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OPEN-FILE REPORT 0-91-02

# PRELIMINARY RESOURCE AND ENVIRONMENTAL DATA: OREGON MARINE PLACER MINERALS

Joint State-Federal
Oregon Placer Marine Minerals Technical Task Force

1991

NOTICE

This report is based on results of a program directed by the joint federal-state Oregon Placer Minerals Technical Task Force, managed by the Oregon Department of Geology and Mineral Industries, and funded by the Minerals Management Service, U.S. Department of the Interior, through Cooperative Agreement. Opinions expressed are those of the authors and do not constitute endorsement by the Task Force.

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the Department. To facilitate timely distribution of information, camera-ready copy submitted by the authors has not been edited by the staff of the Oregon Department of Geology and Mineral Industries.

## EXECUTIVE SUMMARY

The Oregon Placer Minerals Technical Task Force commissioned a reconnaissance-level field investigation of heavy mineral placer deposits offshore southern Oregon, which was conducted during September-October 1990. The objectives of the study were to: 1) successfully identify the concentration, quality, and distribution of placer minerals with depth in the sand section; and 2) collect additional on living resources and geology that would benefit further understanding if the potential for economic placer deposits were to appear favorable. The report is based on multidisciplinary data collected on the cruise and subsequent laboratory analysis of the data and samples obtained.

Geophysical surveys were conducted west and south of Gold Beach (mouth of the Rogue River) and west and south of Cape Blanco. Magnetic anomalies in the Gold Beach area appeared related to bedrock structures rather than concentrations of placer minerals. None of the magnetic anomalies in the two target areas exhibited the shore-parallel shape and orientation of the anticipated drowned beach strand placer deposits. High-resolution seismic surveys were also conducted in the four areas, delineating unconsolidated sediment thicknesses of between 0 and 50 meters, but showing little internal structure within the sand section with which to aid interpretation. Limited side-scanning sonar coverage demonstrated the presence of extensive surficial gravel patches in the vicinity south of Cape Blanco, indicating that the modern sediment in this area is probably a thin veneer over older sediments.

Geological sampling to depth in the sand section with the vibralift/vibracore drill was largely frustrated by the prevailing oceanographic conditions and equipment breakdowns. Four vibralift stations were sampled to a depth of 6 meters south of Gold Beach, and one shallow sample (<1m) was recovered west of Cape Blanco. No vibracores were obtained. However, additional geological sediment subsamples were obtained from each of the 68 surficial grab samples taken for the biology program.

The surficial samples exhibited some enrichment of heavy minerals in the Cape Blanco area, but not the Gold Beach area. The samples taken to depth offshore Gold Beach did not demonstrate any increase in heavy mineral concentration with depth in the sand section: the subsurface sand was texturally and mineralogically similar to that at the surface. Extensive mineralogical and elemental analyses were conducted on depth fractions of all the vibralift samples. Only trace amounts of gold, zirconium, and platinum group metals were found. Titanium and chromium minerals were found in all samples, but only the titanium-bearing ilmenite in the Cape Blanco sample was in sufficient concentration (~3% Ti) to rival existing on-land sources. Beneficiation testing conducted on vibralift subsamples demonstrated that the Cape Blanco heavy mineral product could be

improved by standard beneficiation techniques. The lack of core samples to depth offshore Cape Blanco leaves the heavy mineral potential there unknown. However, the geological resource reconnaissance results as a whole fail to show the presence of an appreciable heavy mineral resource in either target area.

The environmental portion of the reconnaissance was conducted without difficulty. Environmental sediment chemistry analyses were conducted on grab subsamples. Low organic carbon concentrations and the lack of a large silt fraction indicated a low potential for metals mobilization, but nickel and chromium were of sufficient concentration to require possible future bioassays.

The biological sampling program demonstrated the existence of a complex of productive and diverse habitats within the study area. Sand and gravel substrates were sampled and exhibited similar species composition, diversity and relative abundance to other Oregon nearshore areas. Benthic grab samples showed that the sand substrates were characterized by an infaunal assemblage of worms, molluscs and crustaceans. Trawls caught species of commercial interest including dungeness crab, English sole, butter sole, sandsole and Pacific tomcod, as well as many forage species. The complex of different habitats within a small geographic area may be unique on the Oregon coast. Bird observations conducted during the cruise showed the highest densities inside Orford Reef.

## PREFACE

In September 1989, the Secretary of the Interior and the Governor of Oregon announced the formation of the joint state-federal Oregon Placer Minerals Technical Task Force. The purpose of the task force is to define the extent of black sand deposits offshore Oregon, evaluate their economic and strategic importance, and examine the environmental aspects of their development. The task force, with members and advisors representing government, academia and industry, met four times during the period October 1988 to January 1990 and subsequently released a preliminary feasibility study (Open-File Report 0-89-12). The group met again in March and July of 1990 to commission a reconnaissance-level field study which was conducted during September-October 1990. A cruise report detailing the accomplishments of the field study was released in April 1991 as U.S. Geological Survey Open-File Report 91-279. The present report is a summary of field and laboratory data generated by the 1990 Placer Minerals Cruise.

Acknowledgement is due to many persons who participated in the production of this report. The efforts of all the chapter authors are gratefully acknowledged. Extensive word processing of the draft and final versions of the report was performed by Rhonda Marks. The 1990 Placer Minerals Cruise was originally scoped by a technical committee comprised by Ed Clifton, Joe Ritchey, Rick Starr, Brad Laubach, Mark Whitney, Jim Waldvogel, Russ Peterson, and Bob Woolsey. Substantial parts of the plan were provided by consultants LaVerne Kulm, Curt Peterson, Bill Pearcy and Susan Ross. The cruise was led by co-chief scientists Ed Clifton and Rick Starr with a scientific crew of fourteen and ship's crew of ten aboard the M/V Aloha. In addition to the chapter authors, data reduction was performed by Robert J. O' Brien and Howard Jones.

The Oregon Placer Minerals Technical Task Force is supported by the Department of the Interior, Minerals Management Service through Cooperative Agreement No. 14-12-0001-30462 with the State of Oregon, Department of Geology and Mineral Industries. Cash and in-kind contributions for the 1990 Placer Minerals Cruise were provided by the Minerals Management Service; the U.S. Bureau of Mines; the Marine Minerals Technology Center, University of Mississippi; the Oregon Departments of Environmental Quality, Geology and Mineral Industries, Fish and Wildlife, and Land Conservation and Development; the Oregon Division of State Lands; the Oregon Sea Grant College Program; and Portland State University.

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# SECTION 1.0

# INTRODUCTION

## SECTION 1.0.

## INTRODUCTION

### 1.1. Background

The 1990 Placer Mineral Research Cruise resulted from recommendations by the Oregon Placer Minerals Technical Task Force to conduct a field program in 1990 that would provide needed information on the character of mineral resources on the southern Oregon continental shelf and the economic, strategic, and environmental aspects of any development of these resources. The objective of the cruise was to identify the concentration, quality, and distribution of placer minerals with depth in the sand section in at least two target areas on the southern Oregon shelf and concurrently with this examination, collect information on living resources and geology that would benefit further understanding if the potential for economic deposits appeared favorable. Thus, the cruise represented reconnaissance level efforts related to both the resource and the environment.

As a general strategy, the cruise focused on two areas, one off Cape Blanco and the other off Gold Beach (Figure 1.1.), that had been identified in previous studies as having potential for placer mineral concentrations (e.g. Kulm and Peterson, 1990). The goal was to collect a minimum of 4 to 6 cores or bulk samples through the upper 6 meters (20 feet) of shelf sediment in each target area. The location of these sample sites was to be established on the basis of magnetic and high-resolution acoustical profiling data collected in the initial phases of the cruise. The identification of specific mineralogic targets was also to provide locations for sampling of shelf biota in the vicinity of any placer deposits and comparing it with the biota in adjacent areas without mineral concentrations. Mineralogical samples collected from the target sites would receive preliminary examination on board the vessel to assist with the field interpretation of the nature of the deposit and the selection of additional sampling sites. The bulk of the sample would be taken to shore-based laboratories for detailed analysis following the cruise.

### 1.2. Report Organization and Contents

The purpose of this report is to present, within one cover, the multidisciplinary results of the 1990 Placer Minerals Cruise. The data range from at-sea observations (e.g. bird and mammal counts) to results of laboratory analytical procedures (e.g. sediment chemistry). The report is arranged by discipline, with Chapters 2.0.-4.0. comprising the resource reconnaissance and Chapters 5.0.-6.0. comprising the environmental reconnaissance. Chapter 7.0. summarizes the conclusions of the discipline-related

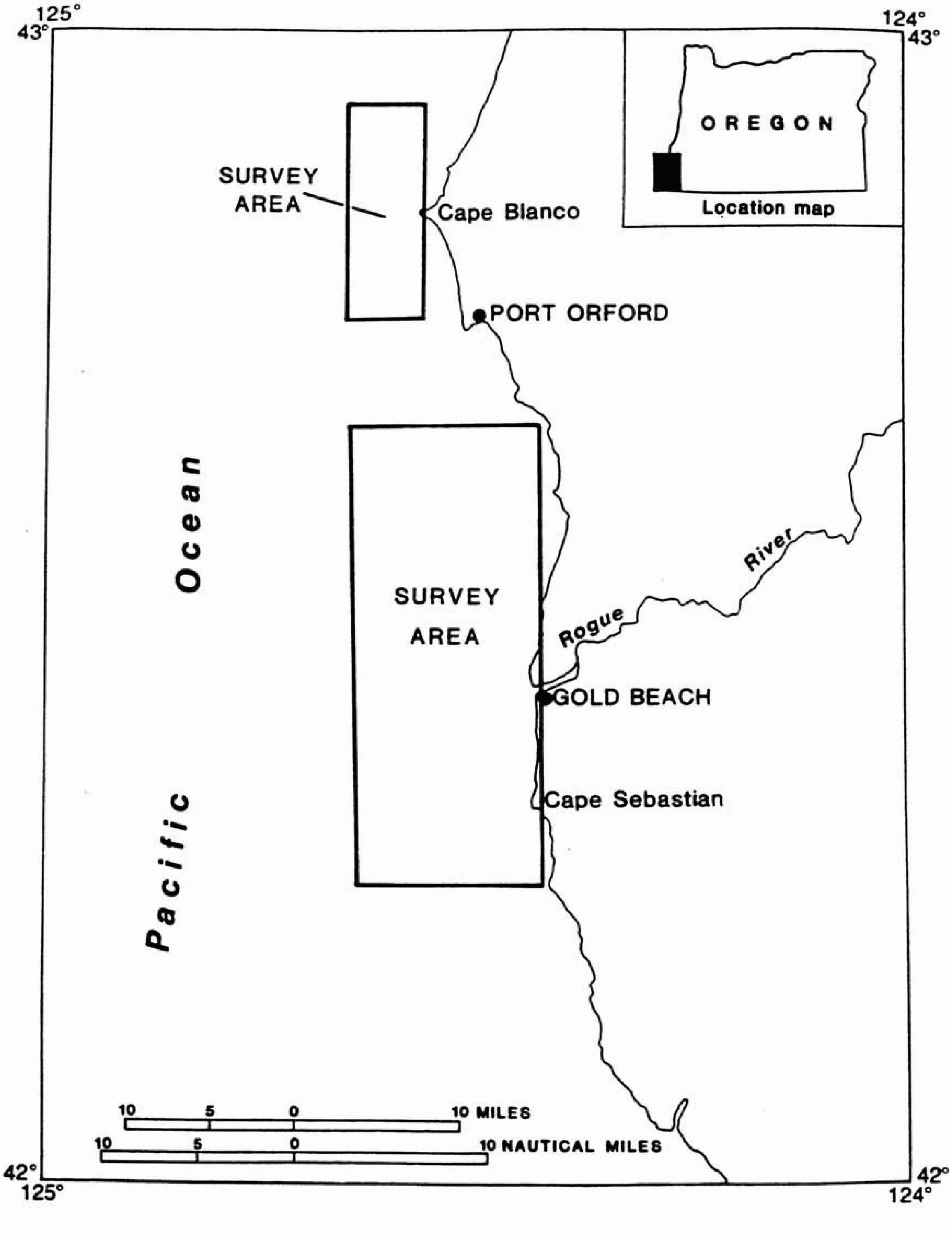



FIGURE 1.1. AREAS OF OFFSHORE RESEARCH ACTIVITY

chapters and Chapter 8.0. presents the recommendations of the task force based on the data and conclusions in the preceding sections.

### 1.2.1. Terminology

A variety of terms has been used in task force discussions, the media, and elsewhere, to describe deposits of interest offshore southern Oregon. The following definitions are presented here to minimize confusion.

**Mineral** - A naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form and physical properties. Chromite and ilmenite are minerals containing the elements chromium and titanium, respectively.

**Metal** - An opaque, lustrous, elemental, chemical substance that is a good conductor of heat and electricity, and, when polished, a good reflector of light. Gold, platinum, chromium and titanium are metals.

**Heavy minerals** - A mineral having a specific gravity higher than a standard, usually 2.85. Examples of heavy minerals are magnetite, zircon, rutile, chromite, ilmenite and garnet.

**Placer** - A surficial mineral deposit formed by mechanical concentration of mineral particles from weathered debris. The mineral concentrated is usually a heavy mineral.

**Black sand** - An alluvial or beach sand consisting predominantly of grains of heavy dark minerals or rocks, concentrated chiefly by wave, current or surf action. Oregon black sands often containing a high proportion of the dark mineral magnetite.

In this and earlier task force reports, the terms heavy mineral, placer mineral and black sand deposits have been largely interchangeable.

### 1.2.2. Citation

Proper citation for a chapter of this report is as follows:

Clifton, H.E., Peterson, C.D. and Connard, G., 1991, Geology/Geophysics: in Oregon Placer Mineral Technical Task Force (eds.), Preliminary Resource and Environmental Data: Oregon Placer Minerals: Oregon Department of Geology and Mineral Industries Open File Report 0-91-2.

## 1.3. Cruise Activities

The cruise activities are described in detail in a previous report (Clifton, et al. 1991). That report includes a cruise data index which is essentially a computer log, with time and navigation, of all activities conducted during the cruise. The cruise report (Clifton, et al. 1991) may be obtained from the USGS Open-File Report Section, P.O. Box 25425, Federal Center, Denver, CO 80225. The following paragraphs are largely excerpted from the cruise report and are presented here for readers who do not have access to that report.

### 1.3.1. Timing and Location

The cruise was scheduled for a 15-day period in the latter part of September and early October 1990. This period was selected in part because it provided the most likely favorable weather for the cruise and also because it followed the closure of commercial fishing seasons. The general areas for sampling included two target areas in the vicinity of Cape Blanco and two target areas in the vicinity of the Rogue River mouth. The placer target sites are summarized in Table 1.1 and Figure 1.2. Target area "Cape Blanco West", about 15 km long and 5 km wide, lies west of Cape Blanco in water depths that range from 15 to 60 m. It included 5 specific target sites (Blanco 1 through 5) that were identified on the basis of earlier studies. A smaller secondary target "Cape Blanco South", containing target sites Blanco 6 and 8 lay south of Cape Blanco in water depths of 20 to 40 m. Its position east of the Orford Reef provided some protection under the worst wind and wave conditions. The target areas in the vicinity of the Rogue River mouth included one ("Gold Beach South") about 12 km long and 3-5 km wide in water depths of 20 to 60 m between the mouth of the Rogue River and Cape Sebastian to the south. This area included target sites Rogue 1, 2, 4, 5, 8, and 9. A second target area ("Gold Beach West"), about 10 km long and 5 km wide, lay in deeper water (40 to 80 m) seaward of the Rogue Reef and included target site Rogue 3.

### 1.3.2. Navigation

The navigational system used on the M/V Aloha cruise was an 80386 DOS based system using inputs from a DECCA 540 Del Norte transponder ranging system and an Ashtech Model XII GPS receiver. Del Norte was used for the majority of the cruise because of its greater positioning accuracy. GPS was used only when the ship was out of range of the land-based transponder stations or in areas of poor station geometry, (e.g. along baseline between stations). The positioning accuracy of the Del Norte system is about 5 meters when three or more of the stations were used for the ranging calculations. GPS accuracy for this cruise was calculated by comparing 40,696 pairs of good Del Norte fixes with GPS fixes. The mean difference was about 21 meters, with a

# TABLE 1.1. PROPOSED TARGET SITES FOR THE CAPE BLANCO AND ROGUE RIVER AREAS

| Prepared by LaVerne Kulm and Curt Peterson, Oregon State University and Portland State University | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date:11/30/1989 | | | | | | | | | |
| Target sites (Blanco 1, 2,3) listed in order of priority (highest number) for each target area (Blanco, Rogue) | | | | | | | | | |
| Area | Latitude* | Longitude* | Water** | Heavy*** | Gold# | Magnetic## | Sediment+ | Topographic feature/ | Target++ |
| | (N) | (W) | depth | mineral | content | anomaly | thickness | Mineral source | objective |
| | | | (m) | (%) | (ppb) | (gamma) | (m) | | |
| **Cape Blanco Area** | | | | | | | | | |
| Blanco 1 | 42° 53.5' | 124° 35.3' | 50 | >30 | 20 | 15 | 0-15 | N. side paleoheadland, Sixes R. | HM, MG, Au |
| Blanco 2 | 42° 53.9' | 124° 34.7' | <36 | 10-30 | 5-20 | 50 | 16 | N. side paleoheadland, Sixes R. | HM, MG, Au |
| Blanco 3 | 42° 51.1' | 124° 36.1' | 33 | 10-20 | >100 | 15 | 0-16 | Bathymetric high headland | HM, MG, Au |
| Blanco 4 | 42° 49.4 | 124° 36.9 | 35 | 10-20 | 50 | 25-30 | 16-25 | S. side paleoheadland | HM, Au, MG |
| Blanco 5 | 42° 50.0' | 124° 36.0' | 30 | >30 | 50 | NA | 0-16 | S. side paleoheadland, Elk R. | HM, Au |
| Blanco 6 | 42° 46.5' | 124° 34.0' | 33 | 10-20 | NA | NA | 0-16 | S. side bathymetric high, Elk R. | HM |
| Blanco 7 | 42° 43.0' | 124° 29.0' | 24 | <10 | 50 | NA | 0-16 | Paleo-shoreline/headland | Au |
| Blanco 8 | 42° 46.5' | 124° 32.2' | 18 | <10 | 0-10 | NA | 0-16 | Offshore Mouth Elk River | Au |
| **Rogue River Area** | | | | | | | | | |
| Rogue 1 | 42° 23.5' | 124° 26.5' | 16 | 10-20 | >100 | 125 | 16-20 | Proximity to Rogue R. source | HM, MG, Au |
| Rogue 2 | 42° 23.7' | 124° 27.8' | 31 | 20-30 | 10 | 210-355 | 0-16 | Proximity to Rogue R. source | HM, MG, Au |
| Rogue 3 | 42° 25.7' | 124° 33.3' | 67 | 20-30 | 5 | 200-255 | 20 | Paleo-shoreline/river channel | HM, MG, Au |
| Rogue 4 | 42° 19.6' | 124° 27.0' | 25 | 20-30 | NA | NA | 16-25 | Paleo-shoreline, south drift | HM |
| Rogue 5 | 42° 20.3 | 124° 26.8 | 22 | 10-20 | NA | 125-140 | 16-25 | Paleo-shoreline, south drift | HM, MG |
| Rogue 6 | 42° 35.5' | 124° 25.5' | 36 | <10 | 10-20 | 40 | 25 | Paleo-shoreline, north drift | MG, Au |
| Rogue 7 | 42° 34.4' | 124° 28.1' | 51 | 10-20 | NA | 225 | 16 | Paleo-shoreline, north drift | HM, MG |
| Rogue 8 | 42° 22.9' | 124° 29.4' | 45 | 10-20 | NA | 230 | 0-16 | S. side rocky reef/paleoheadland | HM, MG |
| Rogue 9 | 42° 22.8' | 124° 29.5' | 48 | 10-20 | NA | 205 | 0-16 | S. side rocky reef/paleoheadland | HM, MG |

**Explanation of Symbols**

*Center of target area. Navigation was old Loran A with errors up to 1-2 km. Latitude (and water depth) most accurate position.

**Water depth in meters. Most reliable indicator of location in east west direction; target location best defined by water depth & latitude

***Heavy mineral concentrations in surface sediments at target site

#Gold content from Clifton, 1968 analysis of surface sediments

##Magnetic anomaly measured in gammas (regional magnetic field subtracted)

+Sediment thickness in meters from sediment overburden map

++Primary objective for target: HM=heavy mineral concentration; Au=gold content; MG=magnetic anomaly

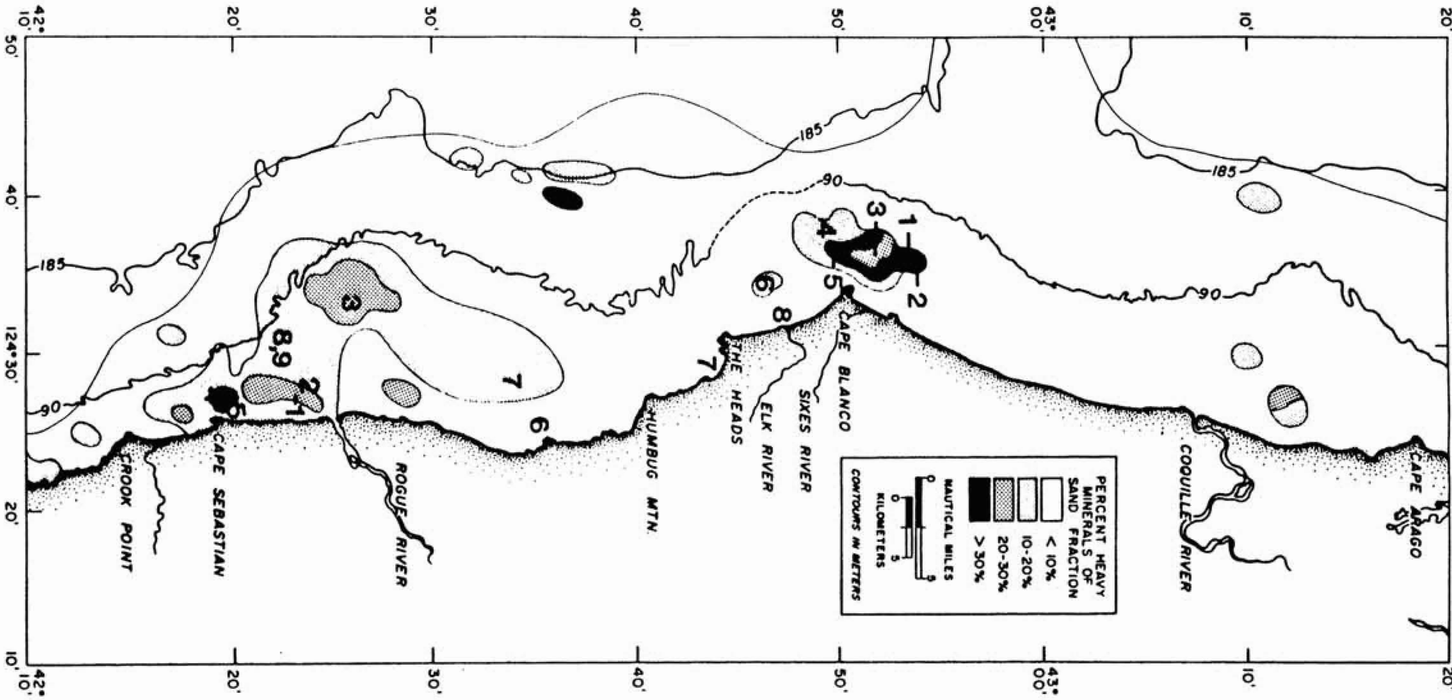



FIGURE 1.2. PLACER MINERAL TARGETS, SOUTHERN OREGON SHELF

standard deviation of 17 meters. Loran C was also used selectively.

Seven different Del Norte shore transponder locations were used during the cruise. Three of them were located directly on bench marks; two were within 33 meters of a benchmark and were located by tape measurement and theodolite and cross-checked by azimuth to a distant benchmark or feature; another was located by resection with 5 other features; and the last, a temporary station used only briefly, was measured from a topographic quadrangle map.

The DOS computer system gave a real-time numerical and graphical display that was used by the helmsman for line following and station re-occupation. Most station keeping was done by maneuvering the vessel about a temporary, bottom-anchored buoy. Del Norte positions were calculated by the computer program from the known locations of the shore transponders and the ranges. GPS positions were calculated by the Ashtech receiver and used by the computer program without modification.

### 1.3.3. Data Collection/Sampling

Geophysics. Geophysical data were gathered via magnetometry, high-resolution seismic profiling, and side-scanning sonar systems. Six magnetic surveys were conducted in the Cape Blanco area and two were run in the Gold Beach area, resulting in a total of 384 km of trackline. Seismic tracklines totaling 198 km were conducted in the study areas; in addition, two longer transects were conducted outside the study areas using LORANC navigation. These transects were from Cape Arago (69.9 km). Side-scanning sonar tracklines totalling 188 km were conducted in the Cape Blanco West and Cape Blanco South areas.

Geology. Sediment samples for geological analyses were collected both by benthic grab and vibracore/vibralift. Surficial sediment samples were sub-sampled from all 68 $0.1m^2$ Smith-McIntyre grab samples with 10 cm square by 1.5 cm thick petri dish. Grab sample locations are shown in figures 6.1. and 6.2. Due to technical problems, only limited sampling was accomplished with the vibracore/vibralift. The gear is described in detail in Section 2.2.4.; vibralift sample locations are shown in Figures 2.24 and 2.35.

Biology. Benthic infauna was sampled with the $0.1m^2$ Smith-McIntyre grab. Fish and benthic epifauna were sampled with a 3 m beam trawl and a 7.3 m otter trawl. Sixteen tows totalling 24 km were conducted. Adult Dungeness crab were additionally sampled with crab pots. Seabird and marine mammal observations were conducted over 351 km of trackline. Locations of biology sampling stations are shown in Figures 6.1. and 6.2.

## SECTION 2.0

## GEOLOGY/GEOPHYSICS

H. Edward Clifton, U.S. Geological Survey,
Curt D. Peterson, Portland State University, and
Gerald Connard, Northwest Geophysical Associates

## SECTION 2.0

## GEOLOGY/ GEOPHYSICS

### 2.1. Objectives

The objectives of the cruise were to successfully identify the concentration, quality, and distribution of placer minerals with depth in the sand section in at least two targets (areas that show indications of containing mineable quantities of black sand placers) on the southern Oregon shelf, and, concurrent with this examination, to collect geological information that will benefit further considerations if the potential for economic placer deposits appears favorable.

