these. These likewise would have moved northward.

Physiography of the Southwest Coast of Oregon

The coastal region of southwest Oregon has two phases, namely: (1) an upland region which is underlain by a complex of various kinds of igneous, metamorphic and sedimentary rocks over which the surface has decidedly youthful topographic expression, and (2) a coastal terraced region composed largely of unconsolidated Pleistocene sediments but partly of older rocks like those underlying the first phase. The first named of the two phases forms the coastal mountains, with which this paper has little concern. The terraced region borders the coast throughout the entire extent of the area studied and in some areas the terraces seem as the treads of a giant stairway rising from the sea. The terraces are greatly dissected in the Seven Devils country between the mouth of the Coquille River and Coos Bay by canyons or steep-sided valleys, some of which are several hundred feet deep. It is these canyons which are responsible for the name of Seven Devils.

The terraces range in elevation from 50 feet for the lowest up to 1500 feet for the highest. Isolated remnants of the 1500-foot terraces are preserved in but few places and the chief evidence for the presence of this terrace is beach gravel occurring at this level. Between 800 to 1000 feet there are large terrace remnants preserved, but only one of these remnants is underlain by unconsolidated sands. This is on the top of the ridge just north of Sixes River at the locality of the old Peck Mine. There is another well preserved terrace in the range of elevation from 500 to 600 feet. The best occurrences of this terrace are north and south of the lower reaches of the Sixes River and just south of the Elk River in the same area, and in the Seven Devils country between the mouth of the Coquille River and Coos Bay. Where this terrace is underlain by Pleistocene sands, they constitute a more or less thin veneer over older rocks. A known maximum thickness of over 100 feet of sands lie upon this terrace in the region of the Sixes and Elk Rivers. Another well developed terrace lies between the levels of 300 to 350 feet, and is best shown in the Seven Devils country. A terrace in the range from 150 to 170 feet above sea level is present along many parts of the coast and may be followed easily from Cape Arago to the Sixes River and beyond. There is another terrace with elevation of about 100 feet above sea level and another can be recognized at an elevation of around 50 feet. The 50-foot terrace is well-developed in the vicinity of Bandon and just north of the mouth of Rogue River. The 100-foot terrace may be seen in the region of Hubbard Knob and north of the mouth of the Coquille River. It has been stated that there has been some warping of the terraces, but until large scale topographic maps have been made of the coastal areas, it will be extremely difficult to work out the exact situation with respect to warping of the terraces and their correlation along the coast.

Occurrences of the Black and Gold-Bearing Sands

It is probably correct to state that some black minerals and some gold and minerals of the platinum group are present in all of the sands of the present coast and in the Pleistocene sands which lie beneath the raised marine terraces of the coast, but ordinarily the quantities of these minerals are very small.

Deposits on the present coast: There are only a few places on the present coast where the conditions of coastal topography, wave action and supply of sediments are of the character to bring about the washing away of the smaller and lighter particles and the concentration of the larger and heavier particles as the black sand deposits. On the part of the coast studied by the writer, the places where this is now taking place are about the mouth of Five Mile Creek, south of Cape Blanco, in the bay south of The Heads at Port Orford, about the mouth of Euchre Creek and south of the headland of Sisters Rocks, about the mouth of Rogue River, and about the mouths of Myers Creek and Pistol River in the bay between Cape Sebastian and Crook Point. There are numerous other places where there are small local concentrations of black sands, but none of these has any commercial importance. These concentrations may be seen as thin films of black minerals at places where waves and currents, or winds, are competent to remove such minerals as quartz, but are ordinarily not competent to transport such heavy minerals as ilmenite, magnetite, chromite, gold and platinum. The high concentrations of black minerals are in bays and generally in the inner parts of bays. Furthermore, the sands have a tendency to concentrate toward the north sides of the bays, or south of the headlands which limit the bays on the north. Such is the case at Cape Blanco, about the mouth of Five Mile Creek between Five Mile Point and Cape Arago, and at other places. Reasons for this distribution are given on other pages. It may be assumed that somewhat similar distribution due to the same causes existed during the times of the earlier advance and retreat of the sea to and from the level of the 1500-foot terrace. The retreat was first to a position now beneath the sea and subsequently the land sank to its present position.

Deposits beneath the 30-100-foot terraces: The black and gold-bearing sands beneath the Pleistocene terraces have been found from elevations of 30 to 40 feet above sea level to 800 feet above. The lowest occurrences beneath the surfaces of the terraces are in the sea cliffs between Hubbard Knob and the headland on which the Geisel Monument is situated, between Hubbard Knob and Otter Point, south of the mouth of Two Mile Creek in the Seven Devils country, and in the Madden, Eagle, and Pioneer mines.

In the occurrences in the vicinity of Hubbard Knob and Otter Point, the Pleistocene sands rest unconformably on serpentinized rock at an elevation of about 35 feet above sea level. At one place north of Hubbard Knob the basal deposits of the Pleistocene sands consist of 2 feet of gravel. The gravel is succeeded by about 10 feet of rusty-colored sands. This is the oxidized black sand zone. This is overlain by 40 to 50 feet of yellow water-laid sands and a couple of feet of soil. The surface is essentially flat with gentle rise in elevation inland. This is the 100-foot terrace of that part of the coast. Deposits of black sands with about the same relationships are exposed in the sea cliff of the bay between the headlands of Otter Point and Hubbard Knob, one exposure being just north of Otter Point and the other just south of Hubbard Knob. Each of these deposits is a considerable distance from what must have been the shore when the 100-foot terrace was formed, and each has an overburden of water-laid quartz sands.

The occurrence of black sands in the present sea cliff south of the mouth of Two Mile Creek is also just north of Five Mile Point. This deposit was discovered and shown to the writer by Mr. Allan Griggs of the United States Geological Survey. The cliff just south of the mouth of Two Mile Creek is composed of steeply dipping Eocene sandstones and siltstones. About three eighths of a mile south of the creek these rocks do not extend so high and are overlain by Pleistocene sands. The approximate descending section of the cliff toward the northern end of the black sand exposure is as follows:

10.	Soil, black	1 to 2 feet
9.	Sands, white, contain some opaque mineral, may be of eolian deposition. About	8 "
8.	Sands, white and yellow, of aqueous deposition	22 "
7.	Sands, dark, with mild concentrations of black minerals and with thin streaks of rich black sands .	1.2 "
6.	Pumice, thin streak	.04 "
5.	Sands, similar to zone 7	2.5 "
4.	Sands, dark, good concentration of black minerals	2 to 3 "
3.	Sands, gray, small content of black minerals	1 "
2.	Sands, yellow. Not certain thickness accurate as some may be slump over Eocene strata . . .	22 "
1.	Sandstones and siltstones, Eocene, inclined, summit above sea level .	45 "

The black sands in this section, zones 4 to 7, have a thickness of 6 feet and they are overlain by 22 feet of white to yellow water-laid and presumably marine sands. These are overlain by 8 feet of sands which may be wind-laid, although the level surface of the overlying 110-foot terrace does not support this interpretation.

A second section was measured 1400 feet south of that described above. This is near the south end of the outcrop and is as follows:

7.	Soil, black	1 to 2 feet
6.	Sands, white, gray, and yellow, perhaps of eolian deposition . .	6 to 8 "
5.	Sands, yellow and gray, of aqueous and probably of marine deposition	50 "
4.	Sands, black, about	4 "
3.	Gravels of pebble dimension . .	1 "
2.	Sands, yellow, of marine deposition. Thickness dependent on irregularities of surface on underlying Eocene sandstones and siltstones	5 to 10 "
1.	Inclined strata of Eocene, summit above sea level	35 to 40 "

The height here of the top of the cliff is also 110 feet. The surface above the cliff is essentially level and is that of the 100-foot terrace.

It should be noticed that the elevation of the black sand zone is inclined to the south and that in the southern section a total thickness of about 60 feet of sands overlies the black sands. This is in contrast to about 30 feet 1400 feet to the north. The overlying terrace has the same height in the two exposures. The outcrop of the black sands extends to the south and to the north beyond the two sections measured. In each of the sea-cliff exposures the inland border of the terrace is at least a quarter of a mile distant, except at the southern end where there is a ridge which extends toward Five Mile Point.

The old Eagle and Pioneer mines in the southern part of the Seven Devils country are beneath the 100-foot terrace. The Eagle Mine is in sec. 28, T. 27 S., R. 14 W. The exposed black sands are highly concentrated and have an overburden of 47 feet of yellow sands. As the surface of the terrace rises somewhat from the top of the face of the mine, it seems likely that the original overburden must have been of the order of 50 to 60 feet. The yellow sands of the overburden are water-laid. Drilling near the Eagle Mine is said to have encountered peat in the overburden.

The Pioneer Mine is in sec. 33, T. 27 S., R. 14 W., only a short distance south of the Eagle Mine. Above the black sand lens there was an overburden before erosion of the order of 60 feet. The sands of this overburden seem to be of aqueous deposition.

Both the Eagle and the Pioneer mines must be at least a half mile from any sea cliff which might have been present when the 100-foot terrace was formed. It is not known how far the black sands lie above bed rock.