### 2.2. Methods

#### 2.2.1. Magnetometer Surveys

Magnetic survey data were acquired at sea in eight separate surveys during the cruise. Six of the surveys were in the Cape Blanco area and two surveys were in the Rogue River area near the town of Gold Beach. A magnetic base station onshore at Sisters Rocks recorded time variations in the magnetic field during the entire cruise. Figure 2.1 summarizes the location of the magnetic survey tracks and the magnetic base station. The nominal trackline spacing is 300 meters in the Cape Blanco North area and 600 meters in the other survey areas. Figures 2.2 through 2.5 show the track locations in the four separate survey areas.

The magnetic data were acquired with a Geometrics G-811 magnetometer with a resolution of 0.01 nanotesla (nT) and recorded at approximately one-second intervals on the USGS data acquisition system. The navigation equipment and techniques are described above under Navigation. The magnetic sensor was towed approximately 180 meters behind the ship (218 meters astern of the Del Norte Navigation antenna) to reduce interference from the ship's magnetic field.

Because of the relatively shallow water in the survey areas, a large float was attached to the sensor. This limited the sensor to a maximum depth of 15 meters. The Geometrics acquisition system indicated that the sensor depth varied from three to seven meters while underway on survey lines and dropped to nine to ten meters during turns. Sensor depth was not recorded digitally.

The magnetic base station was a Geometrics G-856 magnetometer with extended memory supplied and was operated by Oregon State University. Magnetic base station values were measured every two minutes and recorded in the G-856 internal memory during the entire cruise.

Preliminary processing and analysis of the magnetic data were accomplished onboard. After the cruise, the diurnal magnetic variations recorded by the magnetic base station were removed and the data reprocessed.

The onboard processing consisted of 1) editing the navigation data to remove bad fixes, 2) merging the navigation and magnetic data including sensor tow-distance correction, 3) removing a regional field, and 4) plotting profiles and contour maps.

The navigation data were checked by screening for unlikely speed variations and plotting the ship tracks. Bad fixes were removed by hand editing the navigation data. Only Del Norte fixes were used for navigation. The latitude and longitude of the fixes were converted to UTM coordinates. The UTM coordinates of the location of magnetic measurements were calculated by linear interpolation between fixes based on time. The tow-distance correction was calculated by looking backwards along the ship's track the amount of time equal to the ship's speed divided by the tow distance. (Note that this technique does not accurately recover the sensor position during turns.) The UTM coordinates of each magnetic measurement were converted to latitude-longitude. Magnetic anomaly values were calculated using a regional magnetic field correction from the IGRF-1985 (IAGA, 1986) with the appropriate time terms. Profiles of magnetic anomalies projected along the ship tracks were plotted at a scale of 1:40,000. These profile plots provided both a check on data quality and a useful preliminary interpretation tool. The last step in the onboard processing was to grid the survey data using minimum curvature and plot contours at a scale of 1:40,000.

Five of the eight separate surveys cover the northern part of the Cape Blanco area. More than a week elapsed between the first and last surveys in this area. When the surveys were combined, mis-ties between the separate surveys were as large as 30 nT and caused spurious patterns in the contour map commonly referred to as "chevroning." Most of the mis-tie between surveys was caused by diurnal variations which were largely removed during the post-cruise processing using the magnetic base-station data.

A total of 384.3 km of magnetometer survey lines was run during the cruise. The distribution of these lines is shown in Figures 2.1 through 2.5. The data derived from these surveys indicate locations of magnetic anomalies. By evaluating the intensity, size, and shape of the anomalies, we can determine if they are produced by fossil beach or other concentrations of magnetite in the sediment or by

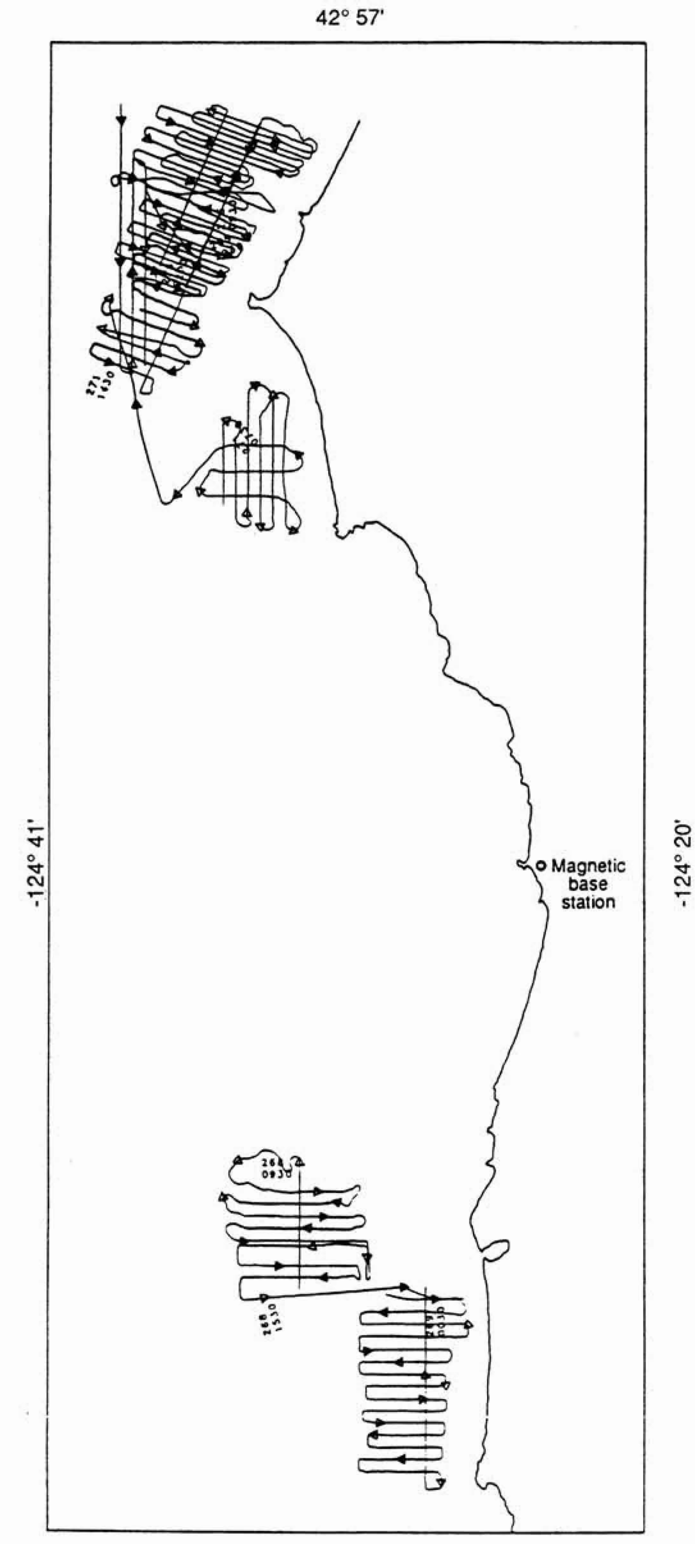



**FIGURE 2.1. MAGNETOMETER LINES, SOUTHERN OREGON**


MERCATOR PROJECTION

STANDARD PARALLEL = 42.6167°

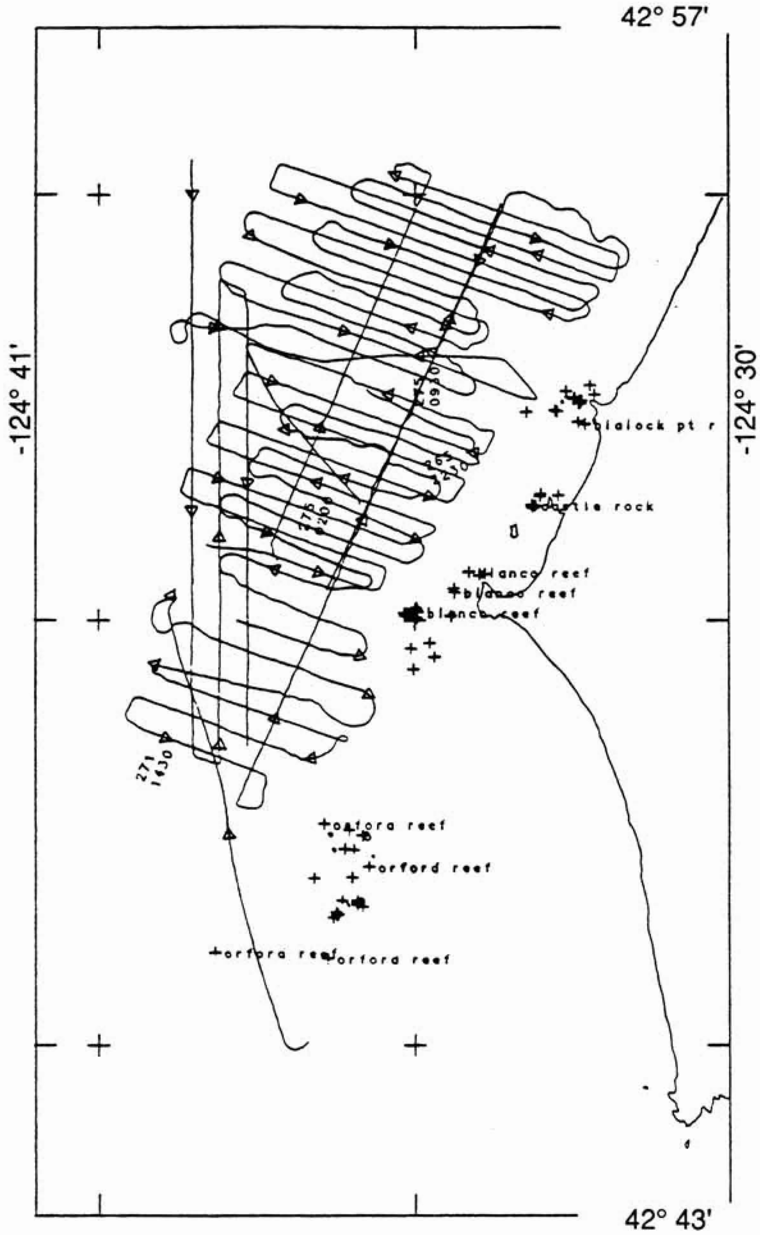



**FIGURE 2.2. MAGNETOMETER LINES, CAPE BLANCO WEST**

MAP SCALE 1:150,000

0 — 10 km

0 — 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

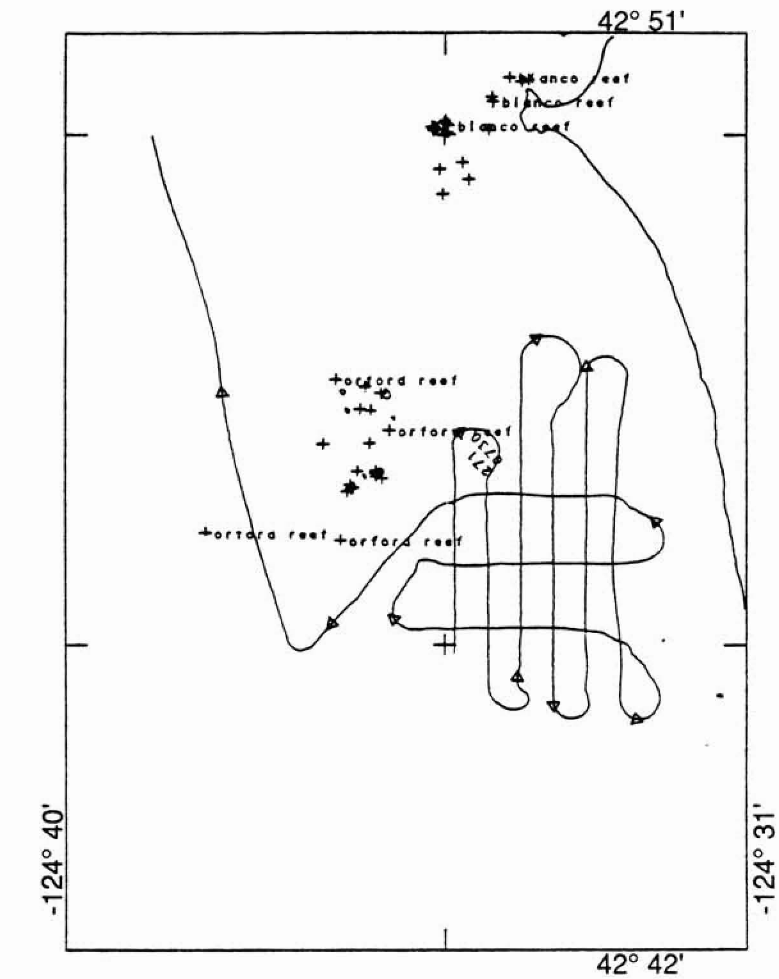



**FIGURE 2.3. MAGNETOMETER LINES, CAPE BLANCO SOUTH**

MAP SCALE 1:125,000

0 10 km

0 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

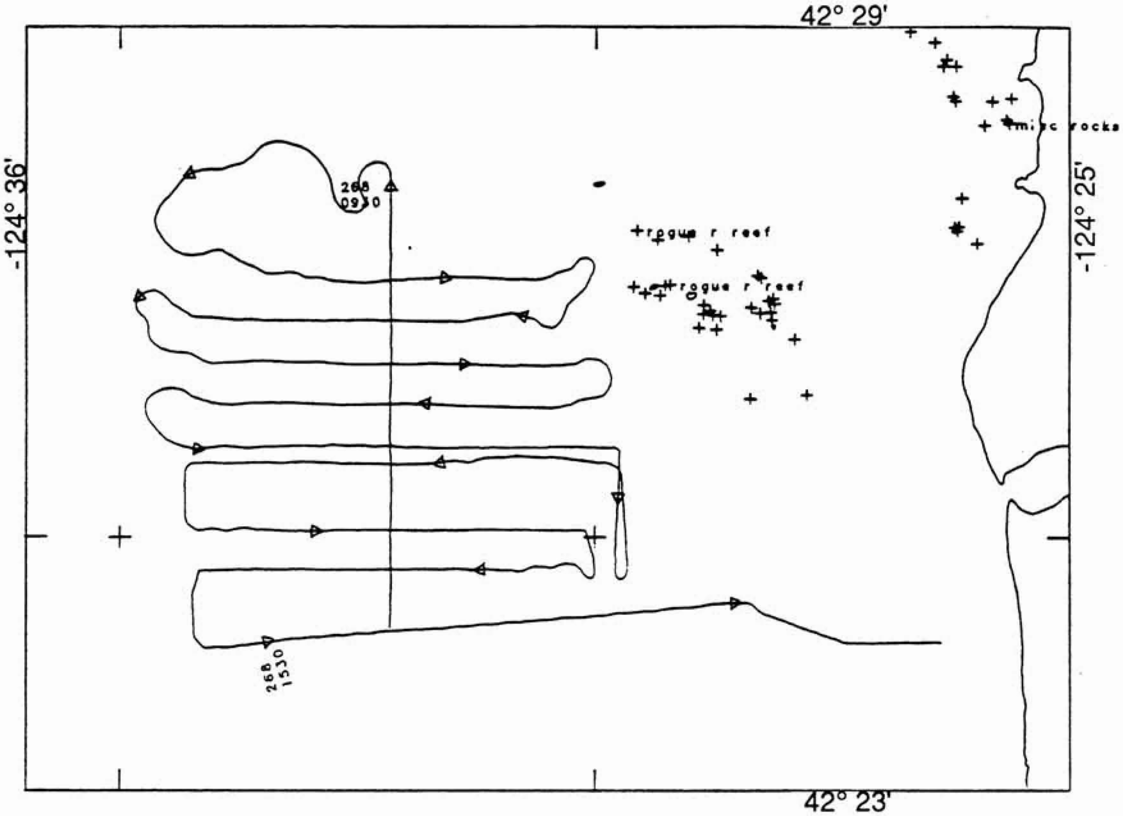



**FIGURE 2.4. MAGNETOMETER LINES, GOLD BEACH WEST**

MAP SCALE 1:100,000

0 10 km

0 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.5000°

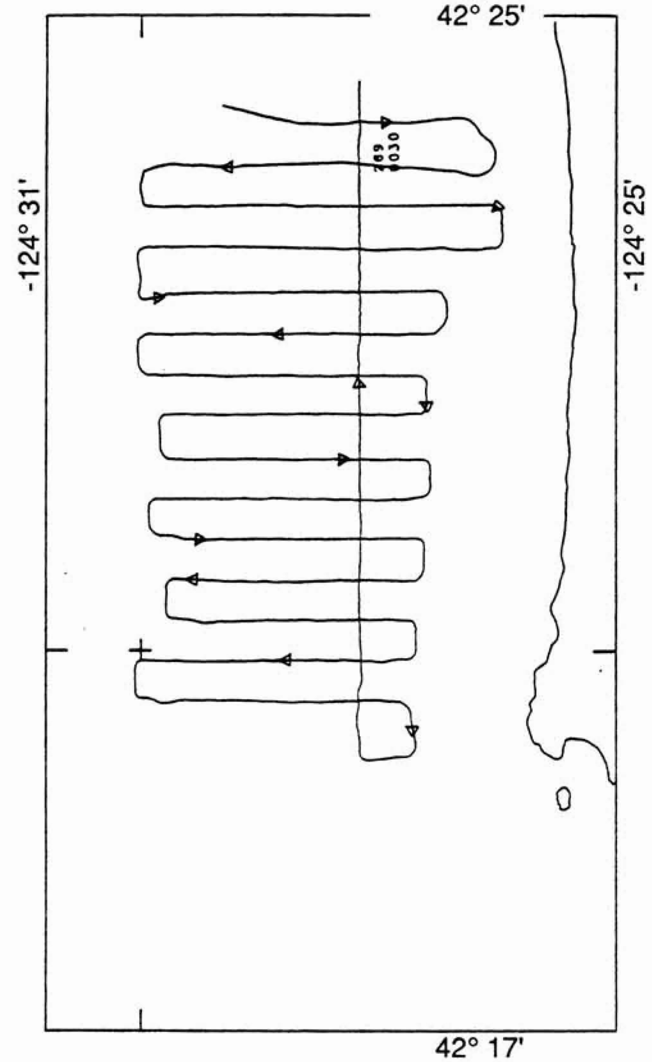



**FIGURE 2.5. MAGNETOMETER LINES, GOLD BEACH SOUTH**

MAP SCALE 1:100,000

0 — 10 km

0 — 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.5000°

magnetic minerals in the bedrock that underlies the sea floor.

Following the cruise, John Bowers of CONMAR (Oregon State University) extracted the magnetic base-station data, plotted the values by days, and compiled statistics for the entire period. The modal value (52718 nT) served as the base reference value for calculating diurnal corrections. A histogram showing the distribution of values recorded at the base station (Fig. 2.6) indicates the largest diurnal variation to occur during the first survey. Figure 2.7 shows the diurnal variation during each of the surveys. A diurnal correction was calculated and applied to the magnetic data using the base-station data.

The diurnally-corrected magnetic anomaly data were contoured with a five nT contour interval along the survey tracklines (Figs.2.8, 2.9, 2.10, and 2.11). The magnetic inclination in the survey areas, approximately 65°, causes some shift and asymmetry in the shape of the magnetic anomalies. The "reduction-to-the-pole" filter (Blakely and Connard, 1989) reduces this shift; it transforms observed anomalies that would be caused by identical magnetic sources but with vertical magnetization and with measurement in a vertical magnetic field. Figures 2.12, 2.13, 2,14, and 2.15 show magnetic contours after the magnetic data was reduced to the pole. The general character of the data remained unchanged, but individual anomalies were shifted by as much as a few hundred meters by the reduction-to-the-pole filter.

### 2.2.2. High-resolution seismic profiling

A high-resolution seismic profiling system was employed during the cruise (Fig. 2.16) to establish and record: (1) bathymetry of shelf bottom (Fig. 2.17); (2) bottom conditions of sediment or exposed bedrock (Fig. 2.17); (3) thickness of unconsolidated sediment above bedrock (isopach) (Fig. 2.17); (4) internal structures within unconsolidated sediment package; (5) warps, faults and/or channel cuts associated with the underlying bedrock wave-cut platform (Fig. 2.17); and (6) folds and/or faults associated with shallow basement rocks. As outlined above, all of the seismic track lines within the Cape Blanco and Rogue River target areas (a total of 198 km) were precisely navigated by the onshore transponder system. Two longer seismic track lines (Fig. 2.16) were run between Cape Sebastian and Humbug Mountain and between Cape Blanco and Cape Arago to constrain regional inner-shelf tectonic deformation adjacent to the target sites. These two lines, 13.8 and 69.9 km long respectively, were navigated by Loran C.

The equipment used for the seismic profiling included (1) two Ferranti Ocean Research Equipment (ORE) Model 5210 A GeoPulse$^R$ power source and receiver units, each producing a