Another deposit beneath the 100-foot terrace is at the old Madden Mine, situated in the NE¼ of sec. 4, T. 32 S., R. 15 W., a short distance north of the Sixes River and on the east side of U. S. Route 101. The overburden on the black sands in this mine ranges from about 15 to 25 feet of yellow sands, depending on the extent of erosion which has taken place since the terrace was formed. The black sand zone is 8 feet thick and consists of gray sands with thin beds and streaks of concentrated black sands. The basal part of the black sand contains gravel with particles to 6 inches in diameter. Bed rock in the form of shale is stated to be immediately below the gravel. Some of the local prospectors believe that this deposit was laid down by the Sixes River at some time in its earlier history when it flowed at a higher level than at present. This interpretation for this deposit is an impossible one. The sands have rounding, sorting, and stratification which could not possibly develop under the conditions of stream deposition and they do have the characters which develop under the conditions of marine or standing water deposition. The overburden was interpreted by Pardee (9, p. 29) as of eolian or wind deposition. The writer does not believe that this view can be accepted and the overburden is believed to be water-laid on the basis of its sedimentary structures and the levelness of the surface of the terrace. The deposit of the mine is perhaps an eighth of a mile from any possible sea cliff corresponding to the 100-foot terrace.

Deposits beneath the 150-170-foot terrace: A considerable number of old mines occur in the 150 to 170-foot terrace. These are discussed below.

The Shepard property, formerly known as the Fletcher-Myers property, is in sec. 16, T. 27 S., R 14 W. The black sands beneath this property rest on or a little above bed rock and in some places there is gravel at the base. The bed rock rises eastward toward the sea cliff which existed when the 150 to 170-foot terrace was formed. The overburden of gray and yellow sands of aqueous and probable marine origin has a thickness of the order of 30 feet, except where removed by erosion after the terrace was formed.

The old Rose or Coquille Mine in sec. 21, T. 27 S., R. 14 W., is now known as the Covert property. The surface is flat except for some low ridges which may be of dune origin although they do not have the appearance of dunes. The black sands are everywhere over 30 feet beneath the surface except where a tributary of Two Mile Creek flows through the property. The overburden of yellow sands is referred to marine deposition. The black sands lie from 4 to 6 feet above the surface of bed rock and, locally, they have gravel at the base. The sea cliff corresponding to this terrace lies around a quarter of a mile distant. This property was drilled by one of the companies interested in the chromite in the black sands and a core from one of the test holes showed the following descending section:

4.	Sands, yellow	32 feet
3.	Sands, black	5 "
2.	Sands, yellow, gravel at base	5 "
1.	Bed rock at	42 "

The old Butler Mine, also known as the Zumalt Mine, is near the line between secs. 27 and 34, T. 31 S., R. 15 W., and about 2 miles south of the village of Denmark. It is about 2 miles north of the Madden Mine. The black sands in this deposit are overlain by yellow, water deposited sand, from

10 to 20 feet thick, depending on the extent of erosion of the terrace. The black sands range in thickness to perhaps 5 feet, and rest on gravel which in turn rests on sandstone and shale. Pardee (9, p. 29) believed that the sands of the overburden were wind-laid. The writer does not agree with this view and considers them to be of aqueous deposition. Both mines are perhaps a quarter of a mile from the sea cliff which existed when the 150 to 170-foot terrace was formed.

The Chickamin Mine is on Brown Slough, an east arm of South Slough, south of Charleston in the Coos Bay region. An open pit placer mine on the east side of Brown Slough shows the following descending section:

6. Soil underlain by clay and silt, oxidized and weathered	6 to 7 feet
5. Sands, yellow, locally rusty . .	5 to 6 "
4. Sands, yellow with thin streaks of black sands, beds inclined westward, some beds cross-laminated eastward, others westward . . .	2 to 3 "
3. Gravel, coarse, locally rusty and locally cemented. Zone inclined westward, probably inclined deposition, cobbles to 3 inches in diameter, most around an inch .	5 to 8 "
2. Gravel, particles small to perhaps one - half inch, cross - laminated westward. About	3 "
1. Sands, gray, with thin streaks of black minerals, base not exposed .	2 "

Another section was measured at an old tunnel about a quarter of a mile west of the above described occurrence and on the west side of Brown Slough. This is as follows:

4. Sands, rusty, exposed in cliff above the tunnel	4 feet
3. Sands, rusty, thin streaks of black sands present. Exposed on side of tunnel from base to roof	6 "
2. Sands, yellow, have westerly cross-lamination	2 "
1. Concealed to floor of slough. About . .	60 "

No gravel is exposed in the tunnel section and the hillside above the tunnel is covered with thick timber. A road up this hill, a short distance to the south, shows an overburden of 70 feet of yellow sands of aqueous deposition, at least in part. Not all of this section is exposed. The total thickness present thus totals a little more than 140 feet and hence the reference to the 150 to 170-foot terrace.

Concentration of black minerals at the Chickamin Mine is not great so far as the exposures indicate. Pardee (9, pp. 23, 24) was of the opinion that two zones of black sands are present in the Chickamin Mine workings and he presented a diagram to that effect. The writer sees no evidence for this view, but there are no reasons why such might not be possible. The shores which must have existed when these sands were deposited were probably not very close and the shores which existed when the 150 to 170-foot terrace was formed were at least a mile distant.

Other deposits of black or gold-bearing sands beneath the 150 to 170-foot terrace are in the old mines east of Bandon about the headwaters of South Two Mile, China, Johnson, and Fairy Creeks. Three of these mines were known as the China, Geiger, and Iowa. They were worked for gold and the quantities of black minerals do not seem to be large. In some cases, the gold-bearing and black sands have gravel at the base and they rest on an eroded and irregular bed rock surface. There is an overburden of about 30 feet of yellow sand. Information was obtained that drilling in the vicinity of the Geiger Mine encountered peat before the horizon of the black sands was reached. These deposits are distant from what must have been the shore when the 150 to 170-foot terrace was formed. There have been considerable deposits of wind-blown sands in the vicinity of Bandon and it is probable that a part of the overburden of the mines above described is of this origin. However, the lower part of this overburden seems definitely of aqueous origin.

Deposits beneath the 300-350-foot terrace: Deposits of black sands beneath the 300 to 350-foot terrace are known in the Seven Devils region in secs. 10 and 4, T. 27 S., R. 14 W., and in sec. 33, T. 26 S., R. 14 W. The deposits in sec. 33 are close to the surface and have an overburden which does not much exceed 10 feet in thickness. Much of this overburden may be due to creep or slump from the adjacent steep slope which obviously was a sea cliff when the 350-foot terrace was formed. This steep slope rises to the 600-foot terrace. The black sands in sec. 33 lie at about 340 feet above sea level and hence they correspond rather closely with the terrace surface.

The most extensive black sands known in connection with the 300 to 350-foot terrace are in sec. 10. The overburden here ranges from 0 to 72 feet, the small thicknesses being where erosion has been extensive. It does not seem likely that the overburden originally was less than 30 feet at any place. The black sands in this area which are rich enough to be considered ores range in thickness from 7.5 to 35 feet. The overburden seems definitely to be water-laid. Some small thickness of the upper part may locally be of eolian deposition, but the surface of the terrace does not give a great deal of support for this view. The deposits are adjacent to a steep slope rising to the 500 to 600-foot terrace. This slope, which evidently was the shore when both the deposits and the terrace were formed, is underlain by sedimentary rocks of Eocene age. The black sand deposits extend outward from this steep slope for at least a quarter of a mile, and they rest on, or a little above, tilted Eocene sandstones and shales. It seems obvious that the black sands of this locality were deposited adjacent to a coast and some of them may have been deposited on a beach. Those at a distance from the steep slope may have been deposited in shallow water offshore. The great thickness of overburden obviously shows that the deposits of black sands are not deposits made at the time the 300 to 350-foot terrace was formed.

High terraces: No deposits of black sands are known beneath the 500 to 600-foot terrace. A section of the sands beneath this terrace was measured on the road to the summit of Grassy Knob which forms the divide between the lower Sixes and lower Elk Rivers. This section is as follows:

3. Clay and sand topsoil to top of terrace	8 to 10 feet
2. Sands, light brown and yellow with silt and clay. These are clearly offshore deposits . . .	22 "
1. Gravel, beach or offshore; rests on deformed Myrtle formation. Color rusty on exposed surface. Begins at base with interbeds of coarse and fine gravel with the largest particles about an inch in diameter, but some particles to 3 and 4 inches. Upper part mostly fine gravel	25 "

The total thickness of this section is 57 feet, but at another locality near the east end of Grassy Knob at least 100 feet of Pleistocene sands are exposed.

The terrace on Grassy Knob ranges in width from perhaps 300 feet to over 1000 or more feet. The surface is strikingly level for much of the area and it is covered with a clay soil. Most of the terrace is bare of timber and given to cultivation or pasture. The remnant on the corresponding ridge south of Elk River is covered with second growth timber. A road to this terrace shows 125 to 150 feet of Pleistocene gravels and sands overlain by clay. Another remnant, largely cleared and pastured or cultivated, lies north of the Sixes River. No exposures were seen on this ridge.

Excellently preserved remnants of the 500-foot terrace occur in the Seven Devils Country, but the Pleistocene sands upon these remnants seem to be thin and they are not known to contain black sands.

Sands beneath the 800-foot terrace are not extensively preserved. The largest remnant of sands beneath this terrace is on the ridge north of the Sixes River where they have been worked for gold at the old Peck placer mine. Two openings were worked on opposite sides of this ridge. The one on the south is now so overgrown with trees and brush that little may be seen. The opening on the north shows much of the original face and the writer excavated this face downward for an additional 14 feet to the approximate floor of the mine. The section of the complete face thus exposed is as follows:

6. Sands, yellow, to top of face. These sands are referred to aqueous deposition and the surface over them is nearly level . . .	20 to 25 feet
5. Sands, gray	6.8 "
4. Sands, gray, cemented, coherent, but not firm	0.75 "
3. Sands, slightly greenish gray, with small patches and streaks of brown	7 "
2. Sands, gray, poorly cemented, relatively coherent, with streaks of brown and yellow	1.25 "
1. Sands, gray, some cemented nodules, no black streaks	1.75 "

The bottom of this section is thought to be not far above bed rock of the Myrtle formation which is somewhat serpentinized in this region. The section shows that there are no really black sands, but there are black minerals in the gray sands. The deposits seem to have been laid down at some distance from the shore as no cliff is apparent for a long distance.

Shapes of deposits: The shapes of the deposits of black sands are known in but few cases, but they appear to be irregularly lenticular if only the black minerals of the black sands are considered. If the sands into which the black sands pass laterally are included as a part of the deposit, the black sands then merely become a portion of a lens. At any occurrence of black sands there is an area for each bed in the deposit which has the maximum quantity of black minerals in that bed. Overlying and underlying beds also have places of maximum quantity of black minerals, but the areas or places of maximum quantities do not necessarily coincide. The following section from sec. 10, T. 27 S., R. 14 W,. is considered a typical one through a black sand zone and the overlying and underlying beds. The section is descending.

	Thickness	Content of Cr_2O_3
11. Brown sand and yellow clay	4.0 feet	2.63 percent
10. Yellow sand	4.5 "	2.39 "
9. Dark brown and black sand	3.0 "	11.50 "
8. Dark brown sand	3.0 "	3.20 "
7. Dark brown sand	5.0 "	2.53 "
6. Dark brown and black sand	5.0 "	18.76 "
5. Hard black sand	4.0 "	2.99 "
4. Dark brown sand	1.0 "	0.66 "
3. Light brown and yellow sand	3.0 "	3.36 "
2. Gray and brown sand with trace of red clay	1.5 "	1.24 "
1. Gray sand and red and blue clay	1.5 "	1.17 "

This section has two levels where the sands contain a high content of chromite. Another closely adjacent section may have the highest chromite content in other beds, and the content may be smaller or larger than those of the section given. The point may be made that the content of chromite and other black minerals in each bed decreases outward in all directions from the place of maximum quantity. It is believed that the section which follows shows these generalizations if it is compared with the section given above. This section is from the same area as the one above.

	Thickness	Content of Cr_2O_3
15. Yellow sand and clay . .	4.0 feet	0.15 percent
14. Yellow sand	2.0 "	0.37 "
13. Hard black sand	5.0 "	12.00 "
12. Dark brown and black sand	3.0 "	9.20 "
11. Light brown sand	2.5 "	4.45 "
10. Brown sand and yellow clay	2.5 "	2.41 "
9. Light and dark brown sand	2.0 "	5.37 "
8. Dark brown sand	2.5 "	9.20 "
7. Dark brown sand	2.5 "	4.74 "
6. Light brown sand	3.7 "	3.58 "
5. Buff sand	2.8 "	3.28 "
4. Light brown sand	1.7 "	2.53 "
3. Dark brown sand	1.5 "	7.37 "
2. Black and dark brown sand	2.2 "	9.85 "
1. Yellow and blue clay . .	1.8 "	3.21 "

The yellow and blue clay is thought immediately to overlie the Eocene sandstones and shales.

Another closely adjacent section shows the chromic oxide content without description. It is given to show the decrease of chromic oxide from the high figures of the two sections already given.

Thickness	Content of Cr_2O_3
5 feet	1.44 percent
5 "	0.45 "
5 "	0.27 "
5 "	0.36 "
5 "	0.72 "
5 "	0.45 "
5 "	0.54 "
5 "	1.22 "
5 "	1.58 "
5 "	0.94 "
5 "	0.67 "
5 "	0.67 "
5 "	1.34 "
5 "	3.05 "
5 "	2.15 "
5 "	1.34 "
3 "	0.63 "

The thickness of any section and the extent of overburden in the area of these sections depend not only on the extent of removal of material by erosion subsequent to the formation of the 300 to 350-foot terrace, beneath which the sands of the sections lie, but also on the elevation of the base upon which the sands rest. This base is at a lower level, in general, the greater the distance from the former sea cliff.

Summary of features: Certain features in the occurrences of the black sands stand out rather prominently. These are: (1) the black sands rest on, or only a short distance above, bed rock; (2) they frequently pass into gravel at the base; (3) they almost always have an important covering of overburden with a range in thickness as great as 72 feet; and (4) the deposits are at distances from the shores (which existed when the terraces beneath which they lie were formed) of a half mile and perhaps more. Any explanation of the origin of the black sands must consider these features.

Sedimentary Conditions Governing Deposition of Beach and Offshore Sediments

Deposition of beach and offshore sediments is related to several factors among which are the supply of sediments; strength of waves and currents and their impingement on a coast; shoreline configuration, both at the beach and in shallow water below sea level; relations of sea level to the land; and specific gravity and dimensions of the sedimentary particles. Some combinations of these five factors are largely responsible for the quantity and quality of the sediments on each part of a coast.

It goes without saying that if a particular mineral is not present in a beach or offshore deposit, its absence may be accounted for in any of several ways, namely: the mineral does not occur in the rocks of the tributary region; the streams entering the sea are not able to transport the mineral from the regions drained; the configuration of the coast and shallow bottom, or nature of the shore processes, preclude the mineral's transportation to and retention in the beach or offshore deposit concerned. It may be possible for a deposit to be made on a beach under conditions of stationary sea level, when formation of the deposit would be improbable under the conditions of a rising or falling sea level. In order that these factors may be understood, they are considered in detail, as their understanding is essential to any interpretation of the origin of the black sands.

Supply of Sediments: Very little is known respecting the quantity of sediments now brought to the sea by the streams or produced by erosion on the coast. Existing streams do not seem to be carrying large quantities of sediments, although the writer saw them only during the dry season. It is known that during storm periods or times of rapidly melting snow in the mountains, the amount of sediments borne seaward by the larger rivers is very considerable. The Rogue River likely was named by sailors who reported that the red-tinged water of a stream they named "Rouge" was encountered by them in passing several miles offshore. That at times the rivers carry large volumes of water is obvious from the great bars of sand and gravel in the channels of some of them. Rainfall is high, but along the coast the vegetation is rank and probably is competent, under most conditions, to cause most of the water to enter the ground to be later yielded to the streams by springs and seepage. The Coos and Coquille Rivers probably do not bring sediments to the sea as the tide ascends each of them for many miles. Extension of cultivation, close pasturage, and the rather unwise practice of burning pasture lands every few years will doubtless lead to greater erosion in the future and hence greater contributions of sediments to the sea. There were evidently large contributions by the streams accompanying the fall of sea level. The major streams antedate the submergence of the land to the level of the 1500-foot terrace and thus their valleys were probably full of sediments when the sea stood that high. These sediments were cleared from the valleys when the land rose and were largely deposited offshore, but some are now doubtless on the beaches. The other source of supply is found in the erosion of the rocks of the shores. This is important where the coast is marked by cliffs as is the case around the headland of Cape Sebastian, the long stretch of cliffs from the mouth of Euchre Creek to Humbug Mountain, around the headland of Cape Blanco, and on the coast of the Seven Devils Country from the mouth of Whiskey Run to Coos Bay. It does not seem likely that much new sediment is brought to many parts of the coast and that on some of the beaches the sediments are brought from offshore, or shifted from one part of a beach to another part.

Strength of Waves and Currents and Their Impingement on a Coast: The strength of waves is related to the size of the body of water (up to a limit beyond which the size makes little difference), the force of the winds, and the extent to which a shore is bordered by shallow water. It may be accepted that the waves of the Pacific Ocean and the currents they produce are as strong as possible so far as the size of the body of water is concerned. Strong winds produce large waves and, in spite of the name, the winds of the Pacific are as strong as those on any other ocean. The way in which waves strike a shore determines the direction of movement of sediments along shore and the directions of the waves are determined very largely by the directions from which the winds blow. Prevailing wind directions on the coast of southwest Oregon are from the southwest and, correspondingly, the waves roll on shore with a southwesterly component for much of the year. If the coast line of this region were perfectly straight with its present trend, the waves would create shore currents which would move north along the coast during the seasons of southwesterly winds and these currents would carry the sediments northward. If the winds came from a northwesterly direction, the waves would roll on the coast from that direction and shore currents would move south and carry the sediments south. The latter condition prevails on the coast of southwest Oregon for some time during the summer months, but in general the movement of the shore