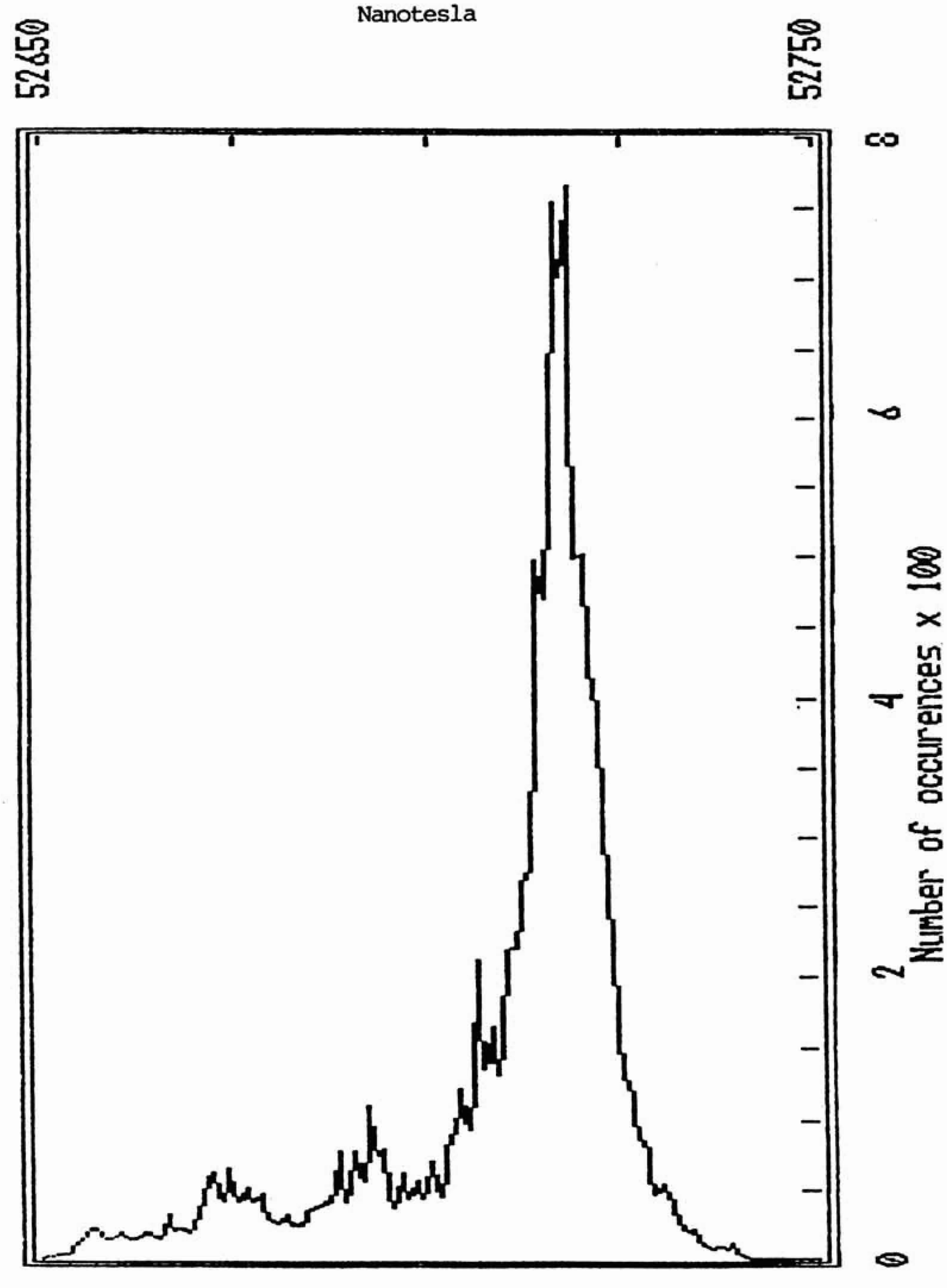



**FIGURE 2.6. HISTOGRAM OF MAGNETIC BASE STATION VALUES RECORDE DURING PLACER MINERALS CRUISE**

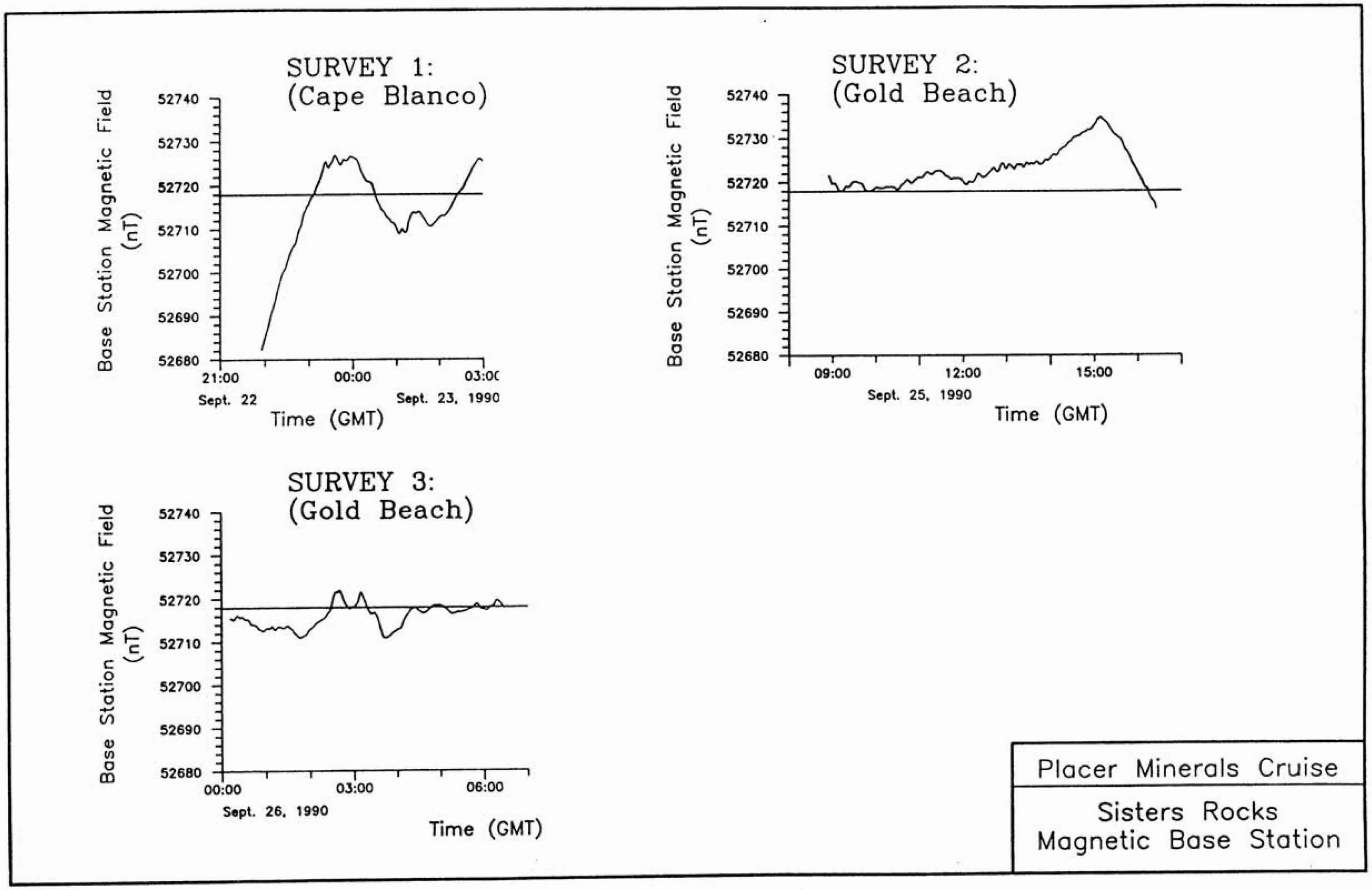



**FIGURE 2.7. DIURNAL MAGNETIC VARIATION**

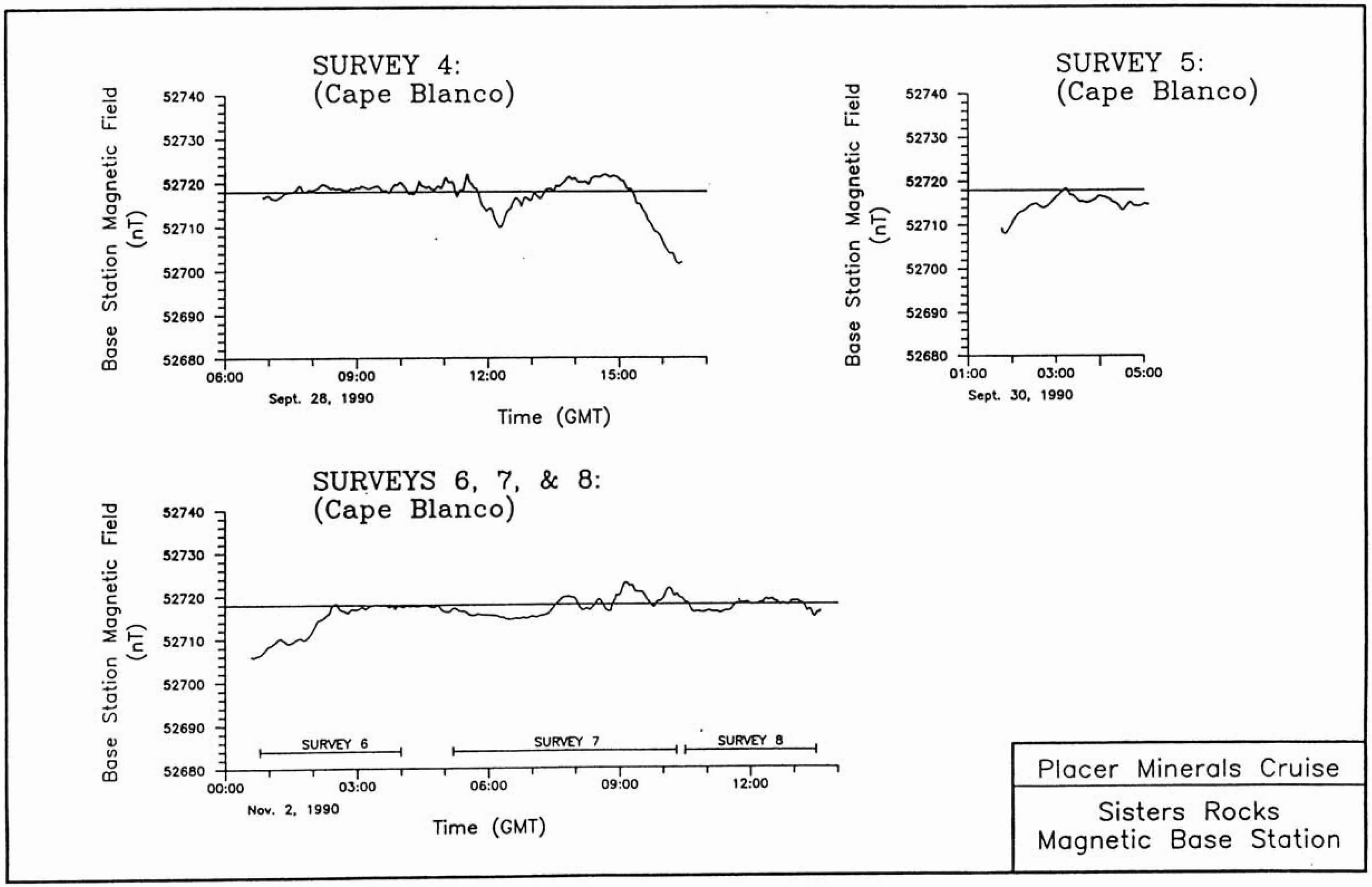



**FIGURE 2.7. DIURNAL MAGNETIC VARIATION (continued)**

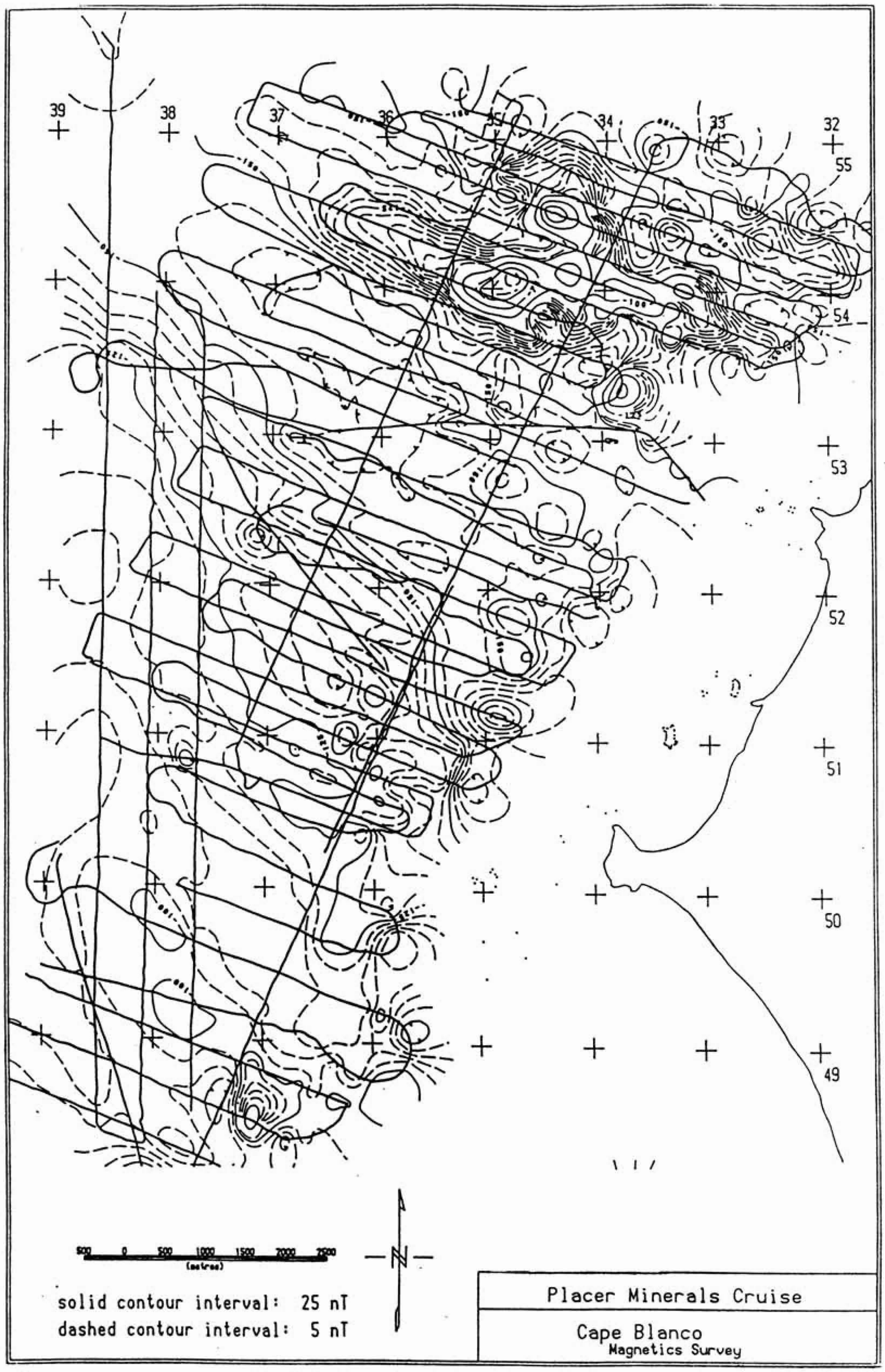



**FIGURE 2.8. DIURNALLY CORRECTED MAGNETIC CONTOUR PLOT, CAPE BLANCO WEST**

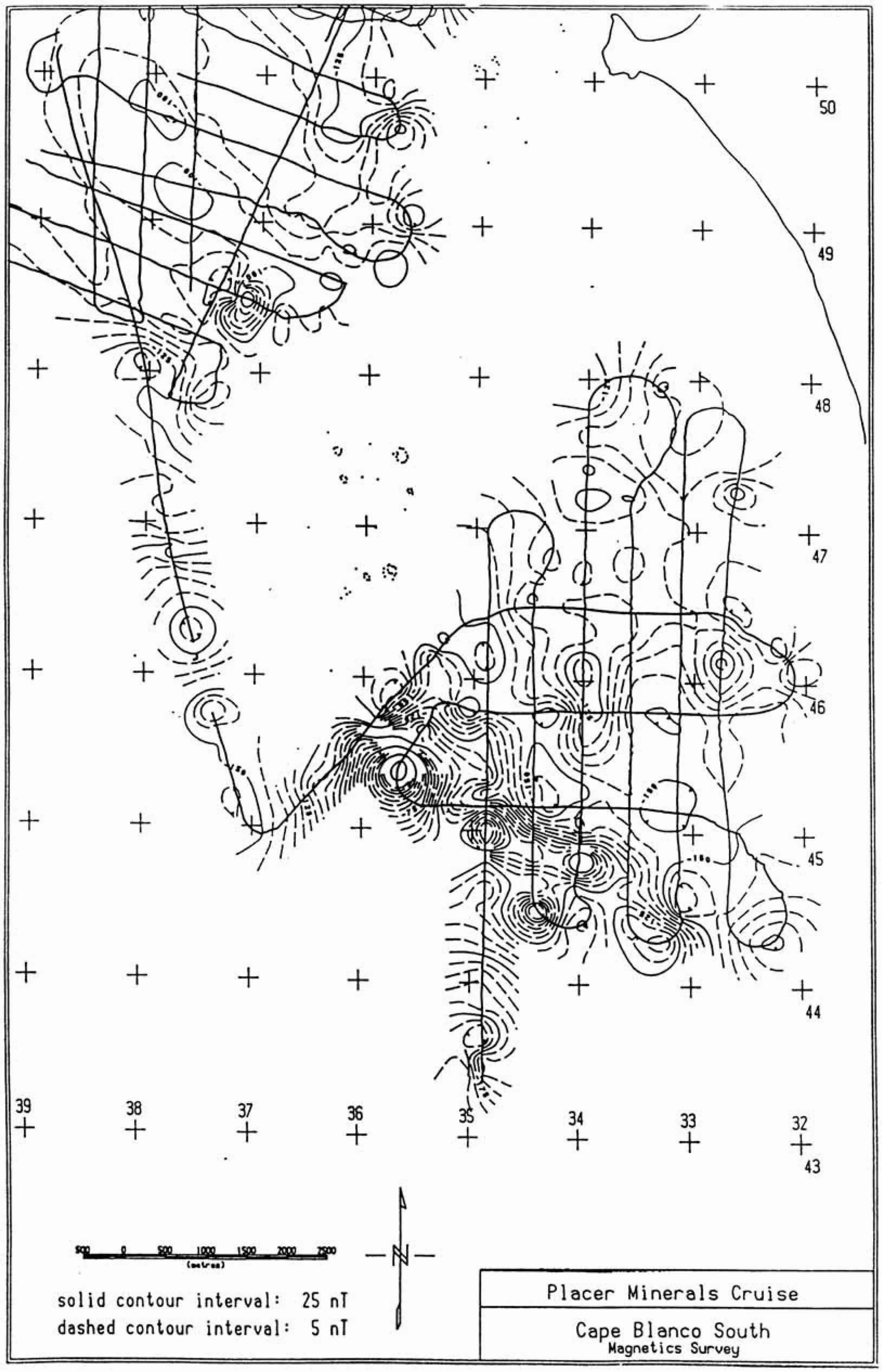



**FIGURE 2.9. DIURNALLY CORRECTED MAGNETIC CONTOUR PLOT, CAPE BLANCO SOUTH**

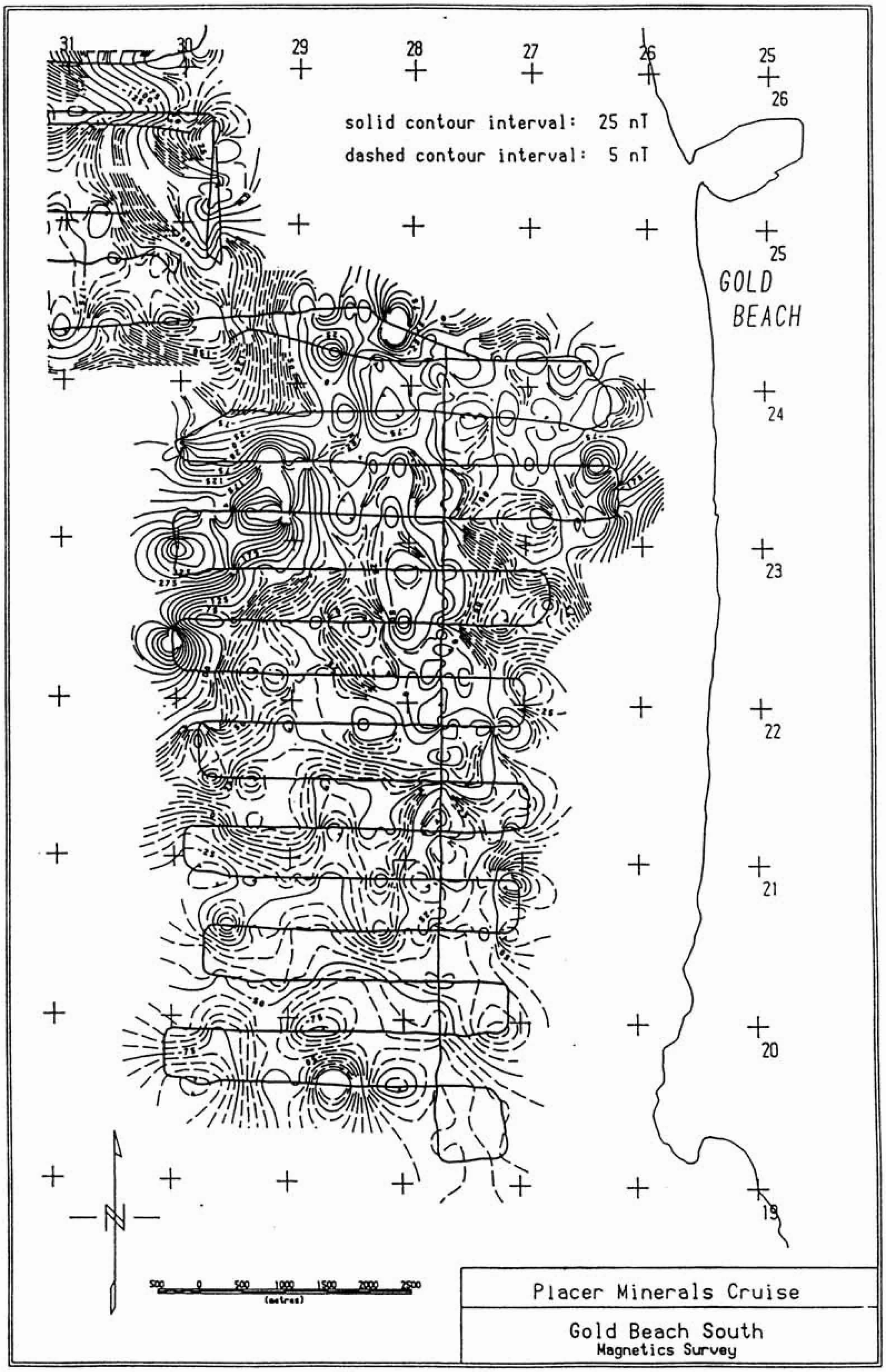



**FIGURE 2.10. DIURNALLY CORRECTED MAGNETIC CONTOUR PLOT, GOLD BEACH SOUTH**

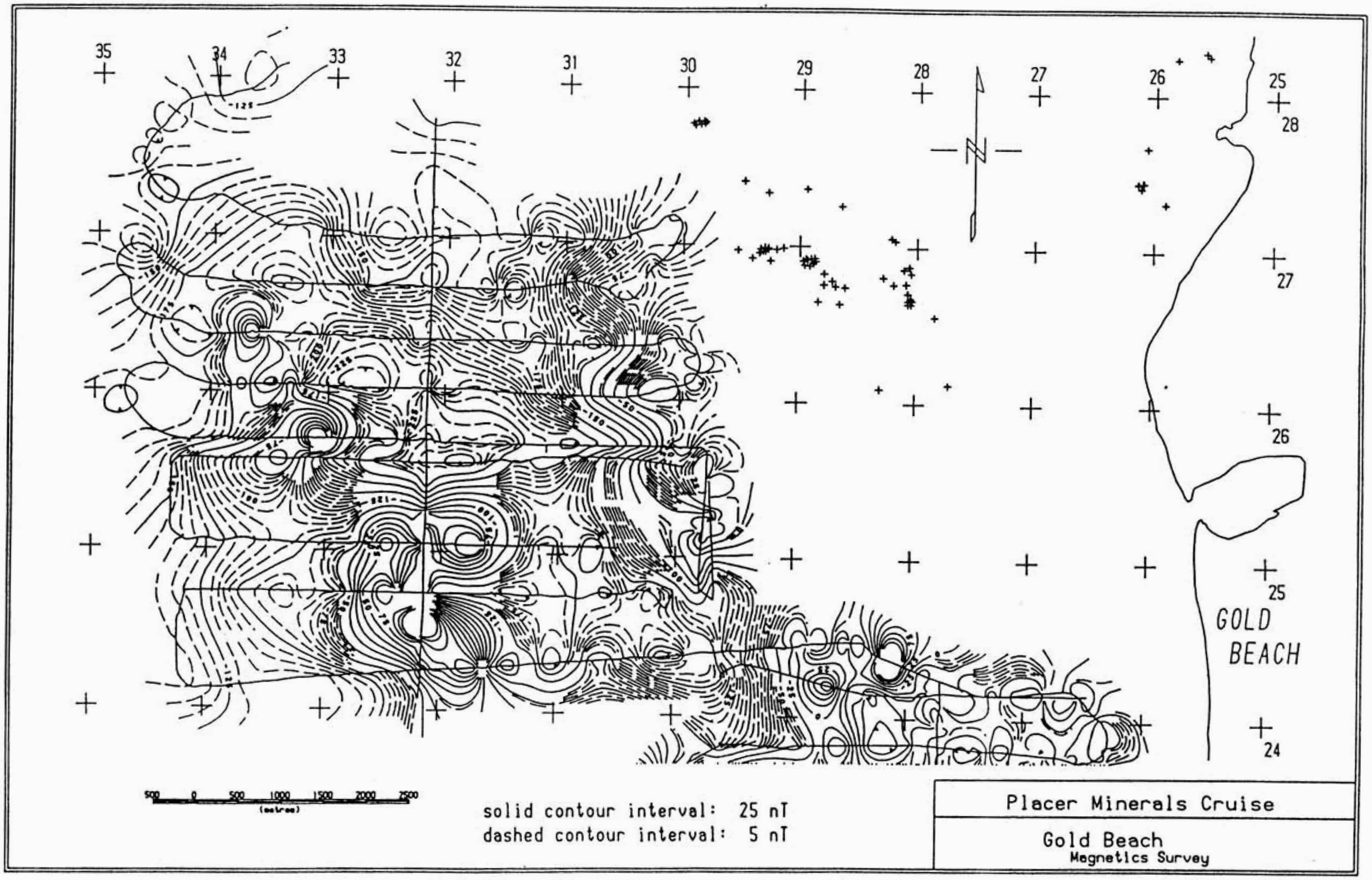



**FIGURE 2.11. DIURNALLY CORRECTED MAGNETIC CONTOUR PLOT, GOLD BEACH WEST**

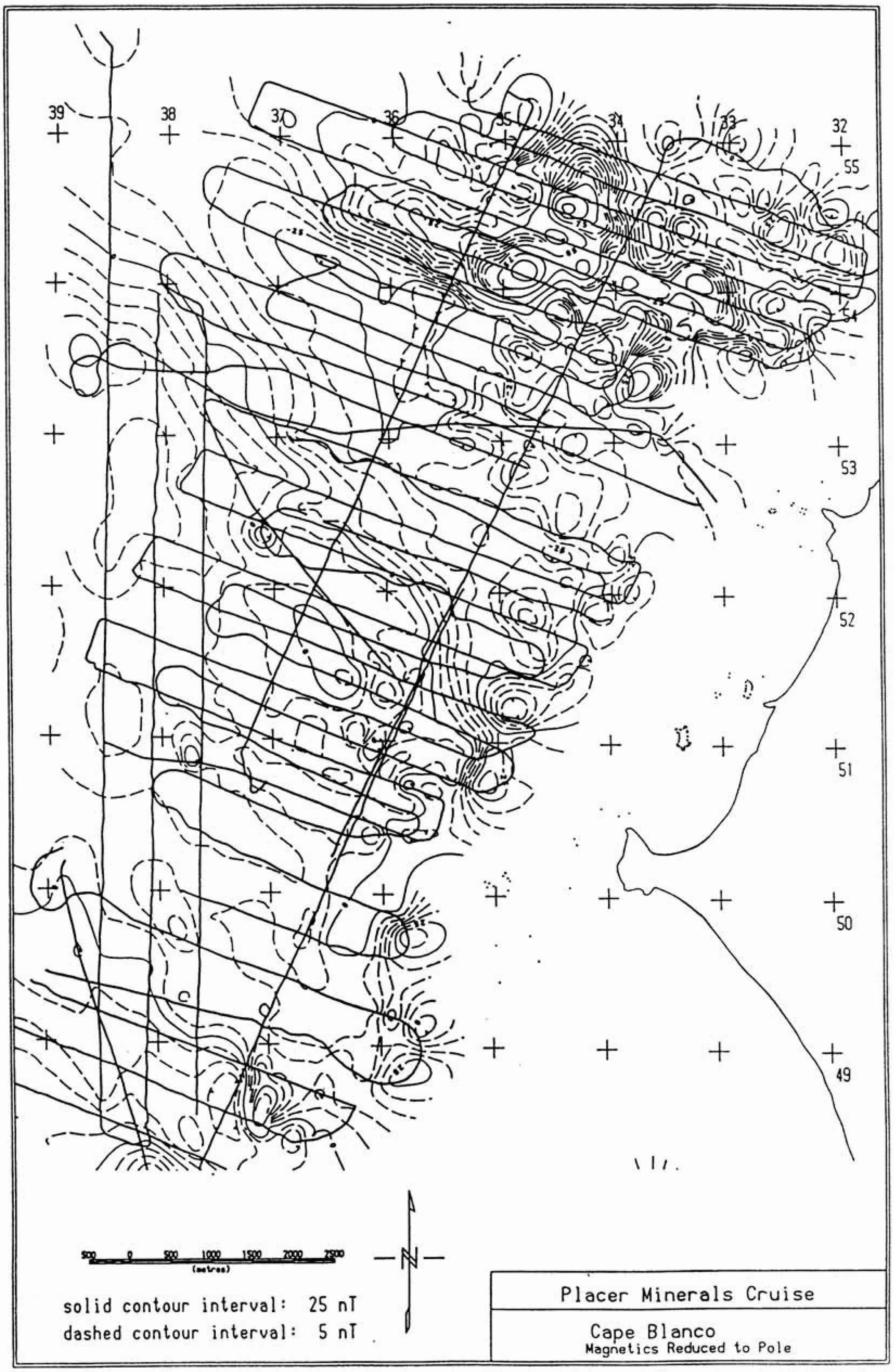



**FIGURE 2.12. MAGNETIC ANOMALIES REDUCED TO POLE, CAPE BLANCO WEST**

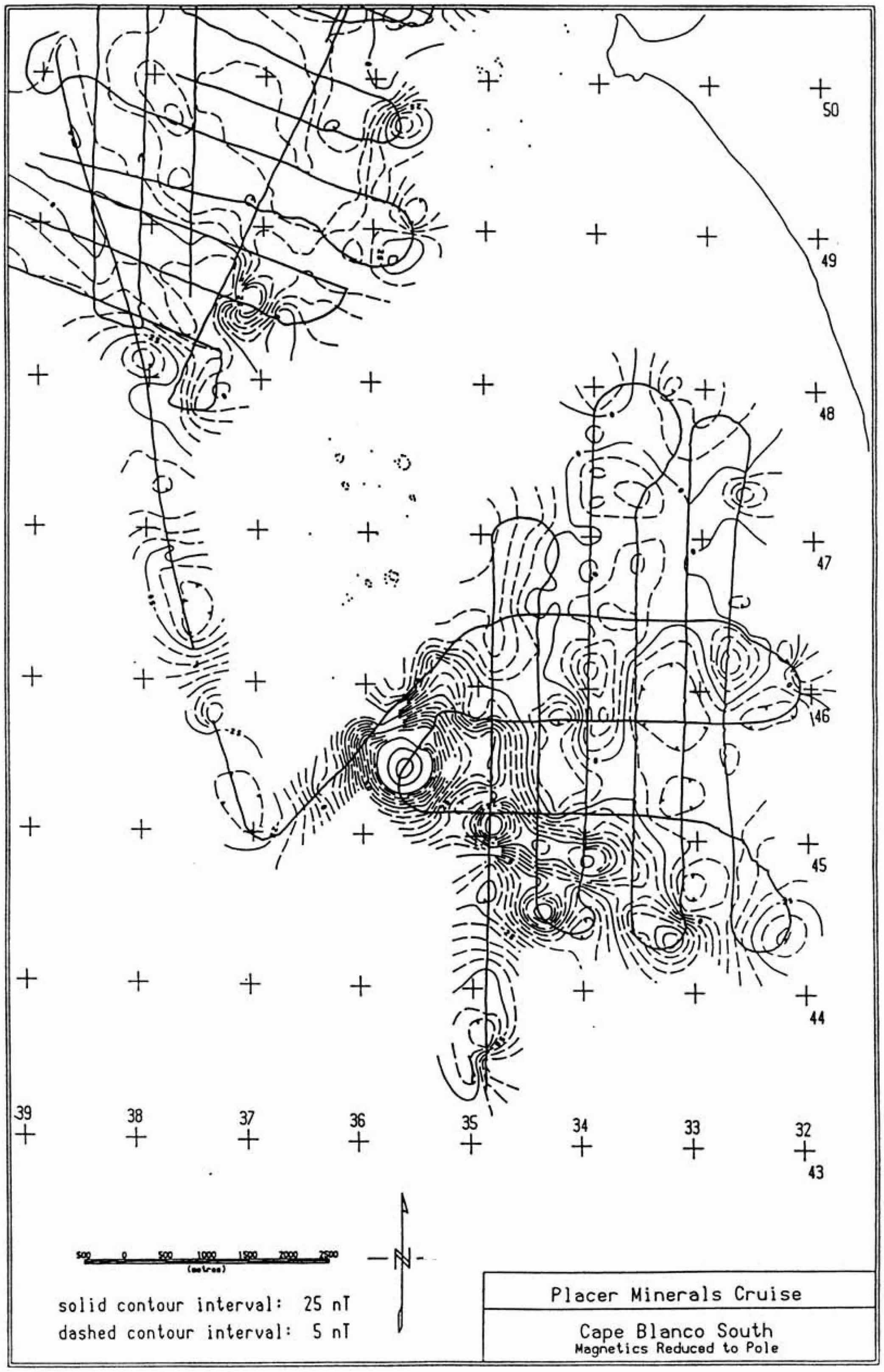



**FIGURE 2.13. MAGNETIC ANOMALIES REDUCED TO POLE, CAPE BLANCO SOUTH**

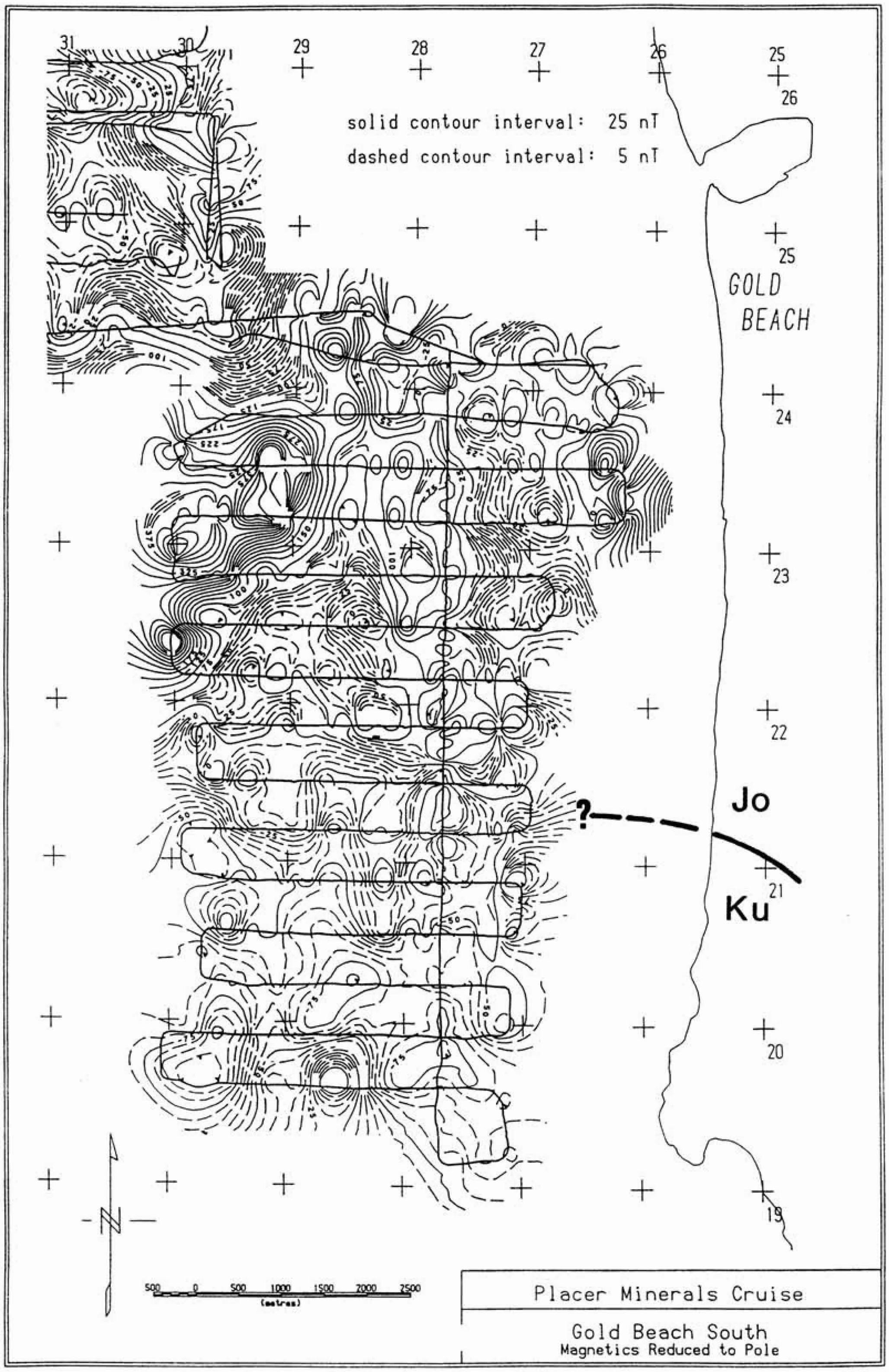



**FIGURE 2.14. MAGNETIC ANOMALIES REDUCED TO POLE, GOLD BEACH SOUTH, WITH CRETACEOUS/JURASSIC CONTACT**

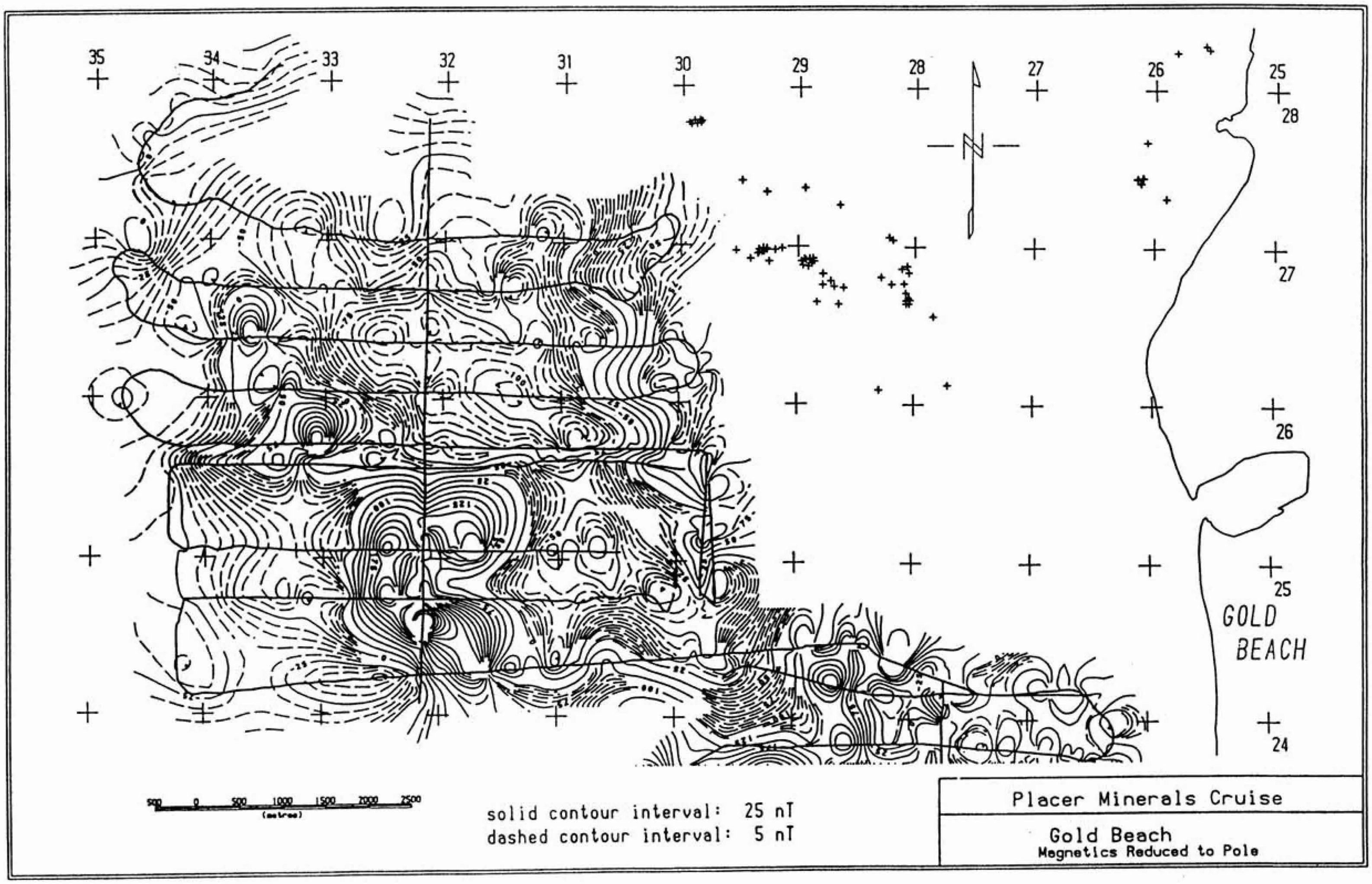



**FIGURE 2.15. MAGNETIC ANOMALIES REDUCED TO POLE, GOLD BEACH WEST**

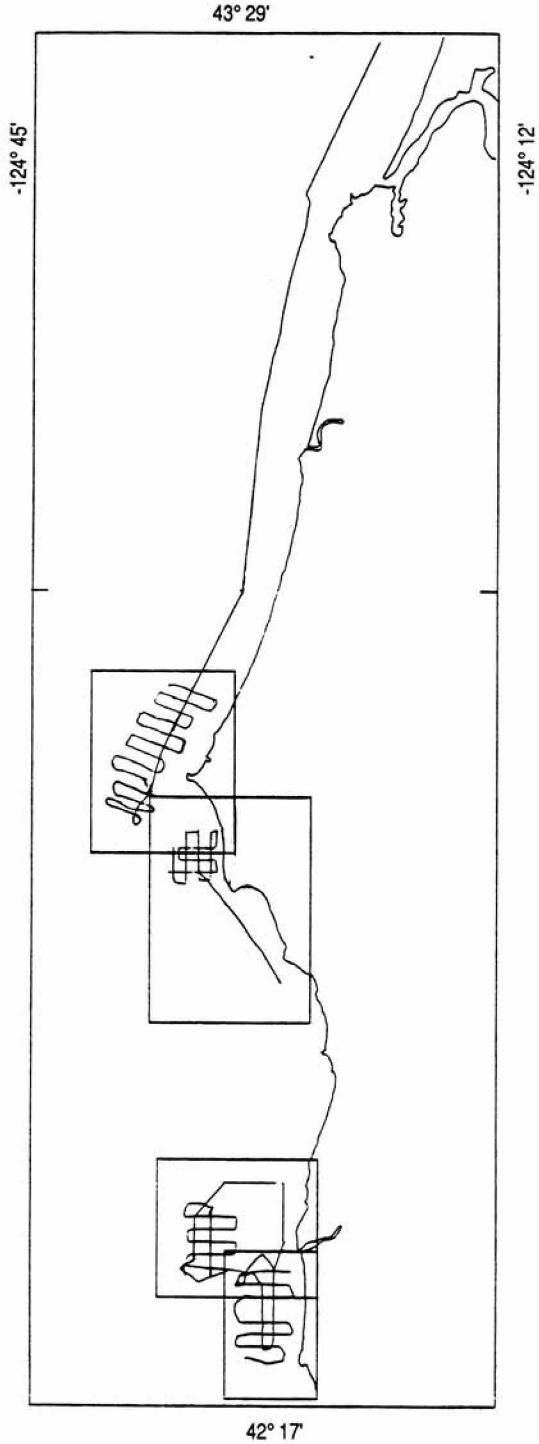



**FIGURE 2.16. SEISMIC LINES, GOLD BEACH TO COOS BAY**

0 25 km

0 15 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.1800°

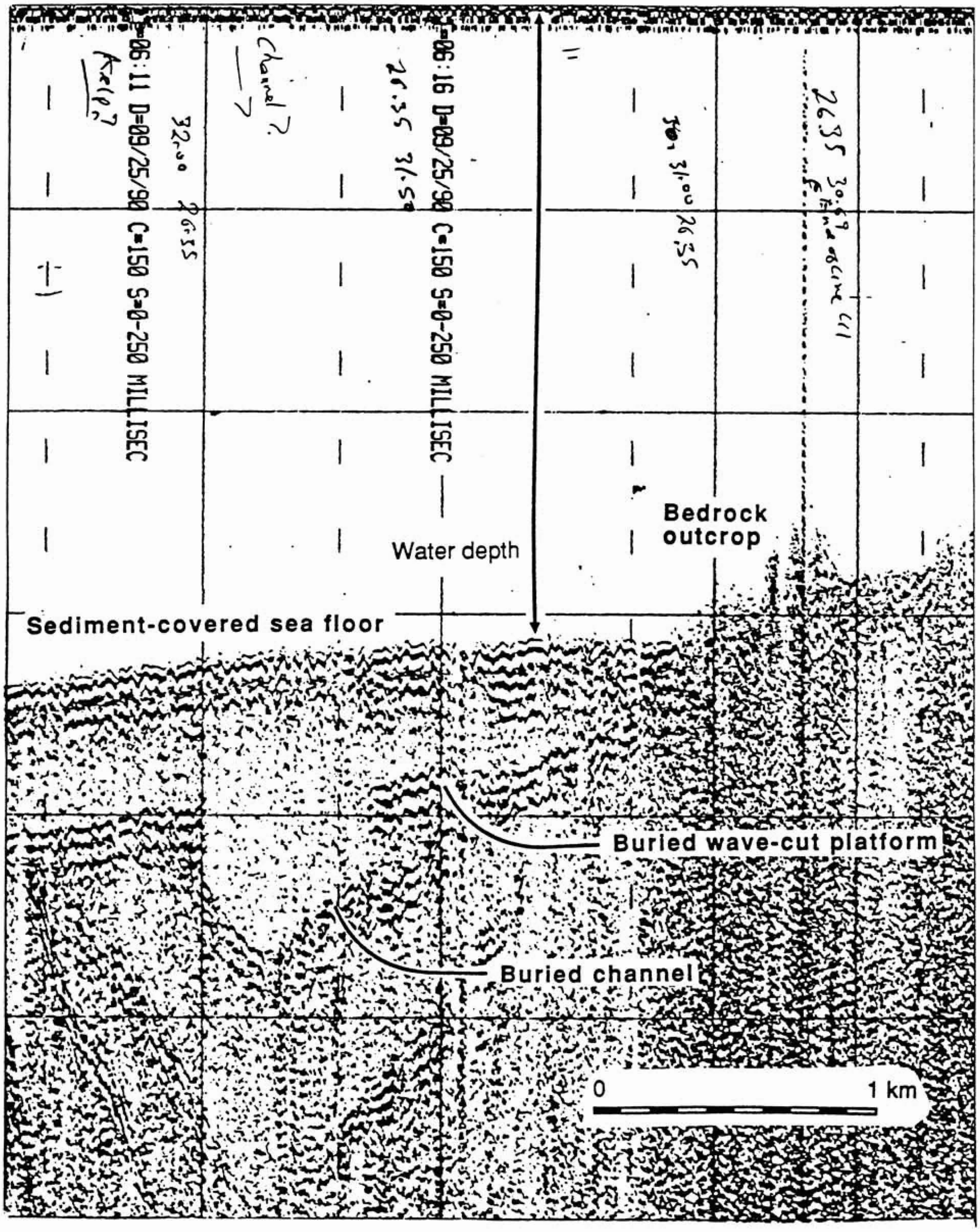



FIGURE 2.17. PORTION OF A HIGH-RESOLUTION SEISMIC PROFILE, GOLD BEACH WEST

broad sonic pulse of 175 J at a 0.25 second repetition rate, (2) one Datasonics Bubble Pulse System composed of a Model BPS-530 Bubble Pulser Power Supply, a model BPV-520 Sound Source producing a narrow sonic pulse of 30 J, centered at 400 Hz, at a 0.25-second repetition rate, and (3) a Model BPR-510 Bubble Pulser Receiver.

The seismic power supply units were run on the ship's electrical supply (220 and 110 v). The sound source plates were deployed on a catamaran (ORE plates) and a modified surfboard (Bubble Pulse) separated by about 5 m, at a towed distance of 10 m behind the ship's stern. A Benthos hydrophone, with 30 elements, over a 5 m active section, was towed at a distance of about 30 m astern the ship, between the sound sources. The incoming signal was filtered with high and low band pass filters to include only frequencies between 500 and 3,000 Hz. The incoming signal was recorded digitally and by analog EPC recorders at 0.25 second sweep rates. All records were annotated for time (generally at 5-minute intervals) and infrequently for the ship's position from the navigation system display terminal in the ship's lab.

The resulting seismic records are of high quality, allowing for the completion of stated objectives above. Initial interpretations of seismic profiles in the Cape Blanco (Figs. 2.18 and 2.19) and Rogue River (Figs. 2.20 and 2.21) target areas during the cruise contributed to the selection of coring and biological trawl sites.

### 2.2.3. Side-scanning sonar surveys

The side-scanning sonar systems deployed from the M/V Aloha included a Klein 531 system and an EEG 272 system as backup. Each of these systems was used in different places to image the sea floor to a distance of 100 m at either side of the vessel

Side-scanning sonar surveys were conducted in the Cape Blanco West (Fig. 2.22) and Cape Blanco South (Fig. 2.23) areas to identify sea floor rock outcroppings and bottom sediment texture in advance of biological trawling in these areas. A total of 188 km of side-scanning sonar trackline was completed on the cruise.

### 2.2.4. Geological Sampling

Sampling during the cruise included material from the surface and from within the sediment column. Samples of surficial sediment were collected using a 0.1 $m^2$ Smith-McIntyre grab sampler, primarily for examination of benthic biology, but also to provide samples for mineralogic comparison with those taken previously in the same locations and for heavy metals analysis. Small plastic square petri