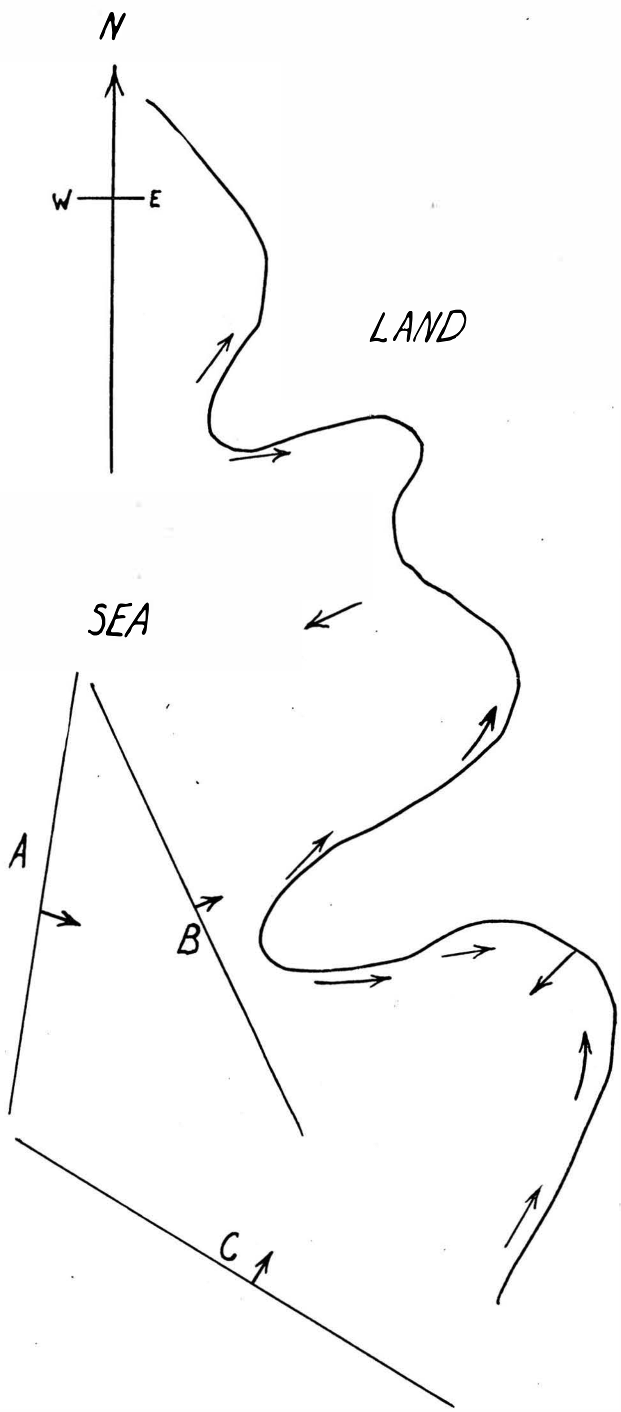

Fig. 2. Diagram illustrating the shore currents due to movement of waves on shore. "A," "B," and "C" represent waves moving on a shore with headlands and bays. With nearness to shore the waves change direction to some degree and tend to become normal to the general direction of the coast at the place, particularly if the coast is bordered by shallow water. The arrows near the shore indicate directions of the shore currents. These are strongest in the direction in which the waves are moving. These currents will carry sediments into the bays and concentrate the heavy and large particles about the places where two shore currents meet, each current bringing what it can and the resultant outflowing current made by the two shore currents taking away what it can. The diagram shows the difficulty of transporting sediments around a headland. Waves on the coast of southwest Oregon come mostly from a southwesterly direction.

currents together with the sediments which they carry is northward for most of the year.

If shallow bottom exists along a coast, the strength of waves is dissipated by repeated breaking before the shore is reached, and thus attack on the coastal rocks is lessened and may be entirely eliminated. The coast of southwest Oregon is bordered over considerable areas by shallow bottom on which the waves break and fail to reach the coast with much power to erode. The inner part of this shallow bottom is certainly in part cut by the waves and the outer part may have been made by deposition. It has some control on the movement of the shore currents and also in modifying the directions of approach of the waves on the shores.

Shoreline configuration, both at the beach and in shallow water: Any shoreline ordinarily consists of an alternation of bays and headlands in all degrees of dimension and relation with every so often a headland of more than ordinary magnitude and prominence. This is particularly apt to be the case on a subsiding coast as is that of southwest Oregon. In addition, there are openings in most coastlines made by streams. Bays, headlands, and mouths of streams are extremely important in the migration of beach and offshore sediments. The headlands, and the shallow bottom that in places extends outward from them, preclude or seriously hinder movement of shore sediments past them and they may also delay, and perhaps prevent movement around them of shallow water, offshore sediments. Figure 2 represents two headlands. The three straight lines are intended to represent the crests of waves as the waves move on shore. It should be observed that the crests of the waves tend to approximate parallelism to the general direction of the coast. In general, the waves for most of the year should tend to come from a southwesterly direction. Wave A moving on the headlands will move sediments to the south on their south sides and to the north on their north sides. Waves B and C will do similarly. There will be some place between the two headlands where the shore currents indicated by the arrows will meet and make deposits of the heavier and larger sediments carried. This place of meeting will be a place of deposition of black sands if such are carried by the currents. An outgoing current will be produced at this place of meeting of the currents which will carry away the lighter and smaller particles and leave the heavier and larger. As the waves dominantly come from the south, the place of meeting of the shore currents will tend to be toward the north side of the bay. It will be almost impossible to move sediments in either direction around the headlands, with the exception of very fine sediments which may be floated far from shore and thus pass a headland. The mouths of large streams present another barrier to the coastal migration of sediments. Small streams may be completely blocked through the formation of bars across their mouths and these will permit sediments to be transported along a coast as if the streams were not there. A large stream may prevent the formation of a bar and, even if a bar is formed, the stream will maintain an opening in it. This opening will present a serious barrier to coastal migration of sediment. The opening, however, may be crossed. A bar may be built which forces a stream to flow along the coast for some distance before it enters the sea. Sediments may then be transported to the stream along the bar. Subsequently the bar may be breached at some other place and the sediments previously transported to the end of the bar will now be on the other side of the stream and may be able to continue movement along the coast. This is known to have happened at the mouths of Rogue River, Euchre Creek, and Elk River.

On the coast of southwest Oregon the headlands of Sebastian, Humbug Mountain, Blanco, and Arago, and others of less prominence more or less effectively prevent passage of sediments around them. Illustrative of this fact is Cape Blanco. Black sands are brought in abundance to the south side of Cape Blanco and they remain there throughout most of each year in deposits of considerable magnitude. Black sands are extremely rare on the north side of this cape and those present are in small particles. The storms of winter often sweep the beach on the south side of Cape Blanco clean of sands. They are believed to be taken outward to become a part of the offshore deposits although it is probable that some of them are later washed inland from the offshore to the beach. Black sands do not occur in any degree of abundance from the mouth of the Sixes River to Five Mile Point in the Seven Devils Country. Little black sand is brought to this part of the coast by the Sixes and Coquille Rivers and smaller streams, and what little black sand is present may be expected to have largely been derived from erosion of the Pleistocene sands of the terraces in which the minerals of the black sands are present. There is black sand north of Five Mile Point, but the concentration is not large except south of Cape Arago about the mouth of Five Mile Creek. These sands may have been derived from erosion of the coastal sands in which there is an exposure of black sands extending over a quarter of a mile just north of Five Mile Point. The bay about the mouth of Five Mile Creek seems to be about the place where the northward-moving shore currents meet the southward-moving shore currents which are made by the waves striking the coast on the south side of Cape Arago. There is limited development of black sand north of Cape Arago. This lack arises from the fact that it is almost impossible for sediments to migrate northward around this cape and there are no local sources from which the sands may be derived.

As the prevailing directions of the winds on the southwest coast of Oregon are from the southwest, and the waves in general come from the same direction, there is a tendency to produce local concentration of black minerals on the south sides of the headlands, or on the north sides of the bays bounded by the headlands, the concentration taking place where the south-moving currents produced by waves on the south sides of the headlands meet the north-moving currents coming from the south. This situation may be seen on the south side of Cape Blanco, south of Cape Arago, and at other places on the coast.

Submarine shallow water configuration is also important. Figure 3 shows the ideal arrangement under which submarine topography has its maximum influence. The two headlands determine the directions of the shore currents which are as indicated by the arrows. These currents produce a piling up of the waters at the place of meeting and this must be relieved by movement of water offshore, either as a rip tide or as undertow. Whatever the case, a part of the beach and the bottom may be expected to be washed by the current and fine and light sediments will be carried from the

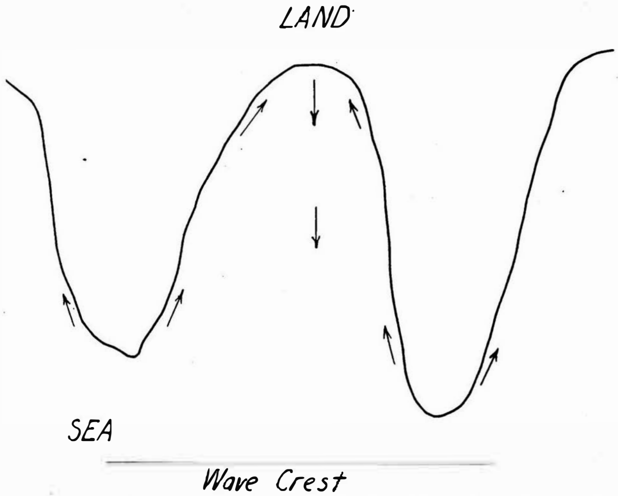

Fig. 3. Diagram illustrating the kind of shore topography best adapted to concentrate heavy and large sediments on the beach if the waves are not very strong, and to concentrate them offshore if the waves are strong.

beach along the bottom of the bay and be deposited where the current loses its power. This leaves the larger and heavier particles on the beach and on the bottom affected by the washing. Times of great storms with large waves and strong outgoing currents are known to have swept many beaches clear of sediments. This is reported to have repeatedly taken place south of Cape Blanco. It is believed that the outgoing currents carry the sediments on such beaches to offshore deposition. All kinds of sediments are affected, and deposits of gravel, sand, silt and clay are thus made offshore.

Relations of Beach and Beach Sediments to Stationary Sea Level: Under the conditions of stationary sea level, a coast may be expected to be eroded and the shore to move inland because of the erosion. Erosion is as deep as the waves and currents are able to affect the bottom and there is developed a wave-cut terrace or bench which is more or less devoid of sediments except at the beach. The products resulting from erosion of the shore and bottom in the production of the wave-cut terrace or bench are in part moved along the coast in a direction opposite to that of the directional source of the wind, a part is moved out to sea and deposited with the offshore deposits, and a part is moved to the beach. The last is particularly true with respect to sediments of high specific gravity and those of the largest dimensions. The fine sediments are moved seaward over the wave-cut terrace and deposited beyond its seaward edge to form a wave-built terrace or bench. The wave-cut terrace is always eroded to a depth commensurate with the erosive strength of the waves and currents, and it constitutes a base level of marine erosion. The wave-built terrace is built to a height also determined by these conditions and it forms a base level of deposition. The two terraces pass into each other, one on rock due to erosion, the other on sediments due to deposition. The sediments of the wave-built terrace rest on whatever made the bottom of the sea at the beginning of the cycle of marine erosion which established the stationary sea level. These might be marine sediments, or, if a land surface had been submerged, the sediments composing the wave-built terrace might have been deposited on rock or soil. A cliff or a slope due to shore erosion would be on the inland border of the wave-cut terrace. The height and steepness of the cliff or slope and the widths of both terraces would be determined by the character of the coastal materials and the length of time sea level remained stationary. Both terraces would be wide if the time were long and the rock easy to erode, and narrow if the time were short and the rock were difficultly eroded. Except on the beach, the wave-cut terrace would not have any permanent sediments upon it other than those particles too large or too heavy to be moved by the waves and currents. Figure 4 shows the results of a stationary position of sea level.

The incoming waters of most waves have much greater transporting power than the same waters after they roll on the beach and begin to flow back. The incoming waters received their power from the winds which caused them. The outgoing waters are carried back down the beach by gravity and if a beach has gentle slope, the transporting power of the backflow is small. In other words, the incoming waters have greater power to transport sediments to the shores than the outgoing waters have to transport them from the shores. The incoming waters bring sediments in quantities and dimensions to the maximum extent that they can obtain and transport. The backflow waters carry back sediments in quantities and dimensions according to their ability. However, since the backflow waters have less ability to transport than the incoming waters, the former leave behind the largest particles as well as particles of greatest specific gravity. The backflow waters carry with

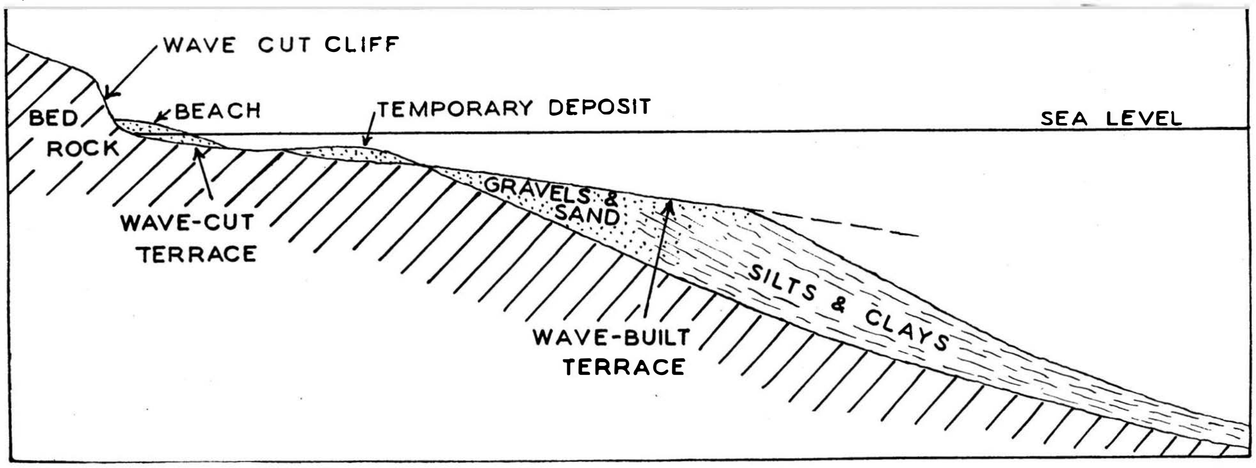

Figure 4. Diagram illustrating a sea cliff, wave-cut terrace, and wave-built terrace. The sea cliff and wave-cut terrace were produced by erosion, the wave-built terrace was produced by deposition with the sediments made by the erosion to which the sea cliff and wave-cut terrace are due. Both the wave-cut and the wave-built terraces are at the level of the base level of erosion and deposition. Permanent deposits are not made on the wave-cut terrace or on the wave-built terrace after it has reached the level of the base level of deposition. Deposits may be made beyond the wave-built terrace to the level indicated by the dashed line. As a coast is eroded, the sea cliff moves inland, the wave-cut terrace is extended and lowered somewhat and the beach deposits are moved inland with the cliff. A rising sea level will permit permanent deposits to be made over the entire wave-built terrace and over the seaward margin of the wave-cut terrace and some of the beach sediments may be buried. If the rise of sea level is great enough, both terraces will become covered with sediments. A wave-cut terrace may not be cut or a wave-built terrace built if the rise of sea level is rapid. The deposits on the landward margin of the wave-built terrace may be expected to be coarser than those on the seaward margin. The sediments over the surface of the wave-built terrace may also be expected to be coarser than those upon which they rest. Concentrates of heavy minerals may be made where sands are indicated in the diagram.

them smaller and lighter particles than incoming waters brought to the shore, together with the smaller particles of the beach sediments already there.

Some materials of the beach may have come by way of shore currents and some may have been derived from the rocks of the shore. The results of this selective transportation is that the coarsest particles and the particles of highest specific gravity are left to form the beach sediments and the particles of smaller dimension and lower specific gravity are carried outward beyond the wave-cut bench to form offshore deposits, or they may be carried along shore by the shore currents and deposited in bays with quiet water. When particles become very small, specific gravity ceases to have much importance so that sediments of both high and low specific gravity may be deposited in the offshore sediments, where, in general, small particles of both high and low specific gravities will be more or less intermingled with very limited concentration of particular minerals. Concentrations require transportation of particles sufficiently large for gravity to have influence. The occasional storm will produce waves of great magnitude and the attack on the beach and the coast is then greater than usual. Outgoing currents of greater transporting power than usual are produced and particles of dimensions and weights which are influenced by gravity are carried to the offshore. Deposits of gravels, sands, and concentrations of heavy minerals may thus be produced there. This action may be observed south of Cape Blanco where, during the months of relatively quiet water, the accumulations on the beach consist of heavy and light minerals, or black and light-colored sands, but during the storms of winter the beach frequently loses all of the accumulations assembled since the last storm and these are believed to be carried largely offshore.

After a bottom has been built to the depth of the base level of deposition, the sediments of this bottom are subjected to repeated washing by the waves and the outgoing waters. The fine and light particles are removed, either carried shoreward or seaward, and the heavy and large particles are thus concentrated. As waves and currents vary in ability to transport, sediments may be temporarily deposited on the wave-cut and wave-built terraces from which stronger waves and currents will later remove the fine materials and leave those too heavy to transport. Thus there may be concentrations of both large and heavy materials on the wave-built and wave-cut terraces—the latter not so likely as the former. The top of the landward part of the wave-built terrace may thus become covered with gravel. Farther seaward it may be expected that there will be sands, and thence farther seaward these will pass into silts and clays. This is shown in figure 4.

Care has been taken in the foregoing discussion to avoid statement of actual dimensions and weights of particles. Weights and dimensions of particles transported are relative to the competency of the transporting agents. Large particles under conditions of low competency to transport may be of sand dimension, but under conditions of larger competency the large particles may be of gravel dimension and the sand dimension will then be small.

The application of the above principles to the black sand problem is as follows: Concentration of minerals of high specific gravity may be expected on the beach, so far as the larger particles of these minerals are concerned, where they will be associated with somewhat larger particles of minerals and rocks at places where the coastal configuration and the strengths of waves and currents make selective transportation possible. There will be dissemination of heavy minerals of small dimension of particles in offshore deposits with concentrations generally in too low percentages for possible economic extraction, and there will be concentration in local lenticular units on the landward edge of the wave-built terrace, particularly where the submarine topography and the coastal configuration lead to strong outgoing currents. Some of these deposits may be sufficiently large for economic consideration.