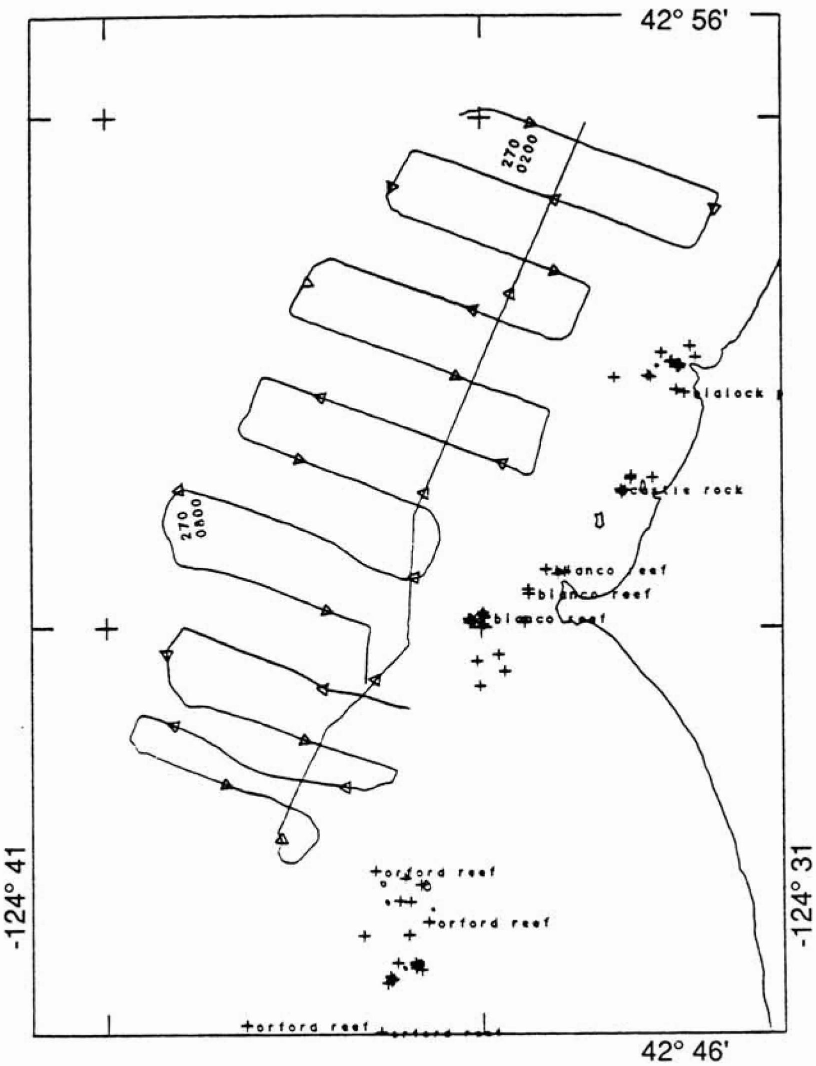



**FIGURE 2.18. SEISMIC LINES, CAPE BLANCO WEST**

MAP SCALE 1:125,000

0 10 km

0 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

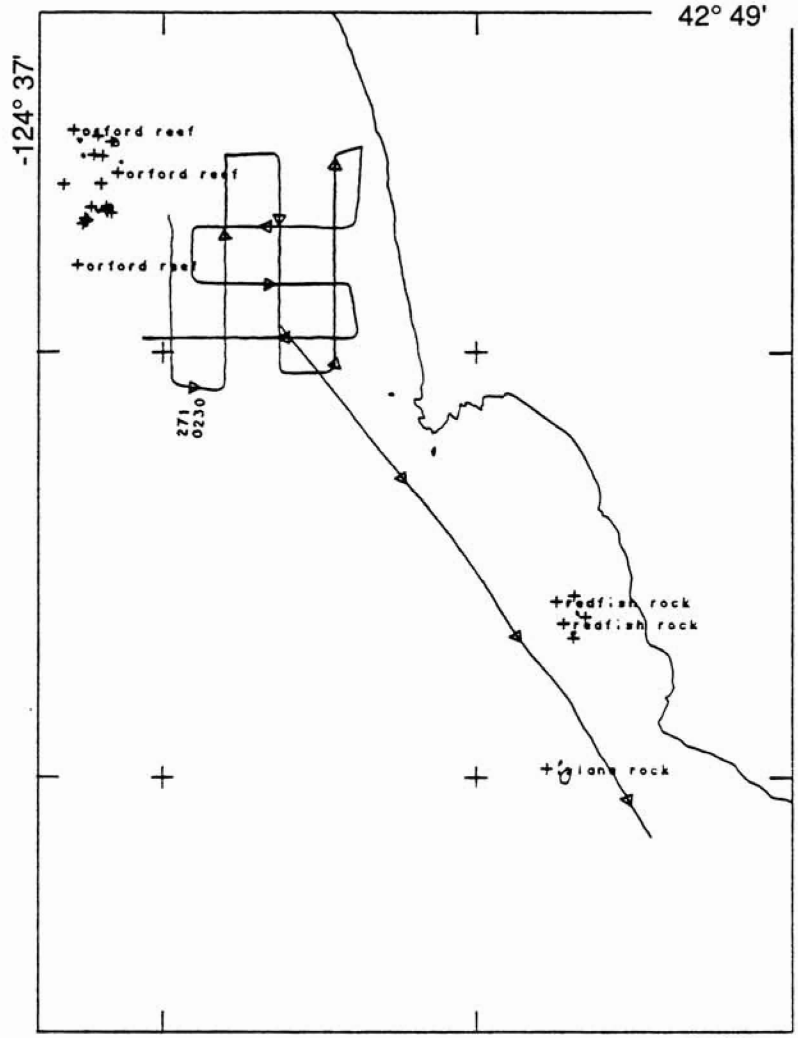



**FIGURE 2.19. SEISMIC LINES, CAPE BLANCO SOUTH**

MAP SCALE 1:150,000

0 10 km

0 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

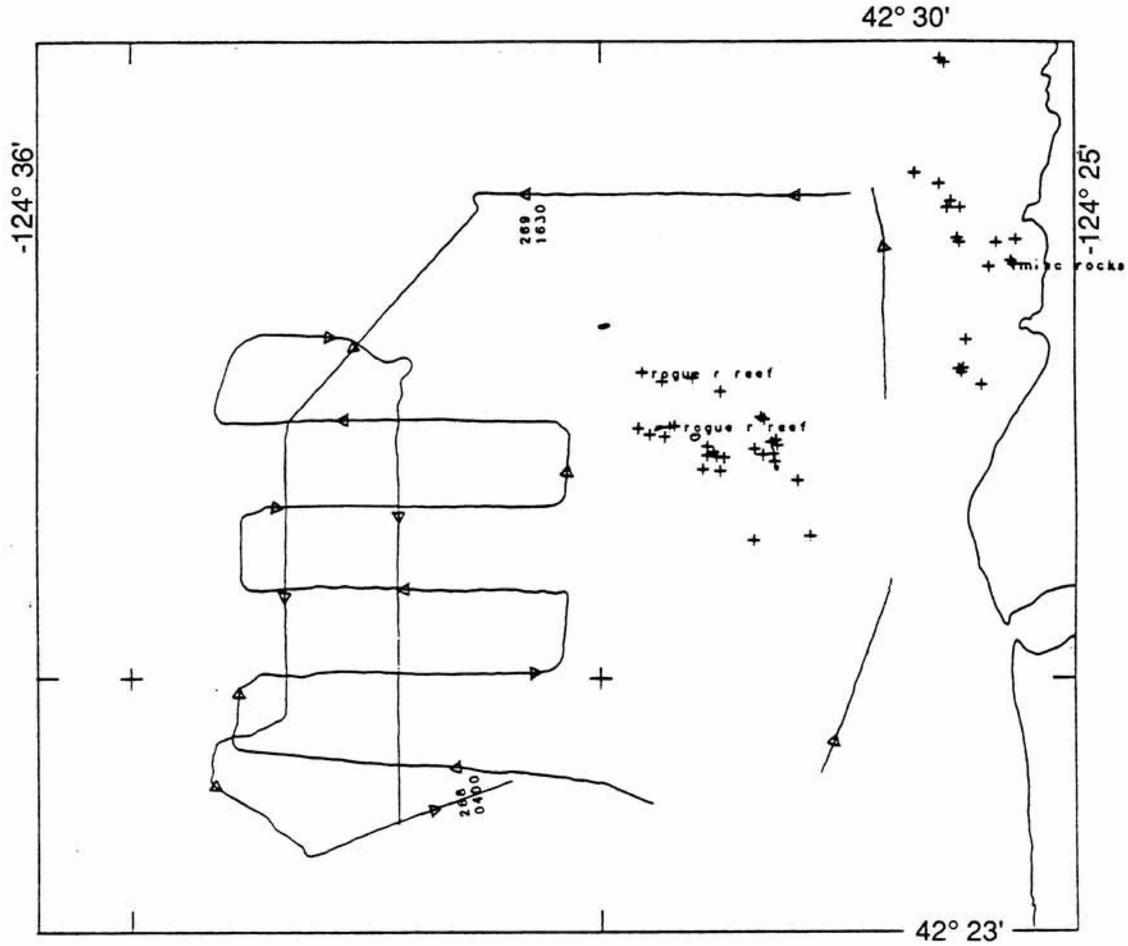



**FIGURE 2.20. SEISMIC LINES, GOLD BEACH WEST**

MAP SCALE 1:100,000

0 10 km

0 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.5000°

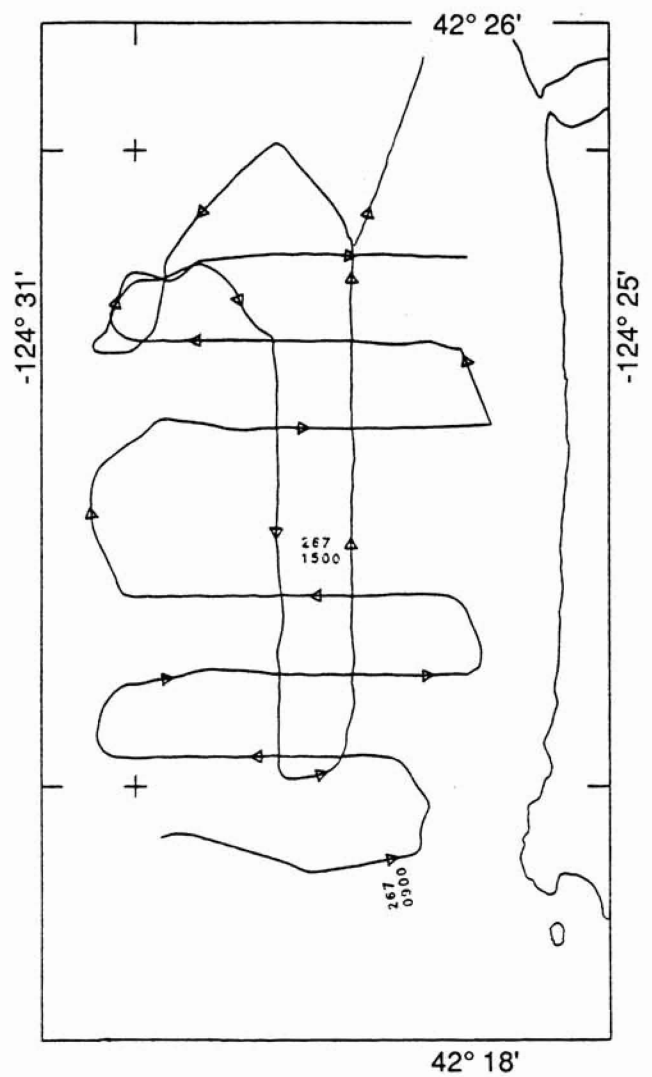



**FIGURE 2.21. SEISMIC LINES, GOLD BEACH SOUTH**

MAP SCALE 1:100,000

0 10 km

0 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.5000°

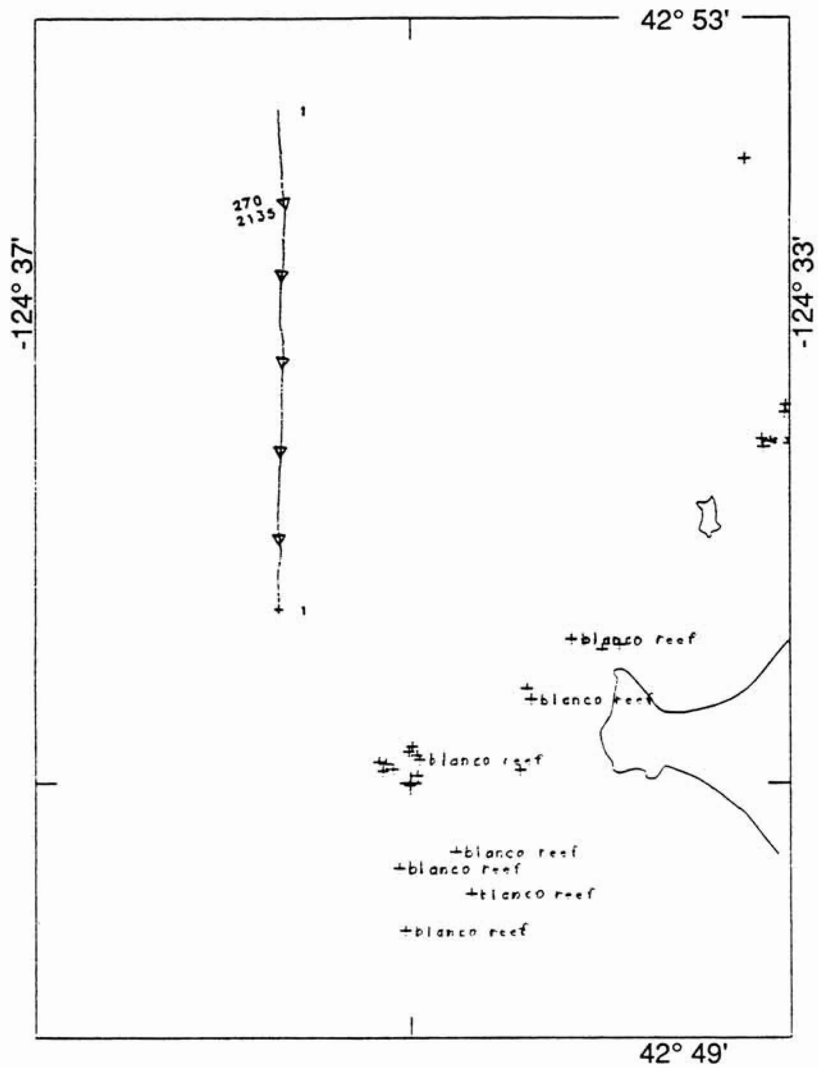



**FIGURE 2.22. SIDESCANNING SONAR LINES, CAPE BLANCO WEST**

MAP SCALE 1:50,000

0 5 km

0 3 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

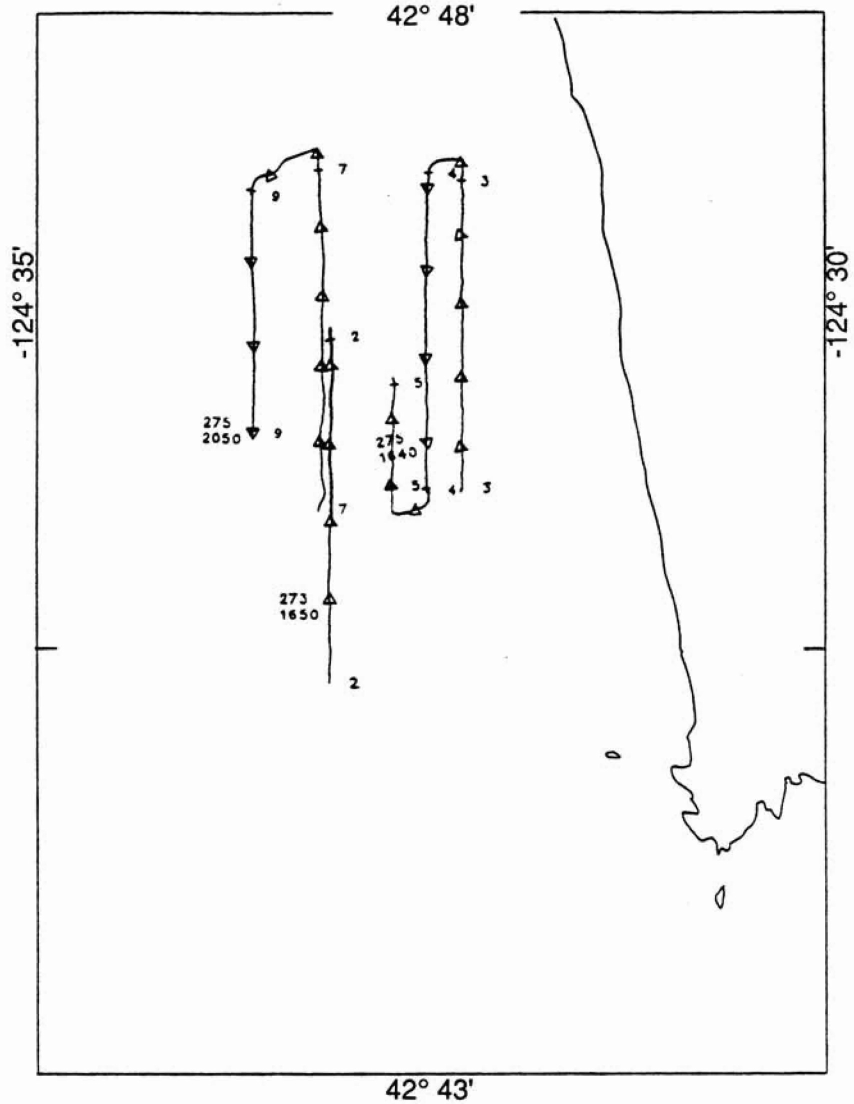



**FIGURE 2.23. SIDESCANNING SONAR LINES, CAPE BLANCO SOUTH**

MAP SCALE 1:60,000

0 5 km

0 3 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

dishes, approximately 10 cm square and 1.5 cm thick, inserted into the surface of the sand within the Smith-McIntyre sampler provided small intact slabs of the sand near the sea floor with could be used to identify active depositional processes.

Both vibracore and vibalift systems were used in attempts to sample the sediment column. The location of all samples taken in the Cape Blanco West target area are shown in Figures 2.24 through 2.31, in the Cape Blanco South target area in Figures 2.32 through 2.34, and in The Gold Beach South target area in Figures 2.35 through 2.38.

Technical support for the drill sampling program was provided by the Marine Minerals Technology Center, Continental Shelf Division (MMTC/CDS), University of Mississippi. The MMTC/CSD considered several factors in selecting the appropriate drill system for the sampling phase of this project. These factors included the severe sea conditions possible on the Oregon coast, the probable sediment characteristics based on knowledge of onshore deposits, and the characteristics of the project vessel M/V Aloha. Limited funding was available for this drill sampling program.

The system chosen for the project was a pneumatically powered, convertible vibralift/vibracore drill, an MMTC/CSD design equipped with a unique drill feed drive. The vibralift/vibracore drill can be used in two different modes, as either a vibracore device where a continuous core of relatively undisturbed sediment can be recovered, or as a vibralift system where a slurry of sediment and water over discrete depth intervals is recovered. The drill feed is able to assist in penetration in either configuration with an available pulldown force of about 1,100 kg (2,500 lbs.), and, with the aid of vibration, it is also able to remotely extract the barrel from sediment. This semi-remote operation of the drill using the feed system permits use of the vibralift/vibracore drill in rougher sea conditions than is possible with most conventional sampling devices.

The vibralift/vibracore drill, capable of sampling to 6 meters (20 feet), has a self-supporting frame and a NAVCO BH-8 pneumatic vibrator mounted to the barrel as the principal drive component for penetration of sediment. The drill frame is constructed with a center guide beam mounted to a heavy steel base (about 680 kg, 1,500 lbs.) and supported by four guy wires (Fig. 2.39). Total weight of the system is approximately 1,600 kg (3,500 lbs.). The guide beam consists of a modified feed system of an Ingersoll-Rand Crawlair rock drill; this pneumatically powered, chain driven feed system allows the vibralift/vibracore barrel to be raised or lowered along the guide beam with a force of about 1,100 kg (2,500 lbs.).