Rising Sea Level: Under conditions of periodic rise of sea level (meaning either that sea level actually rises, or the land sinks) new wave-cut terraces are formed for each stationary position of sea level. Thus each such terrace is backed by a wave-cut cliff, and sediments form a wave-built terrace beyond the seaward edge of each wave-cut terrace. Rise of sea level extends the sea over land, and places any point on the sea bottom at a greater distance from the shore. As sediments, in general, are of smaller dimension with distance from the shore, any new deposits which are made may be expected to be finer than those on which they rest. Thus, offshore deposits of clays and silts may rest on sands or concentrates of heavy minerals. Fine sands may be expected to be deposited over coarse sands and large particles of heavy minerals. Sands and gravels — the coastal rocks in only a few places favor the formation of gravels—may be expected to be the initial deposits over a wave-cut terrace as it is buried. These initial deposits may be rich in the heavy minerals which make the black sands and the extent of such rich deposits, theoretically,

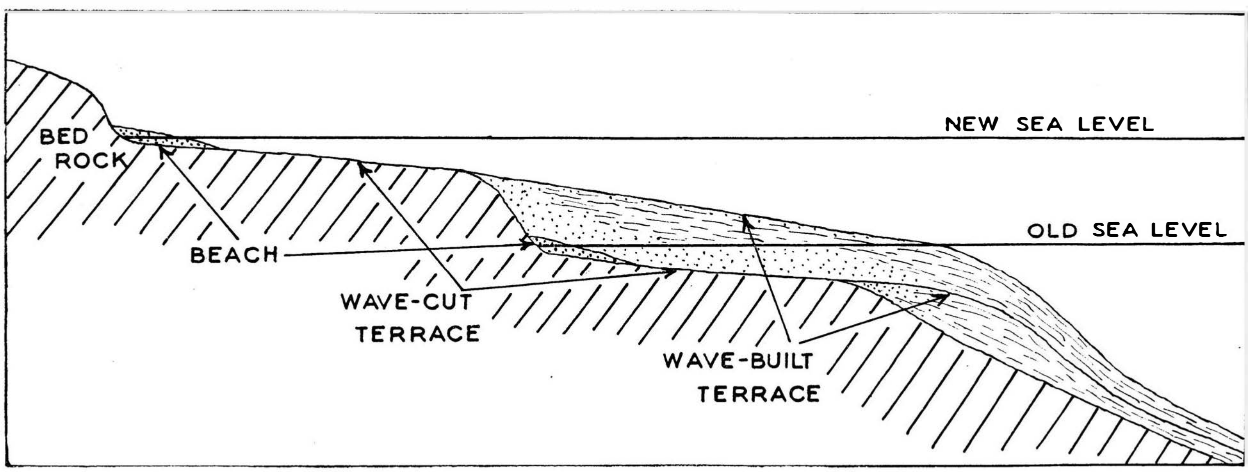

Figure 5. Diagram to illustrate burial of wave-cut and wave-built terraces and possibly local burial of the deposits of the beach on rise of sea level. The tendency will be for the coarser deposits of the beach to move inland with the shore as sea level rises and thus escape burial. The finer deposits of the beaches would be carried seaward. The sandy deposits on the landward margin of the wave-built terrace would migrate landward to become the initial deposits over the wave-cut terrace of the old position of sea level, thus making a continuous deposit of sandy and perhaps gravelly sediments. It would be theoretically possible for these sandy deposits to be rich concentrates of heavy minerals with extent equal to the wave-cut terrace buried. This would be extraordinary, but local deposits would be made where the topographic conditions of the shores and the bottom favored concentration. Some previously temporary deposits on the old wave-cut terrace may be buried, and, perhaps, lagoonal or marsh deposits landward from the beach may also be buried in the midst of sand. Beach deposits would be most likely to be buried under conditions of rapid rise of sea level. Driftwood on a beach may be expected to be floated and carried away as sea level rises unless it is buried in the beach deposits and has become waterlogged. It should be observed that the sediments beneath the older and lower wave-built terrace were deposited under somewhat different conditions than the sediments which were deposited on that terrace as sea level rose.

may be coextensive with the wave-cut terrace which is buried. The initial coarse sediments on the wave-cut terrace may bury some deposits of the beaches, particularly in protected places in bays. As the deposits about the heads of bays frequently contain bogs behind them, the organic sediments in these may be buried with the beach sediments, thus giving rise to a deposit of peat in the midst of sands. Concentrates of heavy minerals of the beach may thus be buried and similar concentrations may be deposited over the wave-cut terrace which is buried beneath sediments. Figure 5 shows the relations of the sediments under these conditions.

Coastal configuration may be expected to change with each rise of sea level. Peninsulas which are lower inland than on their apexes in time become islands and thus cease to act to prevent migration of sediments along the shores. This is well illustrated by Cape Blanco. At the present time this cape does not permit much migration of sediments around it either to the north or south. If sea level should rise as much as 50 feet, the outer part of the peninsula of Cape Blanco would become an island and sediments could then easily migrate along the shore of the new mainland. Deposition of black sands would cease on the south side of Cape Blanco and the black sands would move northward until blocked by some other headland. Under existing conditions of sea level it would not be possible for black sands to accumulate in positions on the present sea shore corresponding to the deposits of the Madden and Butler mines, but if sea level should rise 100 feet for the Madden deposit and to 160 feet for the Butler deposit it would be easy for these deposits to be made. Black sands could not possibly be deposited under existing conditions in South Slough of the Coos Bay region, but if sea level should rise so that the sea could cover the lowland connecting the valley of the Coquille River with Coos Bay to the elevation of the present black sands about South Slough, it would be very easy for deposits of black sands to be made in the present positions about South Slough. This change of coastal configuration with rise of sea level is a fundamental one and must not be disregarded in any interpretation of, and search for, black sands.

Falling Sea Level: It may be assumed that fall of sea level (or rise of land) is not continuous, but periodic, and that sea level will hold stationary positions for longer or shorter periods of time. At the time of the highest position of sea level, deposits of various kinds of sediments may be expected to have been made over the entire submerged surface with the exception of the highest wave-cut terrace. This latter would have only those sediments too large or too heavy to move and perhaps some materials of temporary deposition. Fall of sea level would leave a thin veneer of beach deposits upon this terrace and all others developed and abandoned during the fall of sea level. A wave-cut terrace would be developed for each stationary position of the land as it rose. This would be cut in part or entirely in the sediments deposited during the rise of sea level, and the sediments eroded to produce this terrace would be carried seaward to build the wave-built terrace. Both terraces would have widths commensurate with the length of time the sea level remained stationary. If this was sufficiently long, the landward part of the wave-cut terrace might be cut on bed rock; if short, the landward part would be likely to be based on unconsolidated sediments. Thus, the wave-cut terraces could have shores based on bed rock or unconsolidated sediments. Each successive fall of sea level to a new stationary position would repeat this history.

As the wave-cut and wave-built terraces of each stationary position were abandoned by the sea, a thin veneer of beach deposits would be laid down over the two terraces. It is not likely that this would exceed a dozen feet as a maximum. This would ordinarily be exposed to the attack of weathering and doubtless become decomposed and disintegrated. The deposits, however, might become covered with sands of eolian deposition and thus preserved. Such wind deposition is now going on along many parts of the coast of southwest Oregon and it probably went on in the past. The deposits would be largely in the form of dunes, as is the case now. Bogs would develop among such dunes as they now do, and further drifting of sands would lead to burial of the bog deposits. However, the surface over such deposits would be that characteristic of dunes and the deposits would have the characteristic sedimentary structures made by eolian deposition, both readily and easily recognized. The deposits over the black sands of southwest Oregon do not have surfaces characteristic of eolian deposition and where sections of these overlying deposits are exposed, they do not show the sedimentary structures characteristic of eolian deposition. There are, however, many places on the coast of southwest Oregon where the surface and structures characteristic of eolian deposition may be observed, but these are not above or in the overburden on the known black sand deposits.

Application of the Foregoing Principles to the Black Sands of the Coast of Southwest Oregon

It is believed that when the submergence of the coast of southwest Oregon began, the Coquille River flowed through the lowland extending from the town of Coquille through Isthmus Slough to Coos Bay and had its entrance into the sea in the vicinity of Coos Bay. The present valley of the Coquille River into the Bandon area did not then exist. The Sixes, Elk, Coos, Rogue, and other large streams had already established their valleys in bed rock in essentially their present positions. As the land sank, the mouths of the streams were progressively drowned and when the ocean level reached a level on land that is now 1500 feet above sea level, each of the streams named was reduced to its headwaters. The land then emerged 800 feet. The streams extended themselves across the Pleistocene sands which had been deposited during the previous stage, and which then became exposed. They were free to wander more or less as they wished over these sands, and the structure of the rocks underlying the sands had no influence on the courses they selected. Each stream obviously took the shortest general course to the sea which, in the case of the Coquille, brought it into the Bandon area. The land emerged still more and during successive stationary periods, wave-cut terraces were formed at 350, 150, 100, and finally at 50 feet. The Coquille continued to carve its valley in the older rocks which now border it on both sides between the town of Coquille and Bandon and thus it became fixed in its present channel. Tributaries to the Coos and Coquille Rivers reexcavated the old valley of the Coquille between the town of Coquille and Coos Bay. The Sixes River flowed across the sands covering the rocks of Cape Blanco and the land to the east, at times emptying into the sea south of what is now Cape Blanco and at other times to the north, thus carving the lowland which now exists between the seaward part of the cape and the higher land to the east. It is thought that the drifting of dune sands had considerable influence in finally blocking the river's course to the south, since at the present time there is much accumulation of sands of this origin on that side of the cape.

As the land rose, the sea cut one terrace after another, and the sediments derived from the formation of each wave-cut terrace were carried outward to form the corresponding wave-built terrace. With the next rise, this wave-built terrace was partly or wholly destroyed and the sediments were carried outward to form another wave-built terrace for this new position of sea level. The sediments of each wave-built terrace were deposited over other sediments of the outer portion of the immediately higher wave-built terrace. Thus the deposits of the last wave-built terrace may be expected to overlie deposits connected with all preceding higher wave-built terraces and the sediments of the highest of these terraces rest on sediments deposited as sea level rose. The formation of each wave-cut terrace would usually leave below it some of the deposits of the higher wave-built terraces and also some of the deposits made during the advance of the sea. This would be the case unless this wave-cut terrace coincided with a wave-cut terrace made during the advance of the sea.

Thus, the deposits beneath any of the terraces on the coast of southwest Oregon are not a simple but a composite aggregate. The lowest terrace may include sediments corresponding to each wave-built terrace of the present raised terraces and, in addition, sediments deposited earlier as the land was submerged as much as 1500 feet. There might be a veneer of beach sediments over the top of each terrace which was made as the land emerged from one terrace level to the next. This veneer may be overlain by sands of eolian deposition. The development of the terraces and the composite nature of the terrace deposits is shown in figure 6.

Another factor deserving consideration in the black sand problem is that for every submergence of the land the ability of the unsubmerged rocks to supply heavy or black minerals would gradually become less because of decrease of exposed areas and also to the lessened ability of the streams to acquire sediments. The application of this generalization to the black sands of southwest

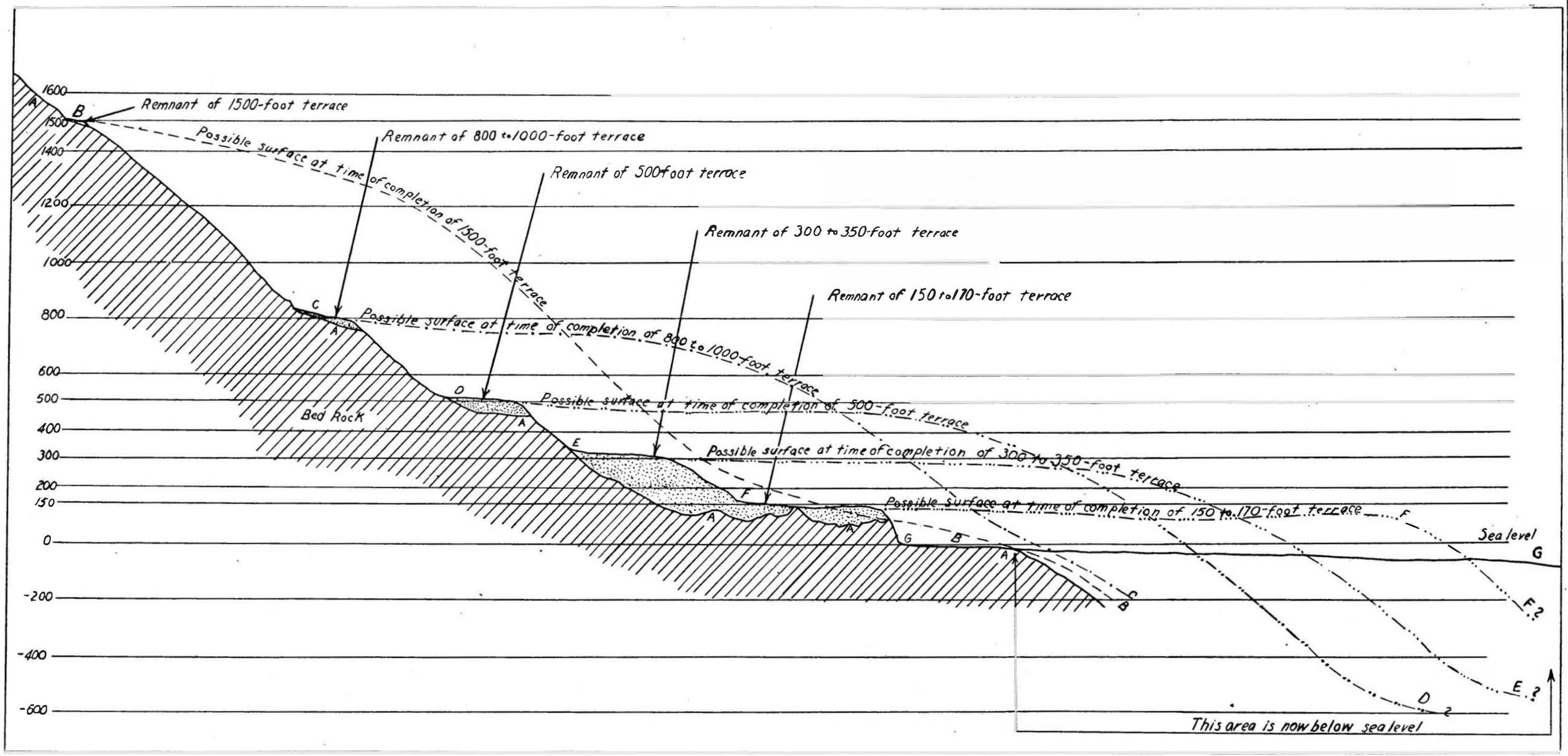

Figure 6. Diagram to illustrate the development of the wave-cut and wave-built terraces and the deposits beneath the terraces on the coast of southwest Oregon during a rise of sea level to an elevation of 1500 feet above the present level and subsequent fall and later rise to the present level.

A-A-A Surface on which deposits were made during the submergence of the region.

B-B-B Surface over the deposits at time of maximum submergence.

C-C Surface over the deposits at time of formation of 800 to 1000-foot terrace.

D-D Surface over the deposits at time of formation of the 500-foot terrace.

E-E Surface over the deposits at time of formation of the 300 to 350-foot terrace.

F-F Surface over the deposits at time of formation of the 150 to 170-foot terrace.

G-G Existing conditions with the lowest terrace and, in most places, the higher terraces being destroyed by erosion. The present surface is that extending over all the terraces to the 1500-foot level. The 100-foot and the 50-foot terraces are not shown. In many places bed rock projects deeply into the terraces and in places it projects through and above their surfaces. The illustration shows that the deposits beneath a terrace may be partly due to those made on advance of the sea and partly those made when sea level fell. In other words, the deposits beneath a terrace may be of composite character. Deposits could have been made both on the advance and retreat of the sea at those places where conditions of supply, wave action, and coastal configuration were favorable. The diagram is hypothetical, but it is believed to represent the general conditions which have existed on the coast of southwest Oregon.

Oregon suggests that the sands beneath the higher terraces are not likely to contain large quantities of heavy minerals and it may be expected that deposits of black sands beneath the 1500, 800, and 500-foot terraces will be small.

Places of Deposition of the Black Sands

Deposits of black sands beneath the 100-foot terrace are found in the sea cliff between Five Mile Point and the mouth of Two Mile Creek, in the Eagle and Pioneer mines in the Seven Devils Country, in the Madden Mine a short distance north of the Sixes River, and in the sea cliff between the Geisel Monument and the mouth of Rogue River. The deposits are situated about 25 feet below the surface at the Madden Mine to about 60 feet at the Eagle and Pioneer mines and in the sea cliff north of Five Mile Point, or, stating it differently, from about 35 feet above sea level to about 60 feet above sea level. That is, the deposits are not at the same elevation above sea level, or the same depth below the surface of the terrace. This may be easily seen in the sea cliff north of Five Mile Point. If sea level were raised 100 feet, that is, to the level of the surface of the 100-foot terrace, the deposits south of the Geisel Monument would be in bays limited by headlands on the north and beneath 45 to 50 feet of water. Those north of Five Mile Point would be covered with water ranging from 30 to 60 feet in depth and would be in a bay limited by a headland north of Two Mile Creek. Those in the Eagle and Pioneer mines would be in a bay limited by a headland of which Five Mile Point is an expression and would be in water about 60 feet deep. And those of the Madden Mine would be in water about 25 feet deep which would be in a bay between a headland extending out from Madden Butte (of which a remnant now rises about 50 feet above the level of the terrace) and another headland on the north extending seaward from the mountain in the rear. The headland at Five Mile Point would have been particularly prominent and would have effectively blocked northward migrations of the black sands, thus, perhaps, accounting for the richness of the concentrations in the Eagle and Pioneer mines. The differences in depths of water should be noted, as these differences bear on the places of deposition.

Deposits beneath the 150 to 170-foot terrace are those of the Butler, China, Geiger, and Iowa mines, the old Rose Mine (Covert property), and the Shepard property (sec. 16, T. 27 S., R. 14 W.). These deposits have a depth range below the surface of the terrace from about 20 feet in the Butler Mine to about 35 feet in the old Rose Mine and, if the sea stood at the level of the terrace, the deposits would be in water about as deep as the thickness of the overburden. The Butler deposits would be in a bay between the headlands of Madden Butte and Stone Butte, those of the China, Geiger, and Iowa mines in a bay east of Bandon which was limited on the north by a headland now represented by the rock ridge at present there, and those of the Rose and Shepard deposits on the north side of a broad bay limited by a prominent headland to the north which now reaches the sea north of the mouth of Five Mile Creek.