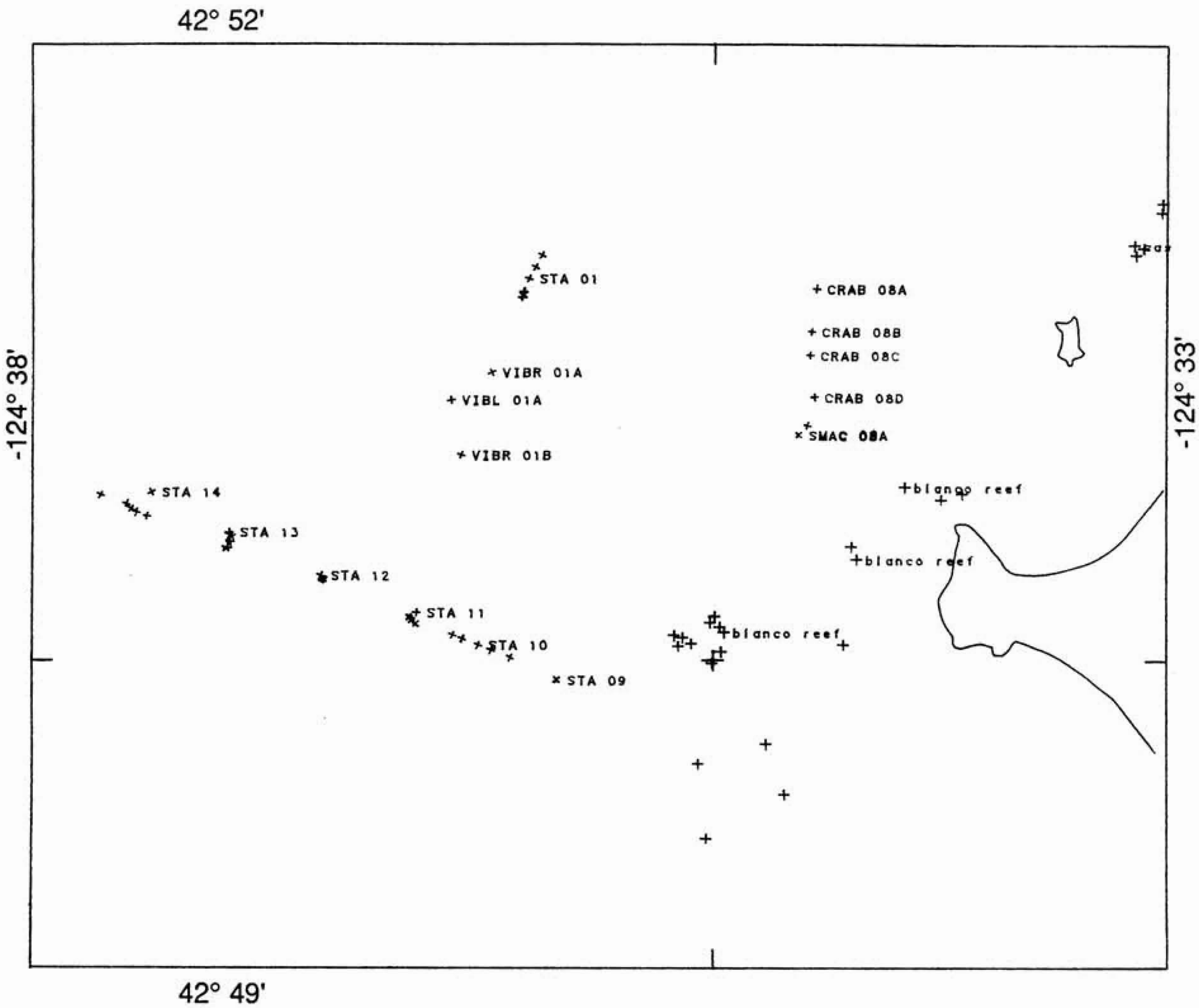



**FIGURE 2.24. SAMPLE STATIONS, CAPE BLANCO WEST**

MAP SCALE 1 : 40,000

1 0 3 km

1 0 2 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

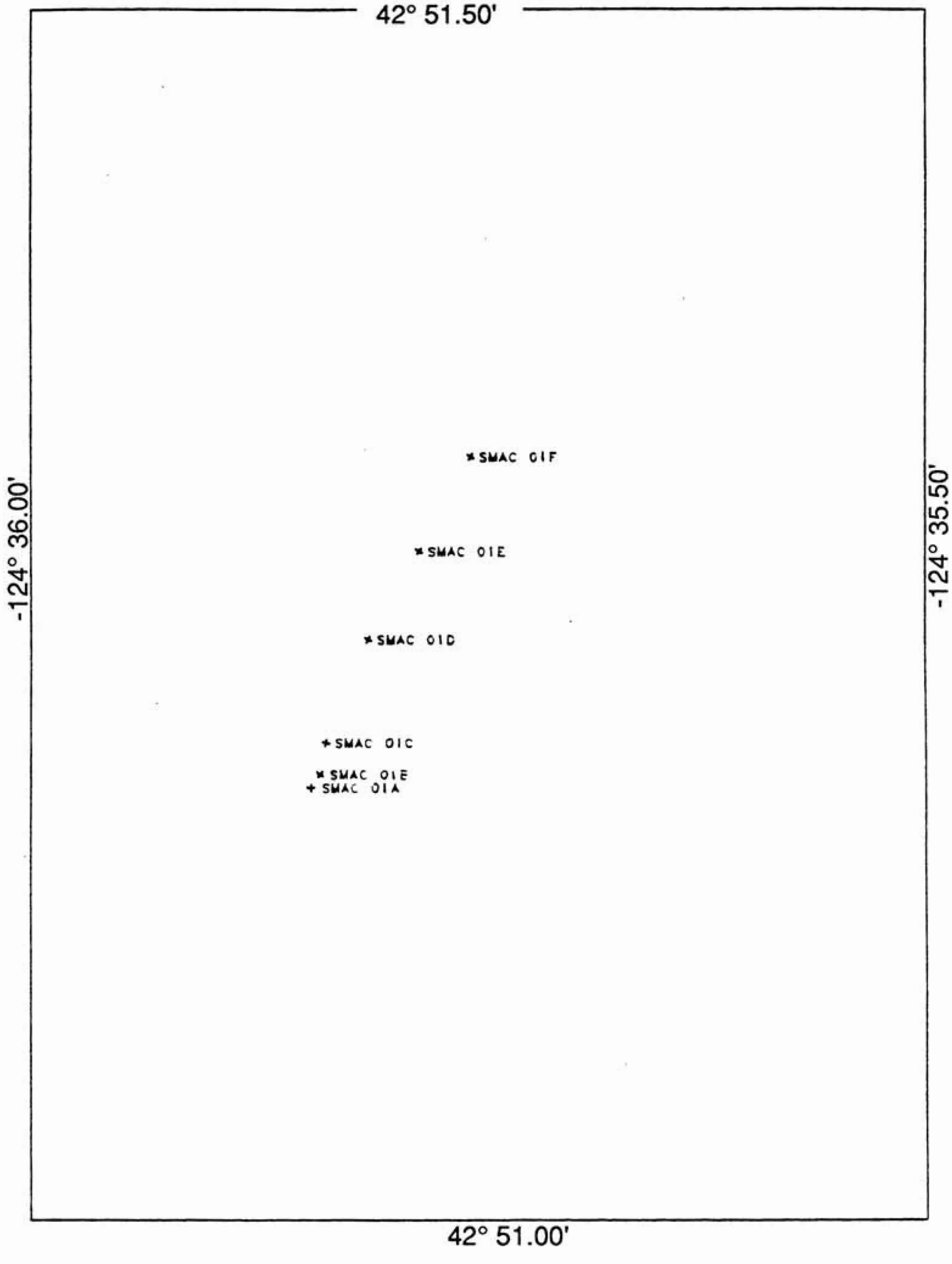



**FIGURE 2.25. SAMPLE STATION 1, CAPE BLANCO WEST**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

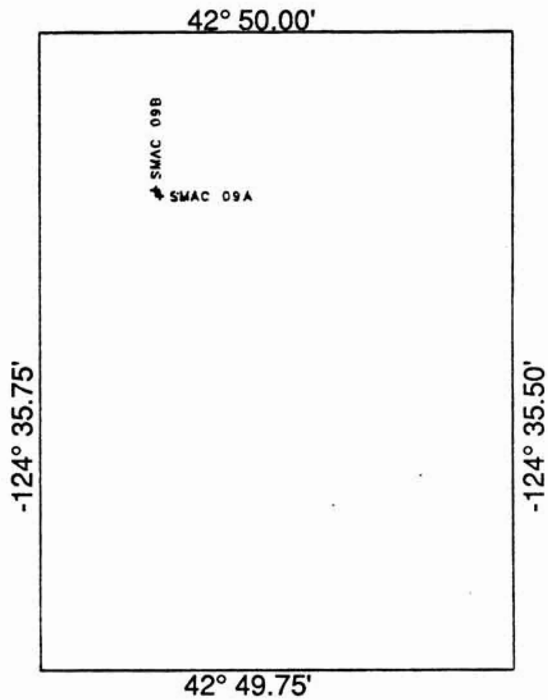



**FIGURE 2.26. SAMPLE STATION 9, CAPE BLANCO WEST**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION

STANDARD PARALLEL = 42.7833°

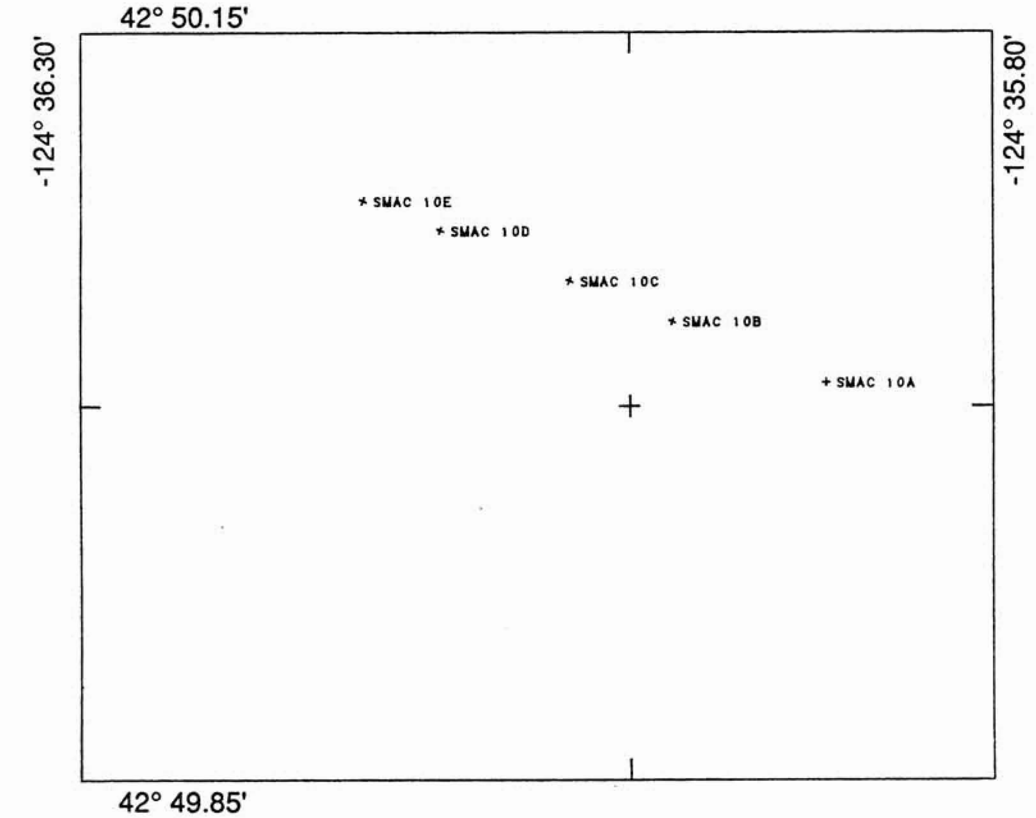



**FIGURE 2.27. SAMPLE STATION 10, CAPE BLANCO WEST**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

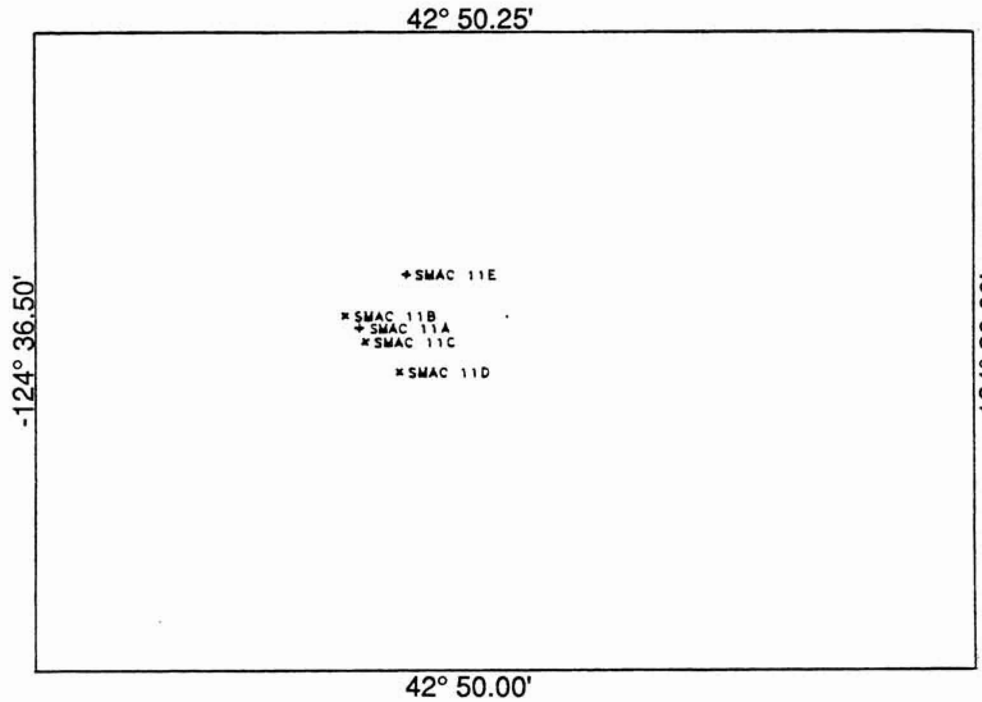



**FIGURE 2.28. SAMPLE STATION 11, CAPE BLANCO WEST**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION

STANDARD PARALLEL = 42.7833°

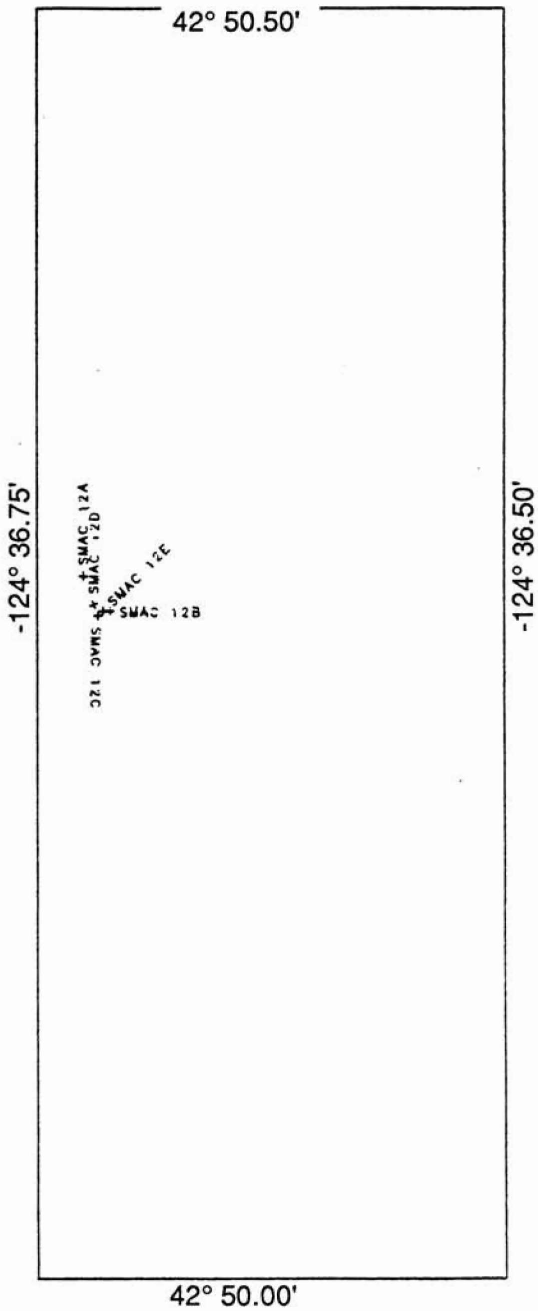



**FIGURE 2.29. SAMPLE STATION 12, CAPE BLANCO WEST**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

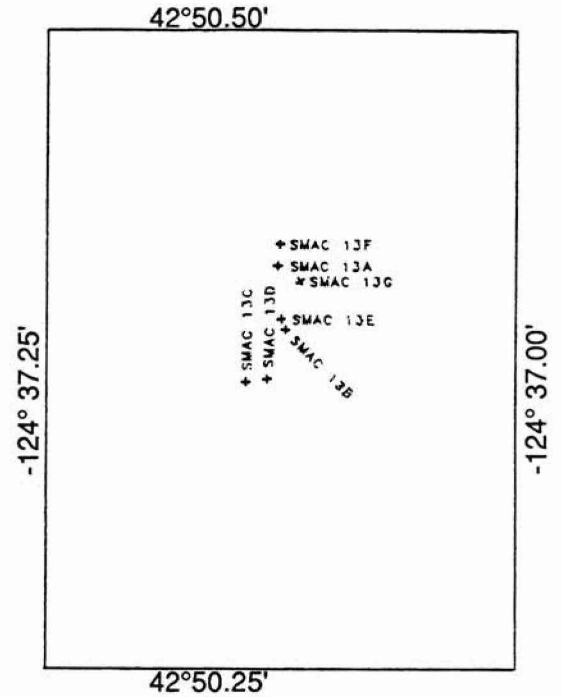



**FIGURE 2.30. SAMPLE STATION 13, CAPE BLANCO WEST**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION

STANDARD PARALLEL = 42.7833°

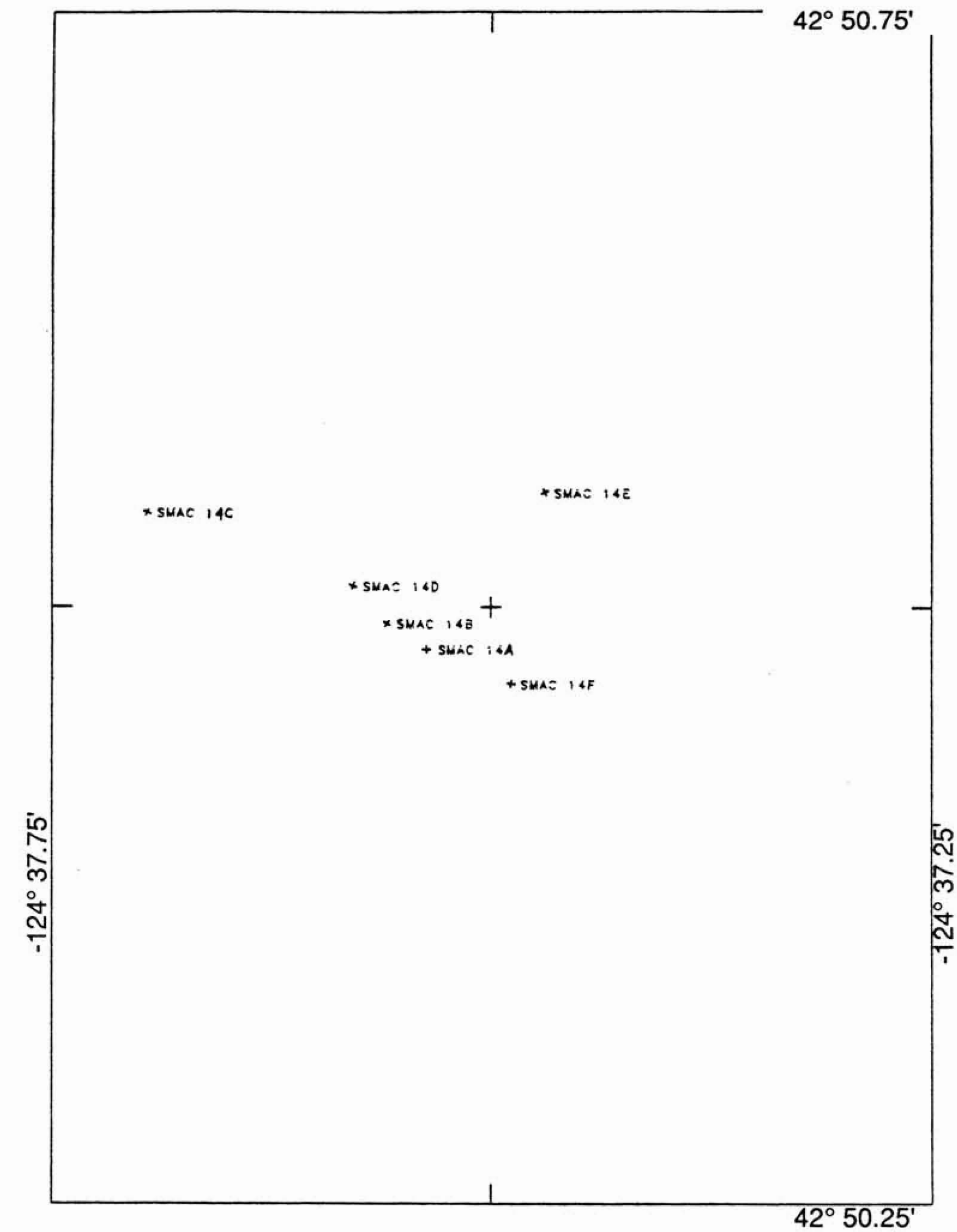



**FIGURE 2.31. SAMPLE STATION 14, CAPE BLANCO WEST**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

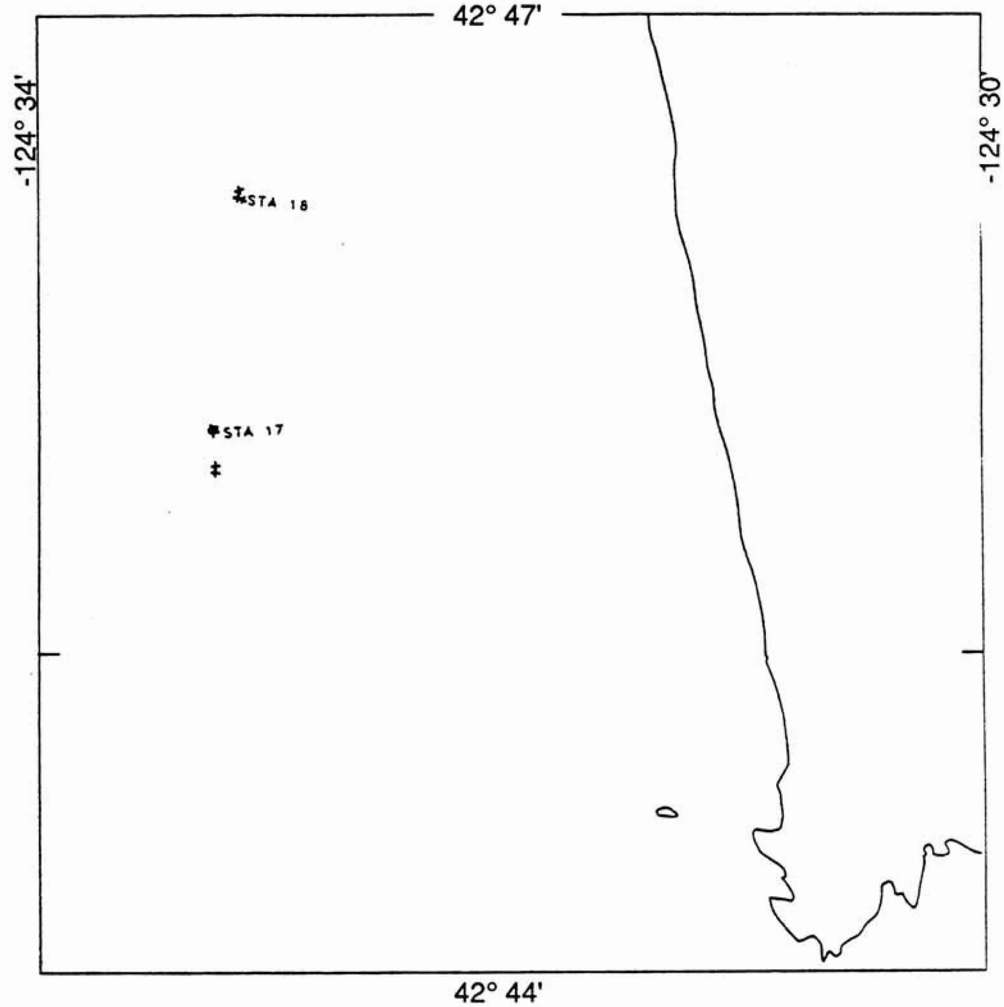



**FIGURE 2.32. SAMPLE STATIONS, CAPE BLANCO SOUTH**

MAP SCALE 1 : 40,000

1 0 3 km

1 0 2 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.7833°

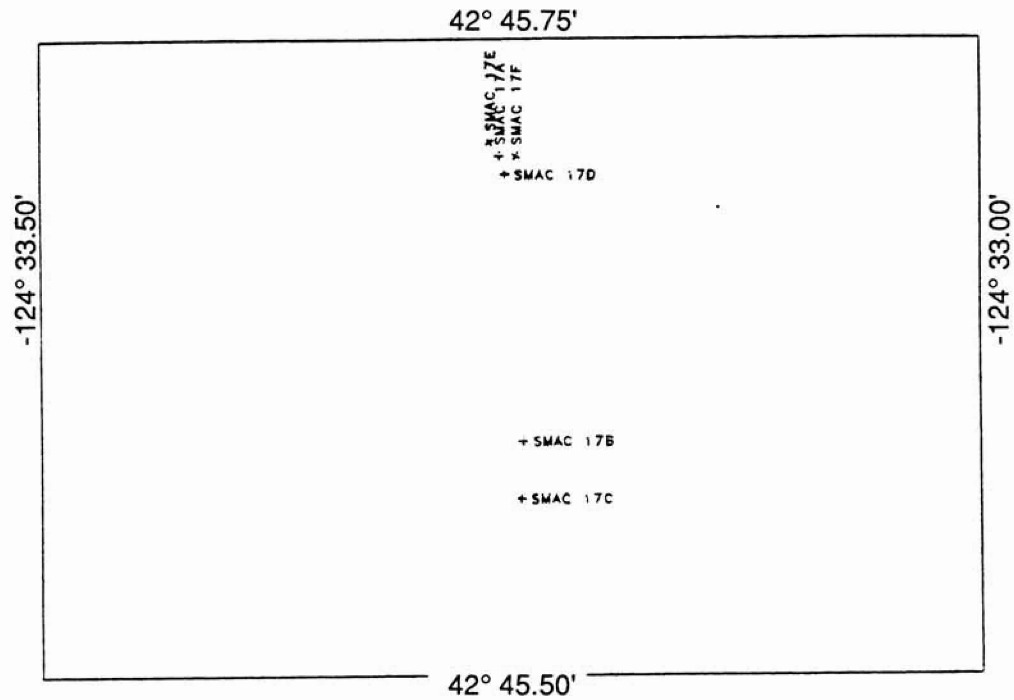



**FIGURE 2.33. SAMPLE STATION 17, CAPE BLANCO SOUTH**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION

STANDARD PARALLEL = 42.7833°

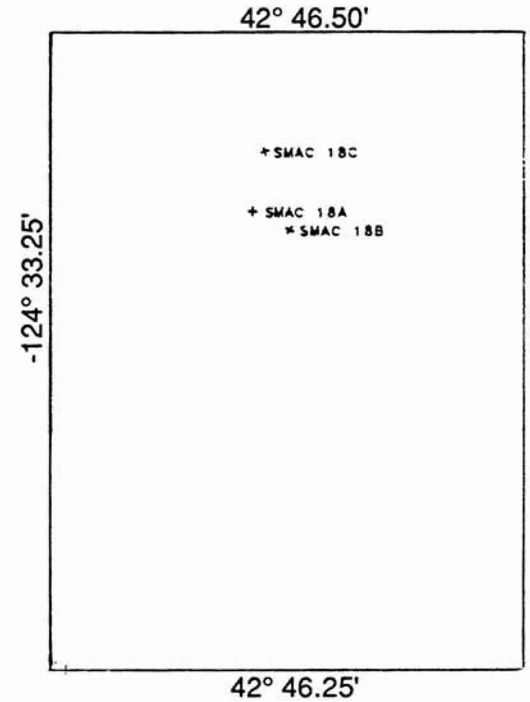



**FIGURE 2.34. SAMPLE STATION 18, CAPE BLANCO SOUTH**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION

STANDARD PARALLEL = 42.7833°

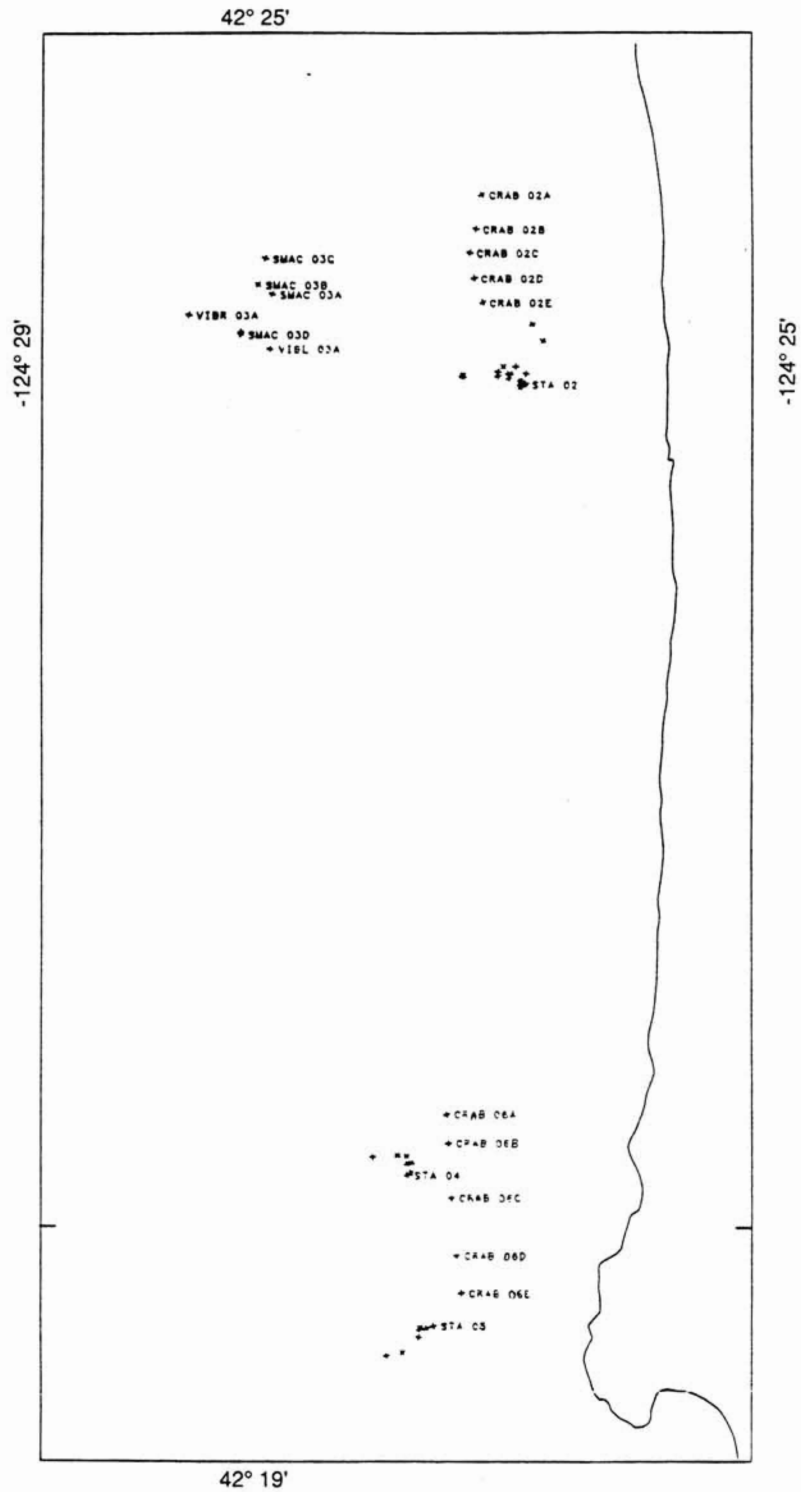
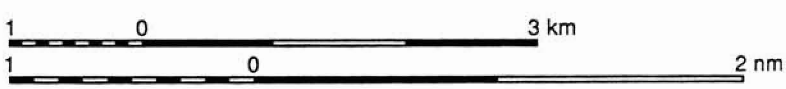



FIGURE 2.35. SAMPLE STATIONS, GOLD BEACH SOUTH.




MERCATOR PROJECTION STANDARD PARALLEL = 42.5000°

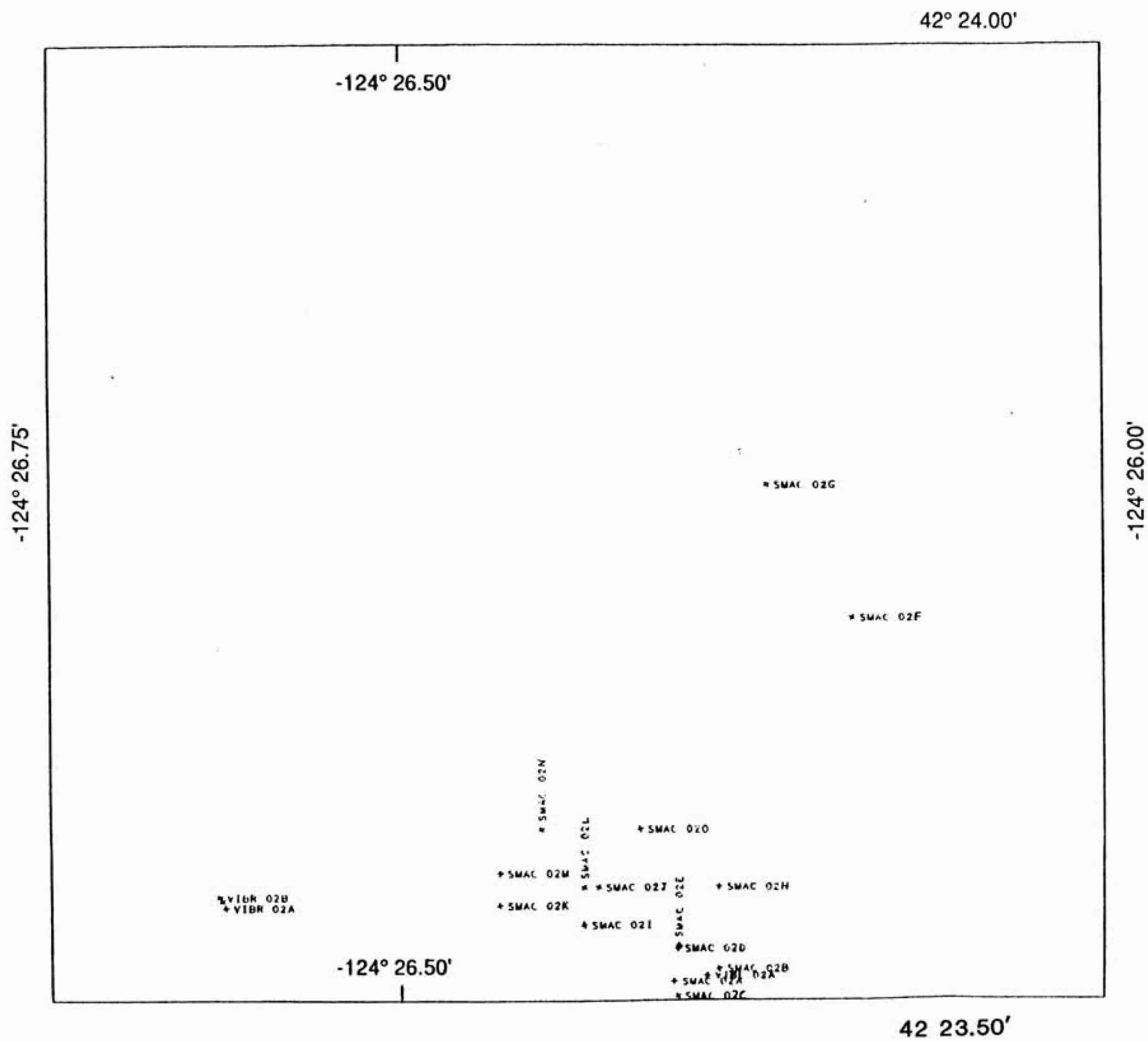



**FIGURE 2.36. SAMPLE STATION 2. GOLD BEACH SOUTH**

100 0 300 m

MERCATOR PROJECTION

STANDARD PARALLEL = 42.5000°

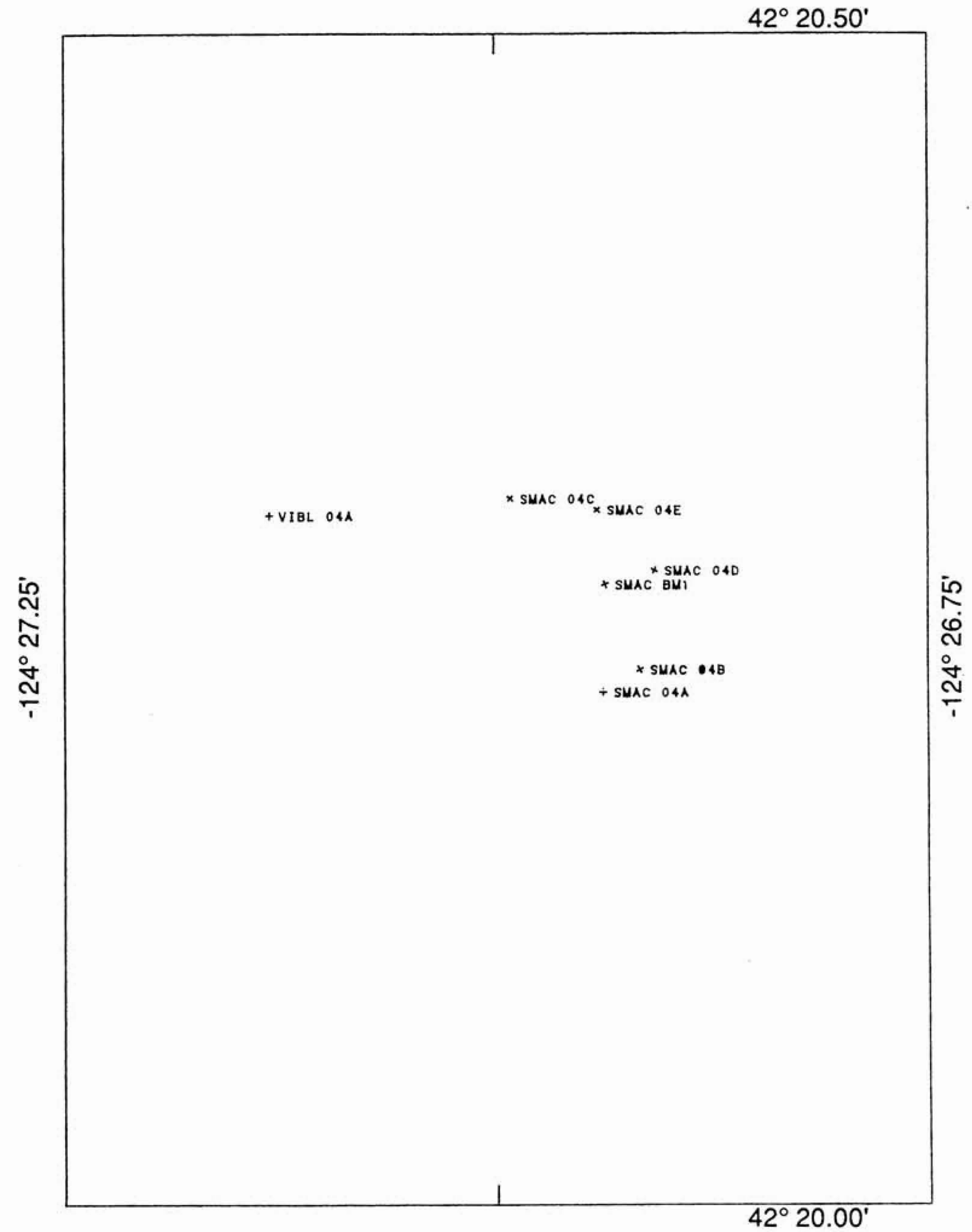



**FIGURE 2.37. SAMPLE STATION 4, GOLD BEACH SOUTH**

MAP SCALE 1 : 5,000

100 0 300 m

MERCATOR PROJECTION STANDARD PARALLEL = 42.5000°

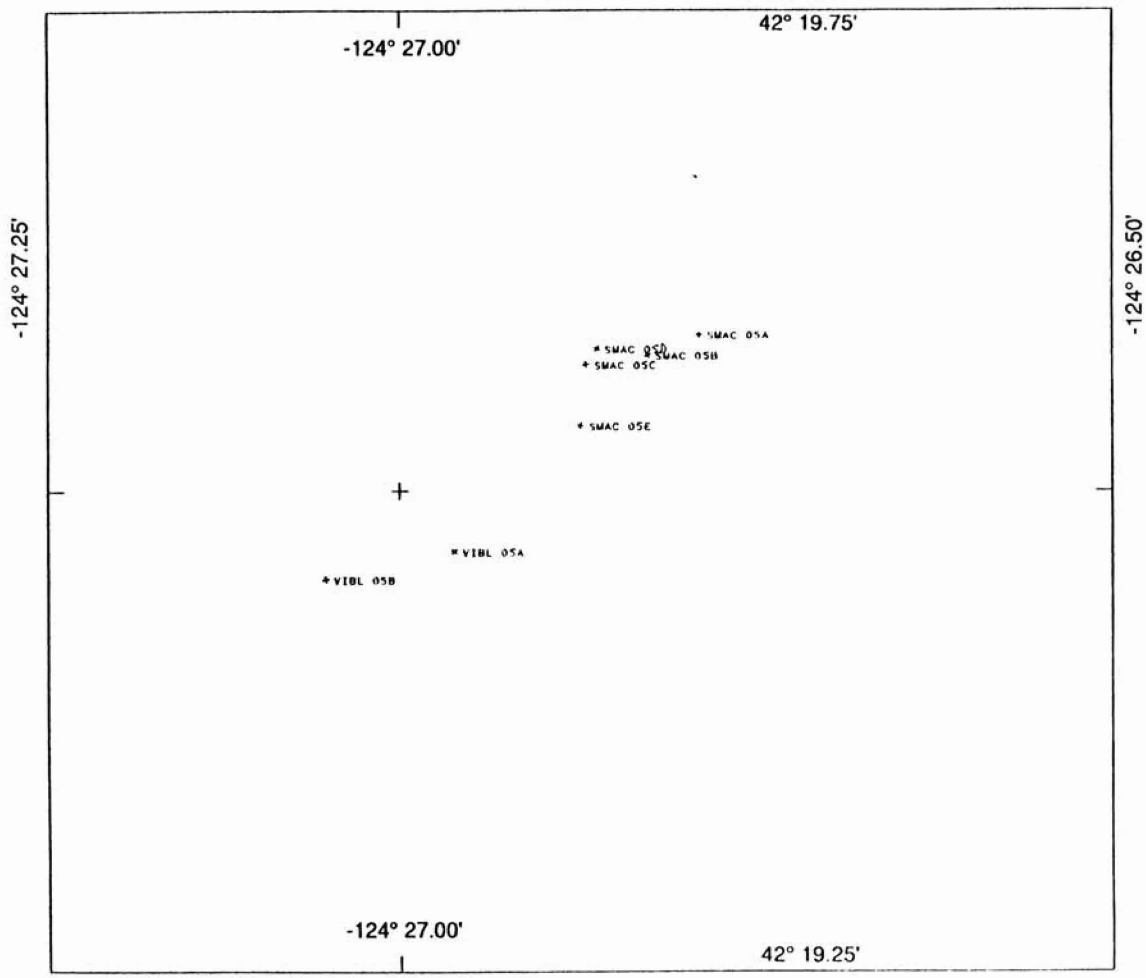



**FIGURE 2.38. SAMPLE STATION 5, GOLD BEACH SOUTH**

100 0 300 m

MERCATOR PROJECTION

STANDARD PARALLEL = 42.5000°

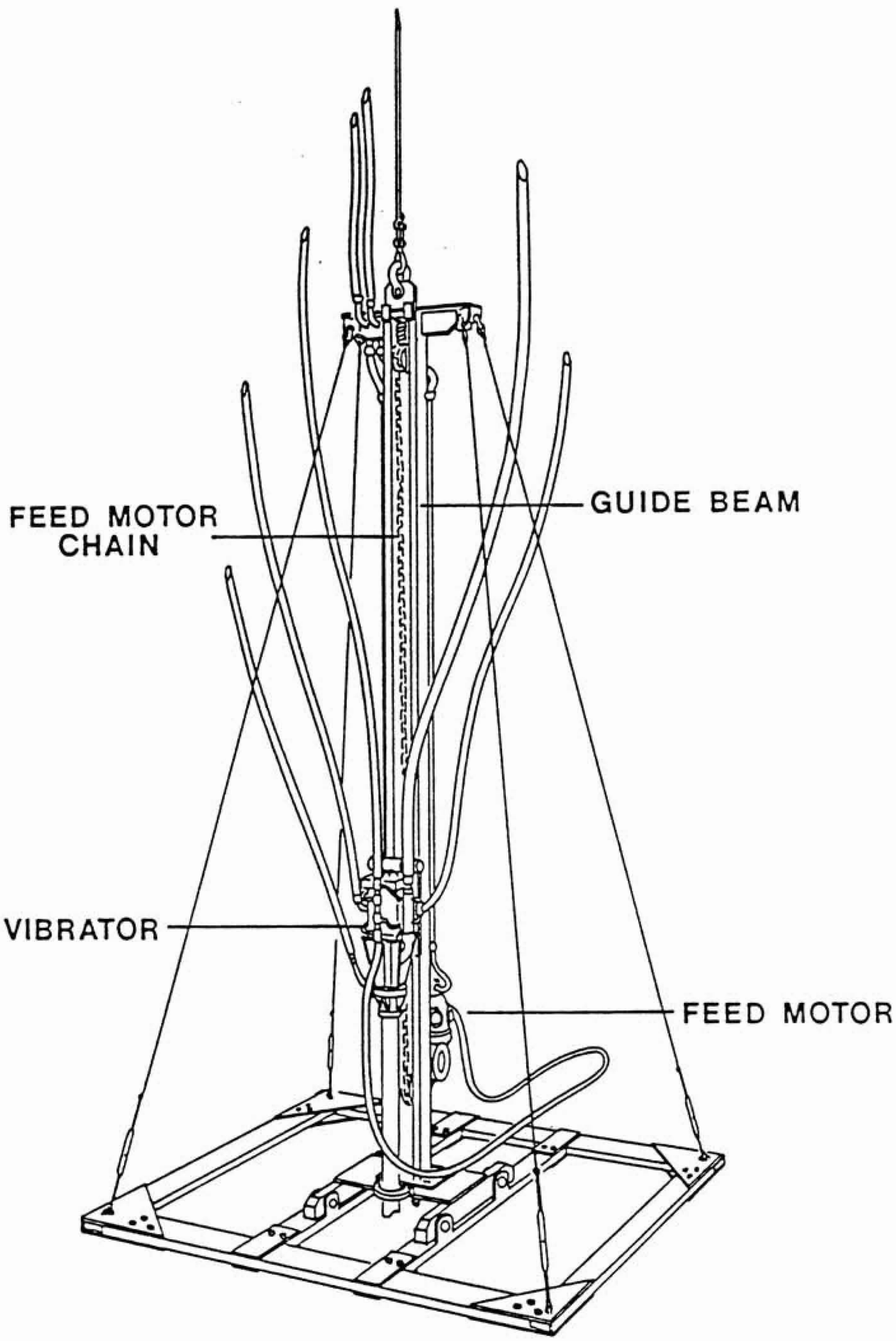



FIGURE 2.39. VIBRALIFT CONFIGURATION

In the pulldown mode, this force provides significant assistance in penetration during vibracoring or vibralifting. The feed system can also aid in the extraction of the barrel from the sediment, although vibration is additionally required since extraction loads may reach as much as 3,600 kg (4 tons). As vibration is detrimental to the recovery of unconsolidated samples, the full capability for remote extraction exists only when operating in a vibralift configuration.

A transducer from a Raytheon DE-719B recording fathometer, mounted near the top of the barrel, aids in determining the position of the barrel relative to the sea floor. As the system rests on the sea floor prior to the commencement of drilling, the fathometer registers a depth of approximately 6 meters (20 feet), the distance from the top of the barrel to the sea floor. As drilling proceeds, the depth indicated on the fathometer record decreases toward zero as full penetration is approached.

When the system is configured to operate as a vibralift drill, the vibrator is equipped with a dual-walled barrel constructed of standard NW and HW drill casing, 7.6 cm (3 inches) and 10 cm (4 inches) I.D., respectively (Figures 2.39 and 2.40). Water is injected into the annular space of the barrel and enters the interior of the inner barrel through holes drilled in the wall of the inner casing near the cutting shoe. The water flows upward, helping to slurry the sediments and lift them toward the surface. Simultaneously, air is injected into the inner casing through a manifold near the top of the barrel (Figure 2.40). The air rises rapidly upward creating an airlift effect, which raises the slurry of sediment and water through an eductor hose to the surface.

Once the vibralift drill system is lowered from the vessel and reaches the sea floor, air and water pressure are activated, and the feed system is engaged to apply a downward force to the barrel. As the barrel penetrates the subbottom, the slurry is propelled upward and is subsampled at appropriate intervals. Once aboard the vessel, the slurry flows into a dewatering cone where a 70-80% solid sediment mixture can be sampled. The overflow from this cone is directed into a smaller dewatering cone where finer sediment can be sampled. Tests have shown that the dual-cone system is capable of reliably recovering heavy minerals to a size as fine as 200 mesh. Following completion of the sampling, the feed system, with the aid of vibration, is engaged to extract the barrel from the sea floor.

The vibralift drill can be converted for use as a vibracore device in approximately one to two hours (Figures 2.41 and 2.42). The conversion is accomplished by removing the inner

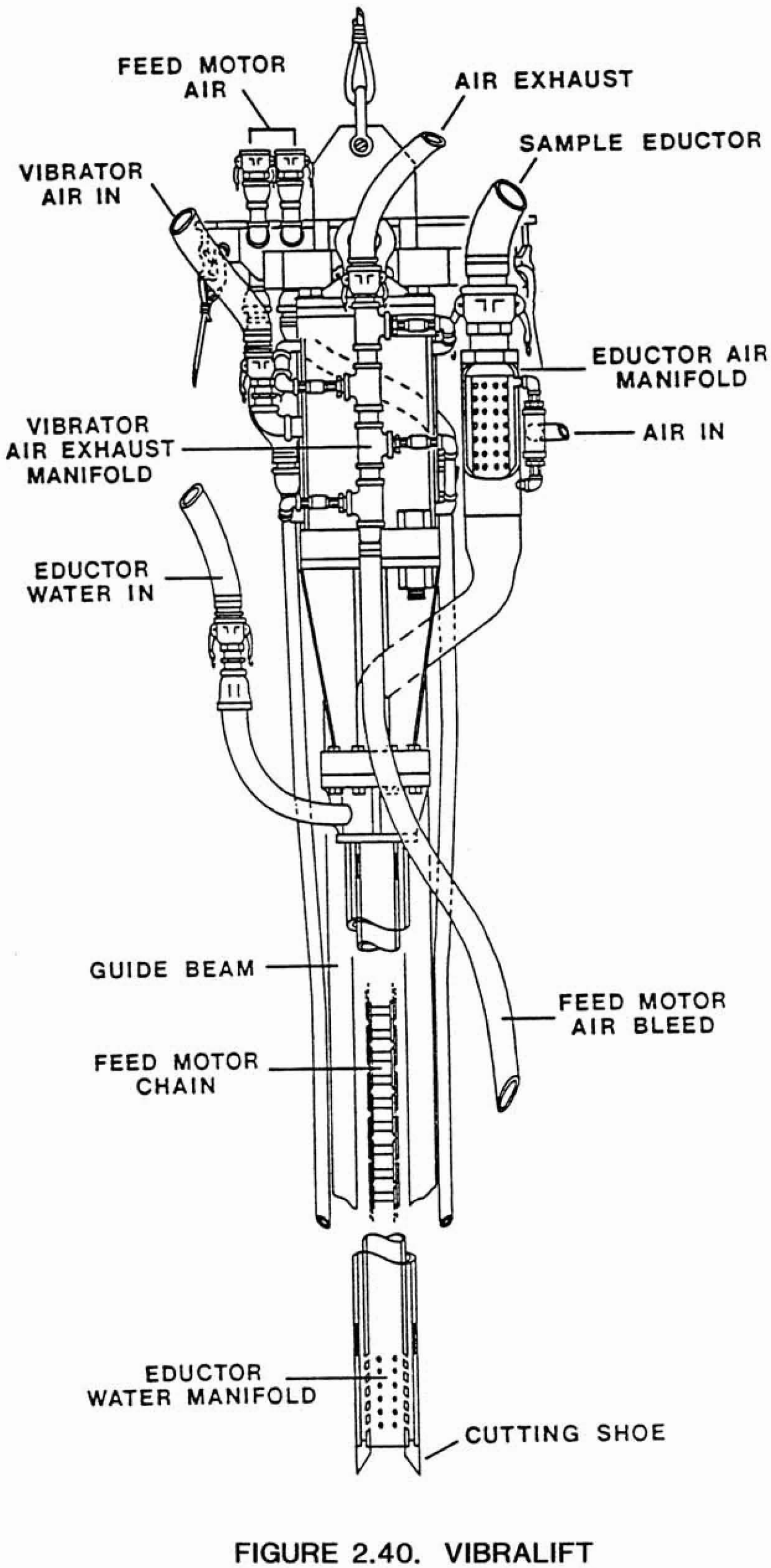



FIGURE 2.40. VIBRALIFT

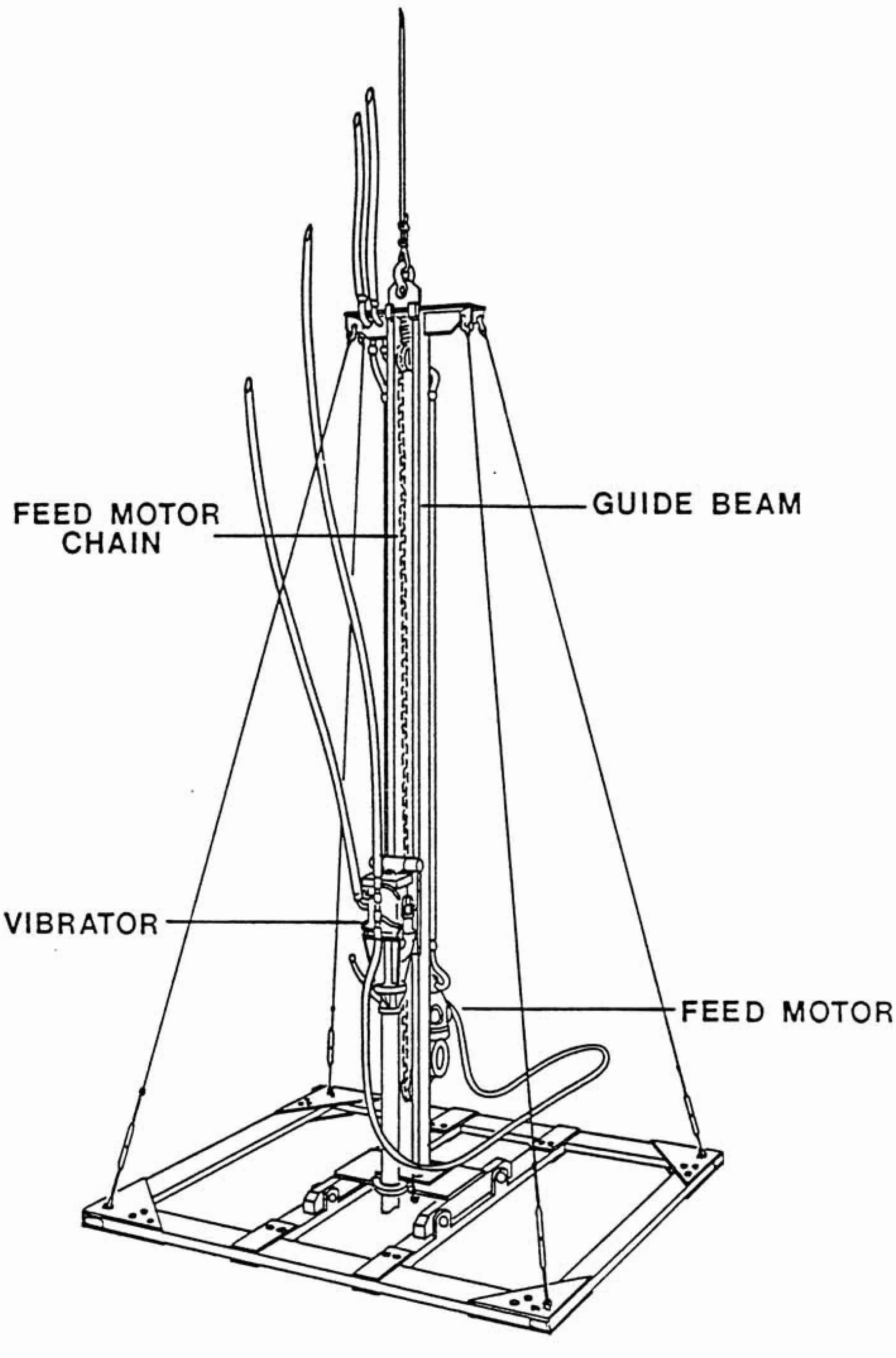



FIGURE 2.41. VIBRACORE CONFIGURATION

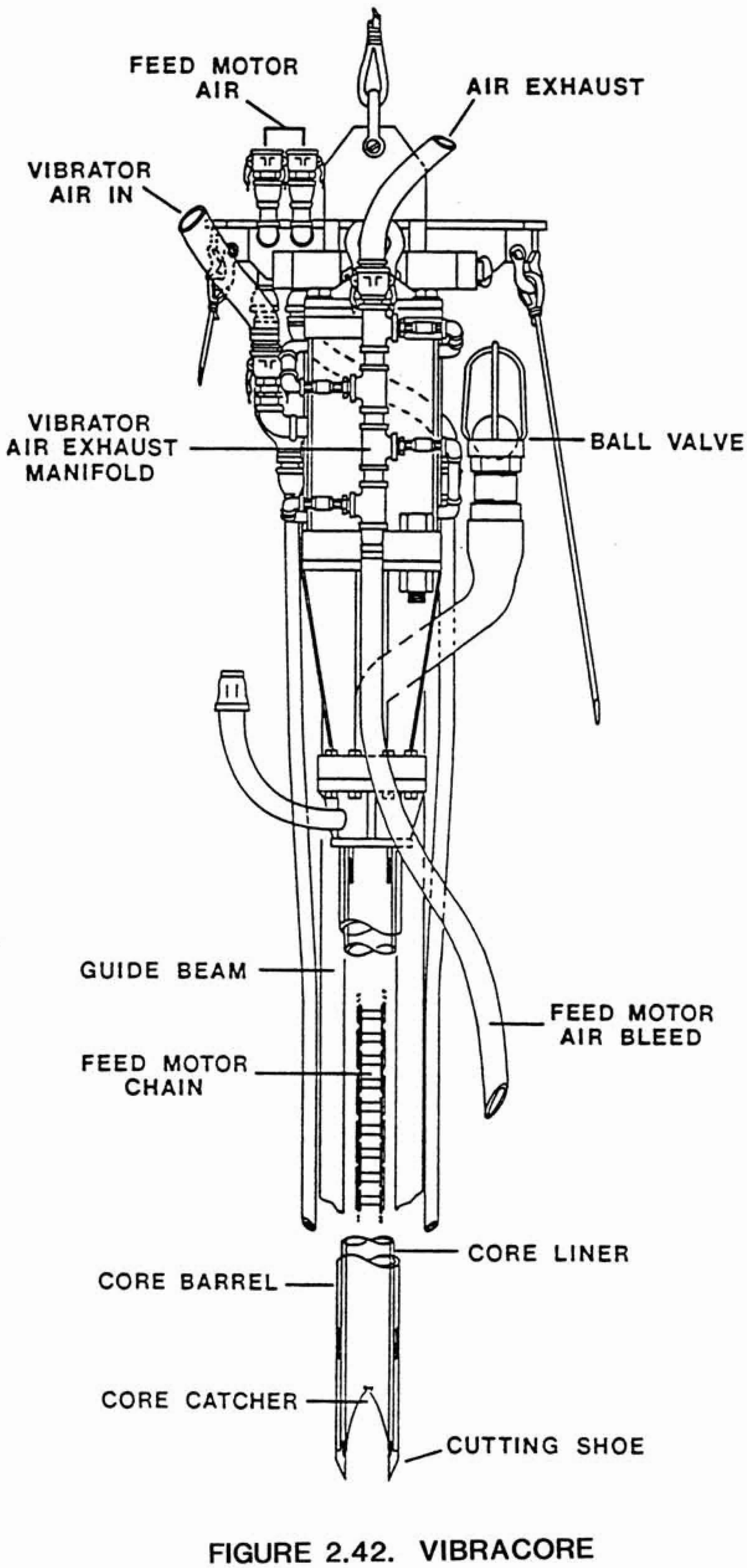



FIGURE 2.42. VIBRACORE

length of NW casing from the dual-walled barrel. The outer length of HW drill casing is retained as the vibracore barrel. A 9.27 cm (3.65 inch) O.D. plastic tube is inserted into the barrel as a core liner, and a core retainer is inserted in its lower end. The liner and retainer are then secured in place by screwing a cutting shoe onto the end of the barrel. The final step is to replace the vibralift air manifold with a ball valve to assist in core retention (Figure 2.42). The vibrator and barrel assembly is attached to the guide beam by means of a hinged plate. The hinge allows the core barrel to be laid across the deck in order to facilitate insertion and removal of core liners.

The pneumatic vibrator provides impact, vibration and weight which combine to fluidize the sediment and assist in driving the barrel downward. The feed system also provides a significant downward drive component as noted earlier. Once penetration ceases, the core retainer and ball valve help to minimize sample loss during extraction and retrieval of the drill system. The vibracore drill is retrieved from the sea floor using shipboard winch power. After the drill is secured to the deck, the core barrel retainer ring is unlatched and the barrel is pivoted forward and lowered to a near horizontal position on the deck. In this position the cutting shoe can be unscrewed and the core retainer and liner can be withdrawn.

The principal problems encountered during the sampling were caused by the rough sea conditions prevalent in the area. Although the vibralift/vibracore drill system is capable of semi-remote operation, the drill ship must remain within a 10-m (30-foot) radius of the drill site. In calmer waters, the ship was able to maintain its position over the site using the bow thrusters and main engine. In harsher weather, it is generally necessary to anchor into the dominant vector of wind or current from the bow and use a stern anchor or thruster to maintain position on the arc of the bow anchor. Unfortunately, the M/V Aloha was not configured for this mode of operation.

During the initial tests of the vibracore drill offshore of the Rogue River, the vessel drifted off site and the lower 10-foot section of the vibracore barrel was broken off at the joint. As the ship's crew became more familiar with the drilling procedure, several sites in this area were sampled using the vibralift drill. Two attempts were made to drill in the rougher sea conditions and strong currents off Cape Blanco, but on both occasions the ship was unable to hold position. On the second attempt, the drill was able to penetrate two meters, but the ship shifted off position and the eductor hose parted.

A significant problem with the drill system design was the large number of air supply and exhaust hoses required to operate the various drill functions (six hoses are needed to control the vibralift and four are required for the vibracore). In water depths greater than 15 meters (45 feet), the hoses became very difficult to handle. A solution to this problem would be the use of a hose reel in shallow water or conversion of the system to a remotely operated electro-hydraulically powered system for deeper operations.

An added difficulty was the necessity to mobilize and demobilize the heavy drill to provide space for the other research activities during the cruise. This resulted in lost time and crew fatigue. Ideally, a drill of this size is secured to the stern using chain binders so that the forward edge of the base of the drill frame is wedged between two pipe studs welded to the stern. As the drill is retrieved, it is guided between the studs where it is wedged into place and prevented from swinging. In this position, the drill can be rapidly re-deployed by releasing the chain binders and letting out the winch cable.