Deposits beneath the 300 to 350-foot terrace are in secs. 10 and 4, T. 27 S., R. 14 W., and in sec. 33, T. 26 S., R. 14 W., of the Seven Devils country. If sea level stood at the surface of this terrace the black sand deposits would be in water in the depth range of 10 to 70 feet in a broad bay limited on the north by a headland which reaches the present shore north of Five Mile Creek. This headland must very effectively have blocked northward movement of the black sands.

Thus, all known deposits with various degrees of simplicity fall pretty much into the same pattern —each in a bay with northward migration of the sands hindered or precluded by a headland.

The black sands have various relations to the shores or sea cliffs connected with the terraces beneath which they lie. In some occurrences they are directly against the sea cliffs as in sec. 33, T. 26 S., R. 14 W., and in others, as in the Eagle and Pioneer mines, they are from a quarter to a half mile from any possible cliff.

Nothing has been stated as to whether deposition took place on a beach or offshore. Black sands are now being deposited on existing beaches, but little or nothing is known of their deposition offshore. Pardee (9, p. 29) states that soundings of the U. S. Coast and Geodetic Survey have found black sands in the existing offshore deposits. The hydrographic charts of the coast show few places with black sands on the bottom. This should not be given much weight, however, for, if the sands of the coast were sampled in only a few places with the sampling done from the surface of water, it is extremely likely that the sampling would show black sands in very few places or perhaps in none.

In essentially every place where black sands are now present on the existing beaches large quantities of drift wood are associated. Logs are reported to have been encountered in some of the mines and wood has been found in a couple of drill holes. No drift wood was seen in any of the workings examined by the writer and evidently it is not common in any of the black sands beneath the terraces. It may be urged that drift wood was not common when the black sands beneath the tereraces were deposited. This seems improbable as the coast must have been covered with timber far into the Mesozoic and it must have been as abundantly transported to the sea by streams in the past as at present. It may have been more abundantly transported in the past than at present as the lower lands on the streams are now cultivated and bare of trees. Man is now a contributor in the form of cut logs, but only a part of the drift wood seems to be of this origin. In respect to abundance of driftwood the black sand deposits beneath the terraces do not resemble the deposits of existing beaches.

In most occurrences of black sands beneath the terraces, they rest on gravels or sands which are immediately underlain by Tertiary or more ancient rocks. Exceptions are in South Slough. These relations indicate that the black sands were deposited either on beaches, or on the seaward edge of the wave-cut bench as a part of the wave-built terrace. Deposits like those about South Slough may have been formed farther seaward.

If the black sands were deposited on beaches which existed during the formation of the present raised terraces, an explanation is required as to how they became covered with yellow sands to a maximum thickness of 70 feet. There seem to be only two ways in which this might have been done. (1) The black sands might have been deposited on beaches at a level below each terrace corresponding to the thickness of the overburden. Sea level at some later time then rose to the level of the terrace and permitted deposition of the overburden. This would have required the cutting of a wave-cut terrace inland from the deposit to a width commensurate with the length of time sea level remained at the level of the terrace. This wave-cut terrace would be more or less continuous with the surface of the overburden. Or, (2) the black and associated sands of the beaches might have been buried beneath deposits made by the wind. The first way would require that each fall of sea level relative to the land was followed by a rise to the level of the terrace concerned with deposits of black sands at various levels as sea level rose. This does not seem probable. It may have happened once, but not the number of times required. The second way requires the overburden to have been deposited by wind, but, as already noted, the sedimentary structures of the sands of the overburden do not seem to be those produced by eolian deposition. Moreover, if the sands of the overburden were deposited by wind, the surface of each terrace would have a dune topography and the surface would bear little resemblance to a terrace. It is considered that eolian deposition of the sands of the overburden is not tenable. There may be eolian deposits on the surfaces of the terraces but they are not sufficient to mask the original surface. The obvious conclusion is that **the black sands are not beach deposits connected with the formation of the present raised terraces beneath which they lie.**

The characters of the black and associated sands show that deposition took place in close proximity to the shore, and the fact that most of them lie on, or a little above, bed rock proves that deposition took place on the beach, or the seaward edge of the wave-cut terrace. It has been shown that they could hardly have been deposited on beaches in connection with the formation of the terraces. Neither could they have been formed on beaches as the land emerged as then an overburden of aqueous deposition would not have been possible. **Deposition must then have taken place during a period of land submergence (or rising sea level).** Each deposit could then have been covered by an overburden whose thickness would have been measured by the extent of the subsequent submergence and the rate of deposition during the submergence. As the maximum land submergence was 1500 feet below the present level, it was possible for as much as 1500 feet of sediment to overlie a zone of black sands deposited at the beginning of the maximum emergence of the land. The deposits could then have been made on beaches or the offshore, but it is difficult for beach deposits to be preserved against the attack of a rising sea level. The deposits around South Slough, in the sea cliff north of Five Mile Point, in the Eagle and Pioneer mines, in the old mines east of Bandon are thought to have been deposited offshore. Pardee came to the same conclusion for some of these deposits (9, p. 23). The deposits in secs. 10 and 4 (T. 27 S., R. 14 W.) of the Seven Devils country were probably deposited on a beach or the seaward edge of a wave-cut terrace. Data are not at hand for opinion respecting the other deposits.

General Conclusions

1. The sands along the existing beaches are hindered and at times cut off in their migration along shore by long headlands around which they cannot pass except with great difficulty. The waves produce shore currents that move into bays and transport sands. When such currents enter a given bay from opposite directions, the sediments they carry are deposited where the currents meet. From this locality of deposition, as well as from the beaches, some of the sediment—the lighter material—is carried seaward by undertows and rip tides. These lighter, more easily transported materials, including some of the smallest particles of the black sands, are deposited offshore beyond the wave-cut terraces.

During big storm periods, strong shore and outgoing currents are able to transport both the large particles of the light minerals and the relatively large particles of the black sands. Such materials are deposited on or just beyond the seaward edge of the wave-cut terrace. As the dominant direction of the wind is from the southwest, the shore currents move northward for the most part and transport sediments in that direction until headlands prevent.

2. The sand deposits beneath the present terraces at the time of their deposition occupied certain positions or locations with respect to the shore topography; the black sands of the existing coast occupy the same relative positions in respect to coastal topography. That is, these old black sand lenses were deposited toward the north sides of bays limited northward by a prominent headland.

3. The black sands beneath the terraces were deposited (under the influence of changing coastal topography) as the coast was submerging, and not as beaches as the terraces were formed. The black sand deposits developed at different levels and different places during the submergence, thus accounting for the different depths beneath the surface of the terraces. The differences in places of deposition arose from changes in the coastal topography as submergence progressed. Present benches or terraces were cut on the Pleistocene sediments after their deposition. In some cases, these recently-formed terraces cut across or into some of the older black-sand zones; in other cases, the black sand zones were revealed by stream erosion.

4. It is not positively known whether the black sands beneath the present high terraces were deposited on beaches or upon or near the seaward edge of the older wave-cut terraces. Sands were probably deposited in both places, but considering the difficulty of preservation of beach deposits against the attack of an advancing sea, an offshore origin for most of the black sands beneath the present high terraces is favored.

5. Summarizing, then, the history of the black sand deposits beneath the terraces is thought to have been somewhat as follows: The black sands were deposited on beaches and offshore as the land submerged to a level 1500 feet below present sea level. Some of the deposits of the beaches may have escaped destruction as the sea advanced. It is assumed that all offshore deposits escaped destruction as the submergence took place. The black sands were buried beneath the offshore deposits as the base level of deposition progressively rose with land submergence, and some of the black-sand zones may have had an overburden of several hundred feet at the time of maximum submergence. Subsequent emergence of the land led to the formation of the terraces whose cutting totally removed some deposits of black sand, cut through others, and in some cases did not cut deeply enough to encounter the black sand zones.

Conjectures as to Black Sand Deposits Which May Be Discovered

It is the writer's opinion that there may be undiscovered deposits of black sands beneath the terraces and also beneath the sea. It is noteworthy that most, if not all of the mines have been discovered on creeks where erosion exposed the black sands and led to their discovery. Black sands may be present beneath some of the areas between the creeks. If one knew the coastal topography at every stage of the submergence, one could easily postulate the places of occurrence of undiscovered black sands. Determination of this topography ought not to be difficult. Although the writer considers it doubtful if black sands will be discovered beneath the 500-foot terrace, it might be well to study the possibilities on the east end of Grassy Knob between the Sixes and Elk Rivers and the corresponding ridge south of the Sixes River. A magnetometer survey would probably solve the problem.

It is also the writer's opinion that deposits of black sands exist offshore on or near the edge of the present wave-cut terrace and on or near the edges of wave-cut terraces which existed since the recent submergence of the coast began. Most of these deposits will be difficult to find. They should be sought for about the mouths of bays from which strong outgoing currents move. Sampling of the bottom sediments by means of either an Ekman sampler or a Peterson dredge would quickly yield the answer so far as black sands on the surface of the bottom are concerned. Black sands buried offshore beneath other sediments would not only be difficult, but also expensive to find and it is doubtful if they could be developed without prohibitive expense.

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