## 2.3. Results and Discussion

### 2.3.1. Magnetometer Surveys

Close examination of the profiles of the magnetic data shows regular oscillations with a wave length of 20 to 60 meters and peak-to-peak amplitudes of one to ten nT. Such oscillations probably result from the movement within the swell of the buoy attached to the sensor. The wavelength of the oscillations changed when the ship changed course and the oscillations were larger in the later surveys when the seas were larger. The presence of these oscillations limits the resolution of the magnetic data for detecting magnetic anomalies of small-amplitude

The largest magnetic anomalies, with amplitudes as large as 500 nT were found in the Gold Beach South survey area at approximately 42° 23' North, 124° 30' West (Fig.2.14). The presence of such anomalies in prior surveys in this area had been tentatively attributed to concentrations of magnetite in the sediment beneath the sea floor. Seismic profiles, however, show that some of these anomalies coincide with nearsurface and outcropping rock on the sea floor, suggesting that the source of the large magnetic anomalies lies in bedrock at or near the sea floor. Moreover, a subtle change in the magnetic fabric on the shelf in the Gold Beach south area approximately coincides with the contact between Jurassic volcanic/sedimentary melange and Cretaceous sedimentary rocks (Jo and Ku, respectively, on Figure 2.14). Most of the prominent magnetic anomalies in the survey areas are accordingly interpreted as resulting from near-surface bedrock.

Earlier geological models considered some of the previously-observed concentrations of heavy minerals on the sea floor to be derived from fossil beaches. Comparison with modern beaches provides a basis for estimating the thickness, general geometry and grade of possible beach placer deposits beneath the sea floor.

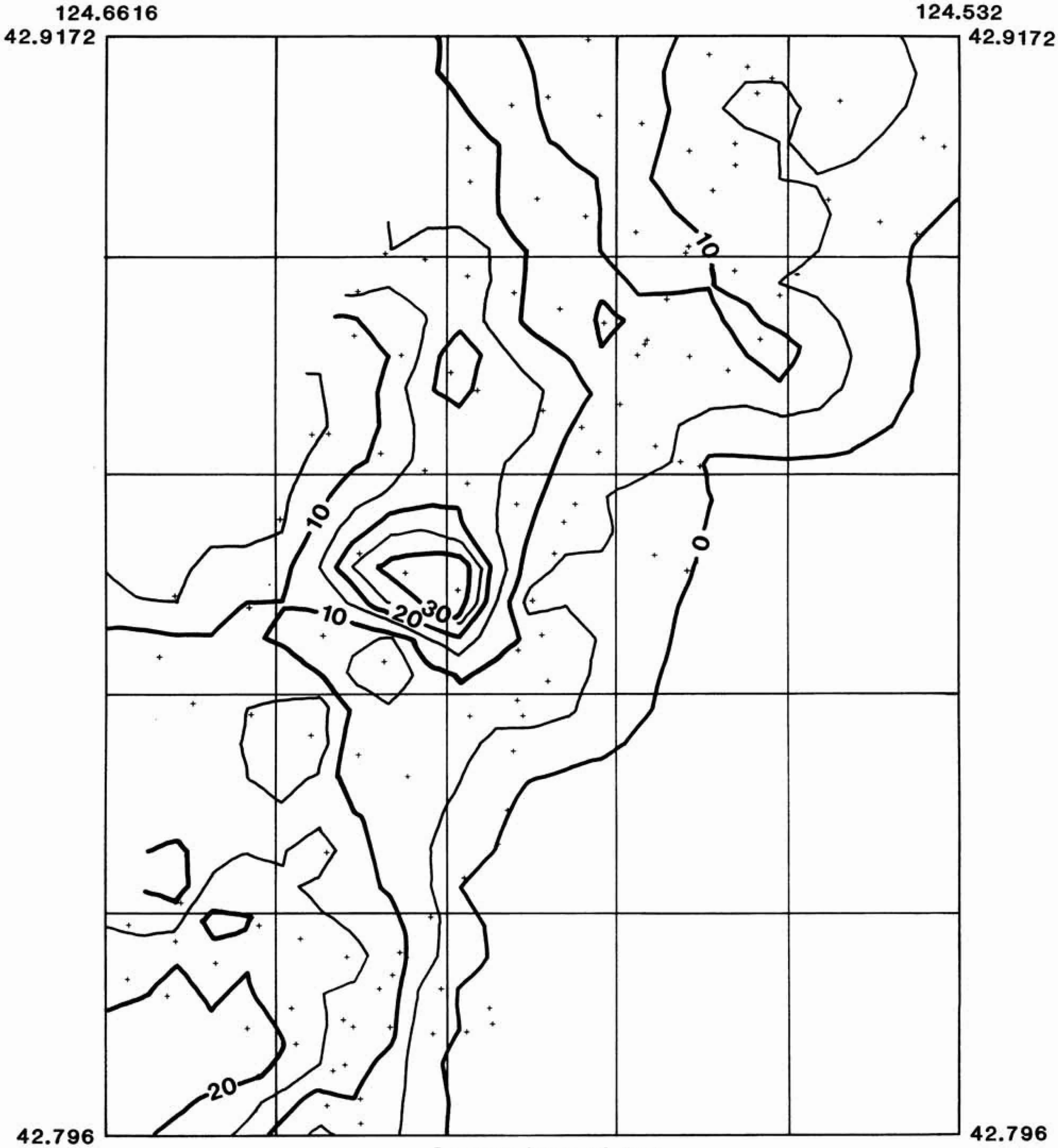
An absence, however, of apparent shore-parallel linear trends of the magnetic anomalies, particularly in the Cape Blanco area (Fig. 2.12) suggests that fossil beaches are not the source for surficial heavy mineral concentrations. As a consequence, other geologic models for concentrating placer minerals must be considered.

### 2.3.2. High-resolution seismic profiling

The thickness and distribution of unconsolidated sediment on those parts of the southern Oregon shelf surveyed during the cruise are shown on a set of sediment isopach maps (Figs. 2.43-2.46). The data upon which the isopach maps are based are presented in tabular form in the Appendix. In most areas, the vertical distance from the sea floor to the bedrock platform below ranges between 0 and 30 m (0-100 ft) (Figs. 2.47-2.51). In the Gold Beach south area (Fig. 2.46), the unconsolidated sediment forms a prism, 20-30 m thick at the maximum, trending more or less parallel to shore about 4 to 6 km from the shoreline north of Cape Sebastian. The prism results from the difference in slope between the bedrock surface and the sea floor; close to shore, the bedrock surface dips more steeply seaward than does the sea floor, whereas on the shelf the seaward inclination of the bedrock surface is more gentle than that of the sea floor. The prism thickens to the south, probably owing to increased tectonic subsidence in this direction. In the Gold Beach west area (Fig. 2.45), the sediment thickens seaward to 15-20 m west of a broad outcropping of the bedrock platform.

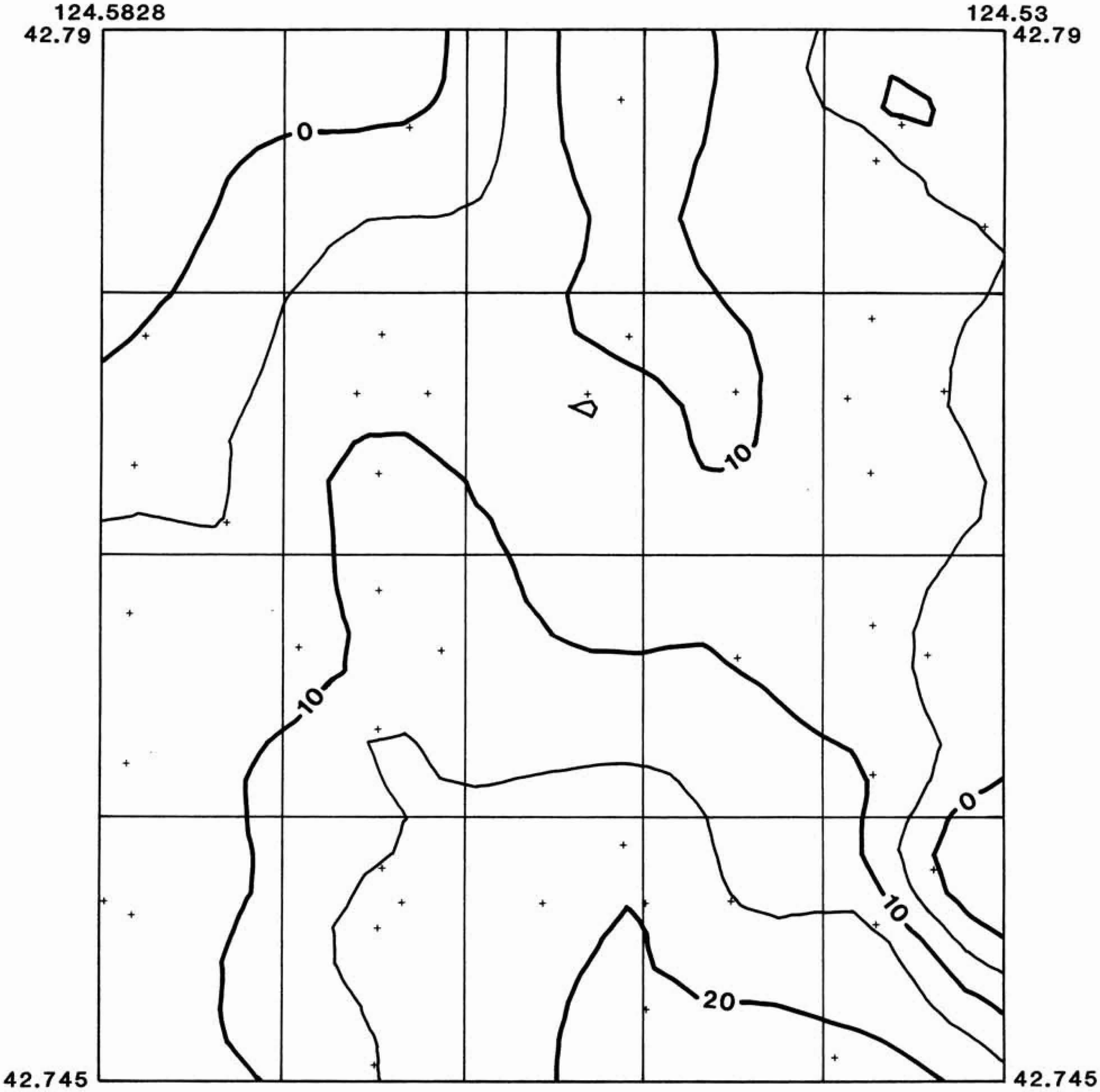
In the Cape Blanco west area (Fig. 2.43), the unconsolidated sediment forms a north-northeast trending prism, about 10-15 m thick. Local basins of sediment more than 30 m thick may result from local tectonic activity here. In the Cape Blanco south area (Fig. 2.44), the unconsolidated sediment cover forms a blanket about 10 m thick over most of the shelf surveyed. A thickening of this cover in the southern part of the area may reflect neotectonic downwarping.

The seismic profiles provide little information about the internal stratigraphy of the unconsolidated sediment above the bedrock platform. The general absence of internal reflectors within the package of unconsolidated sediment and a lack of samples at depth within the substrate preclude a detailed interpretation of the age and composition of this




Contontour interval 5 m

FIGURE 2.43. ISOPACH MAP OF UNCONSOLIDATED SEDIMENT, CAPE BLANCO WEST




Contour interval 5 m

FIGURE 2.44. ISOPACH MAP OF UNCONSOLIDATED SEDIMENT, CAPE BLANCO SOUTH

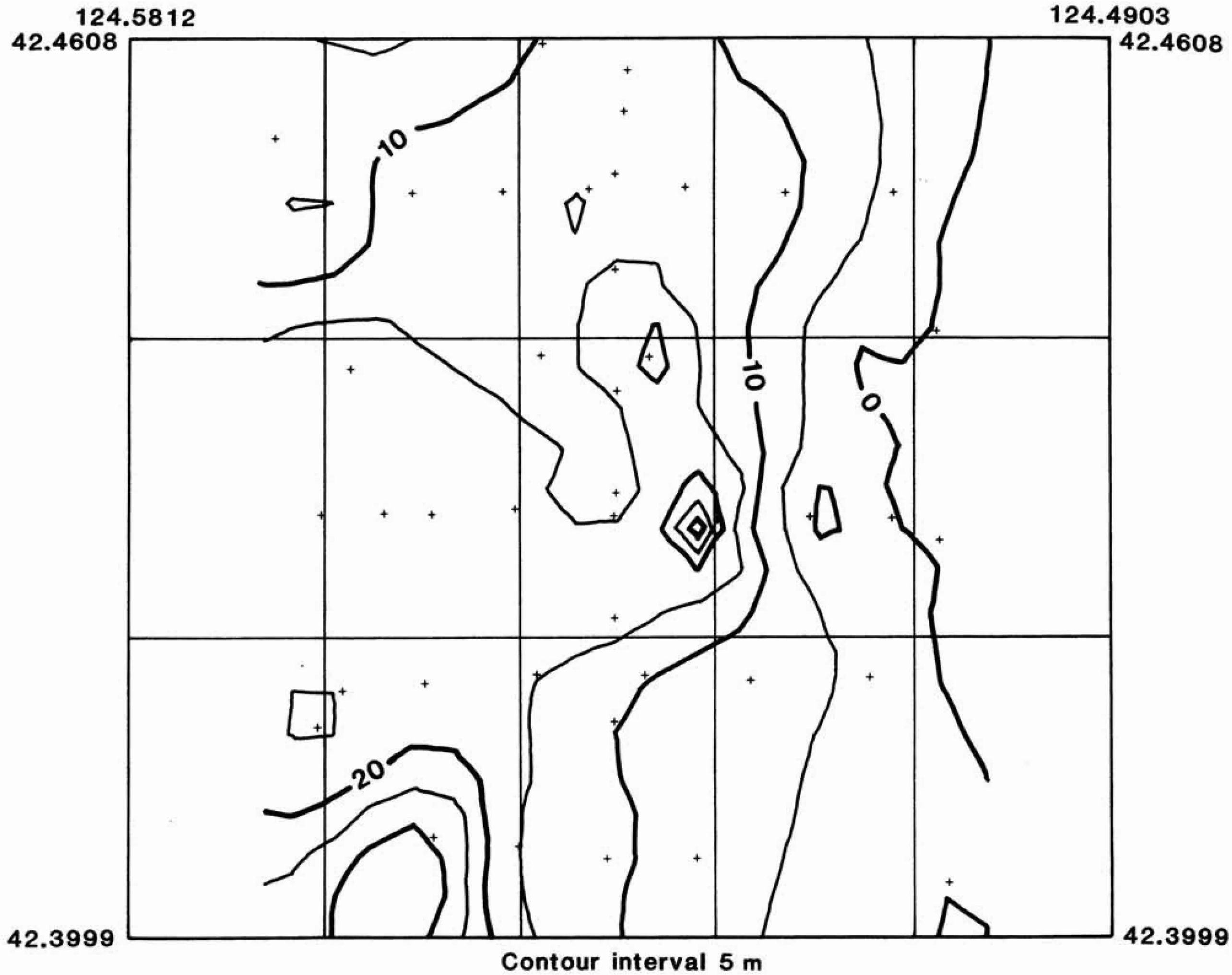



FIGURE 2.45. ISOPACH MAP OF UNCONSOLIDATED SEDIMENT, GOLD BEACH WEST

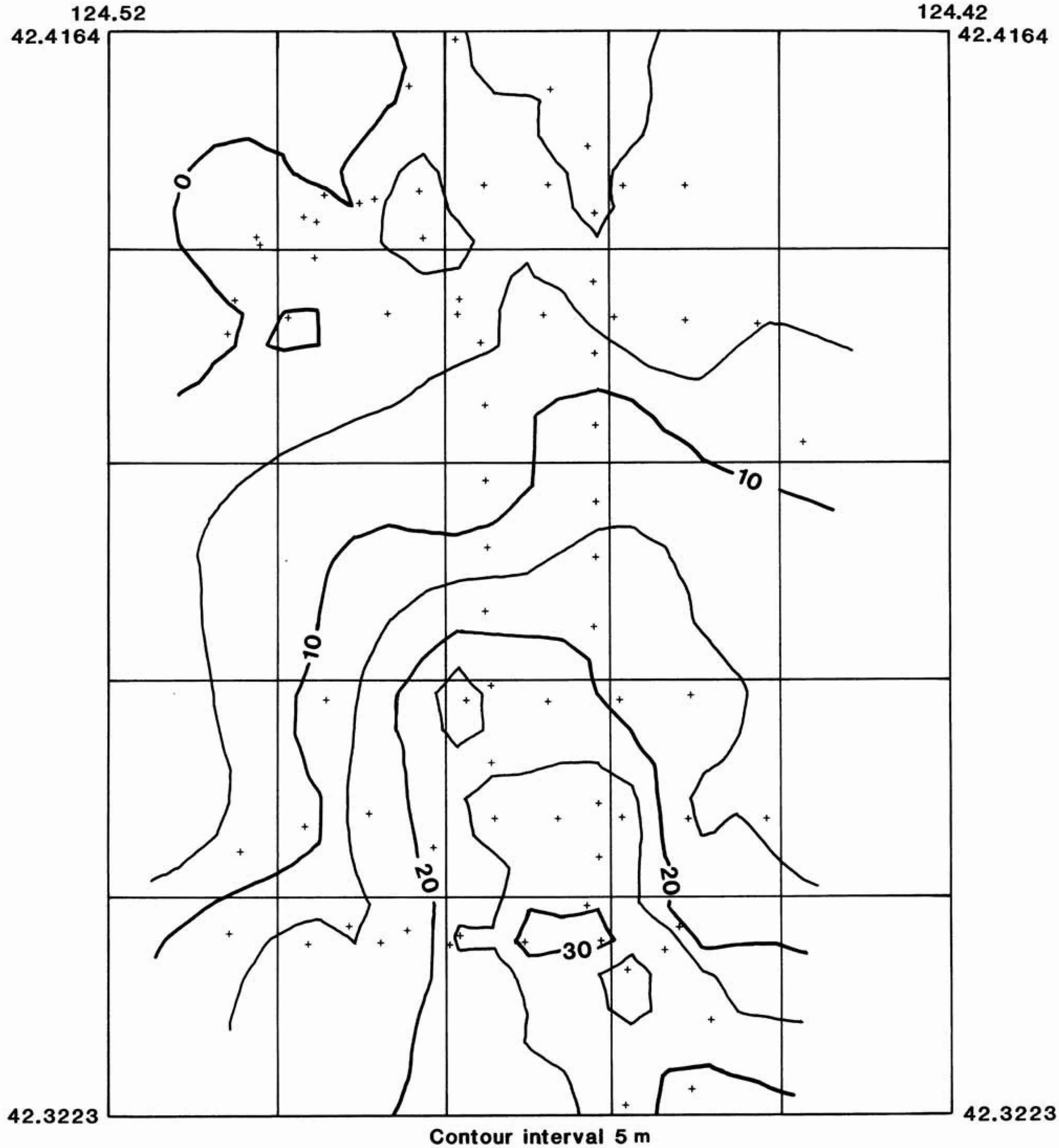



FIGURE 2.46. ISOPACH MAP OF UNCONSOLIDATED SEDIMENT, GOLD BEACH SOUTH

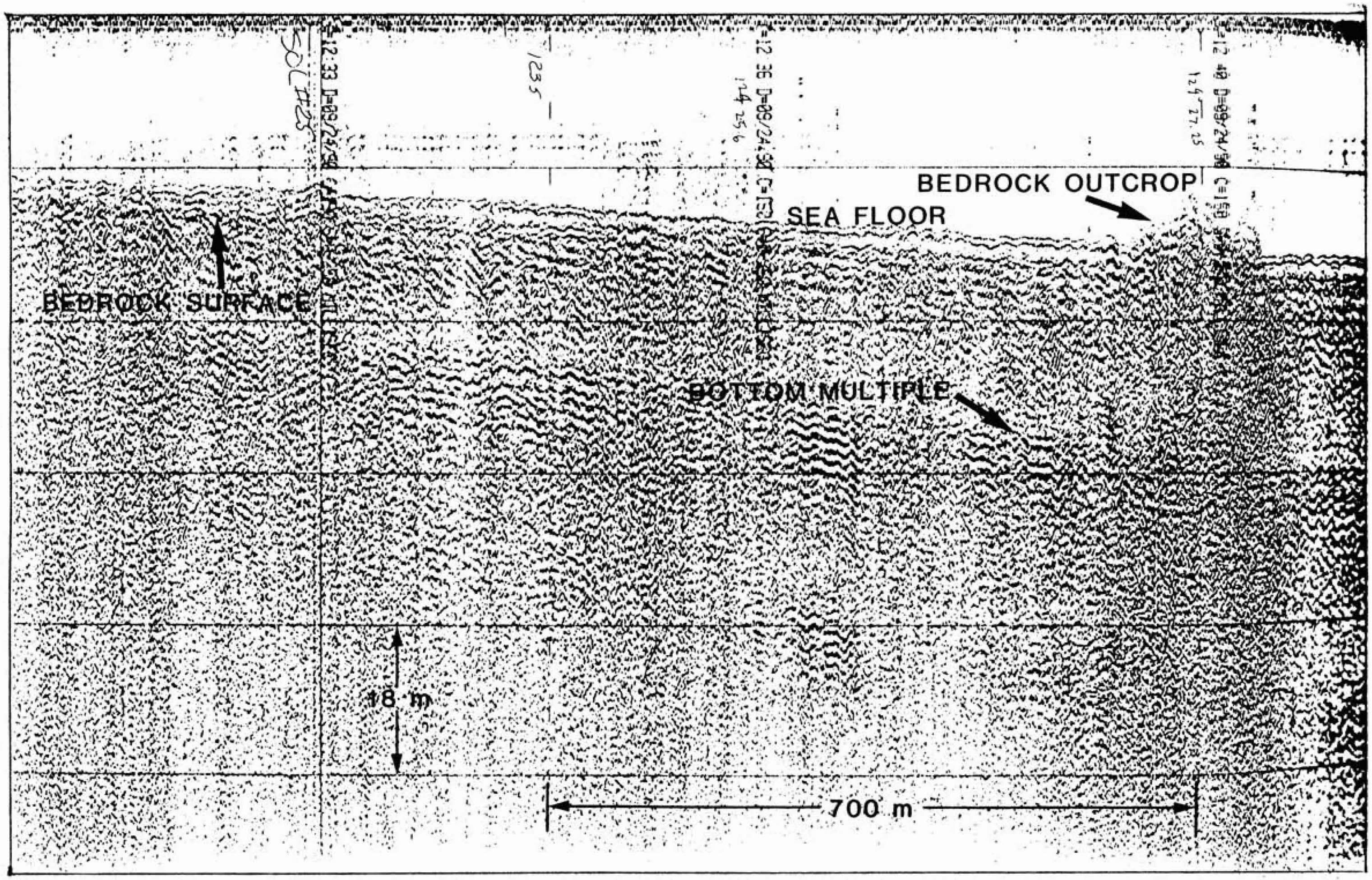



**FIGURE 2.47. SEISMIC PROFILE, LINE 25, GOLD BEACH SOUTH**

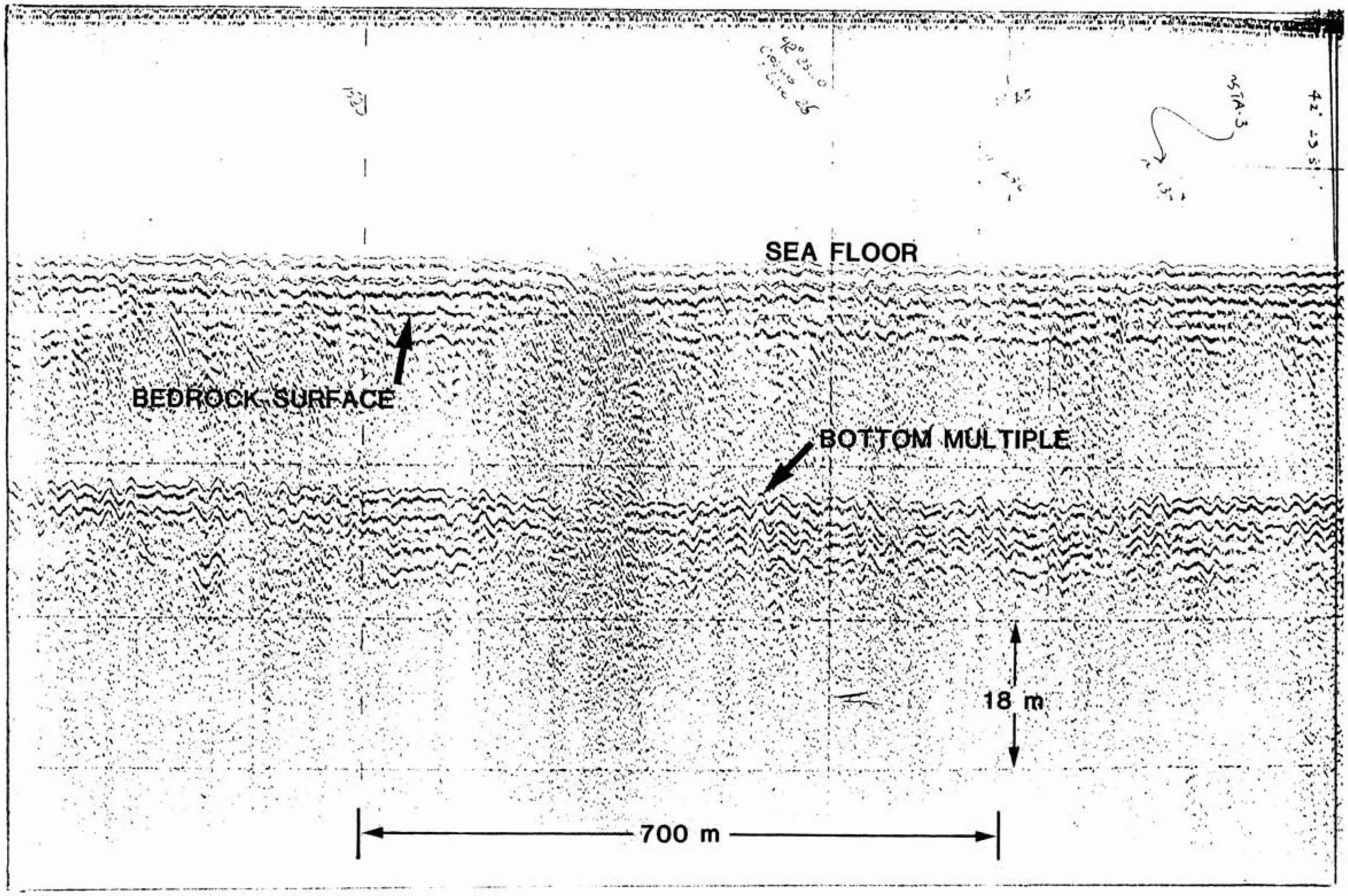



FIGURE 2.48. SEISMIC PROFILE, LINE 19, GOLD BEACH SOUTH

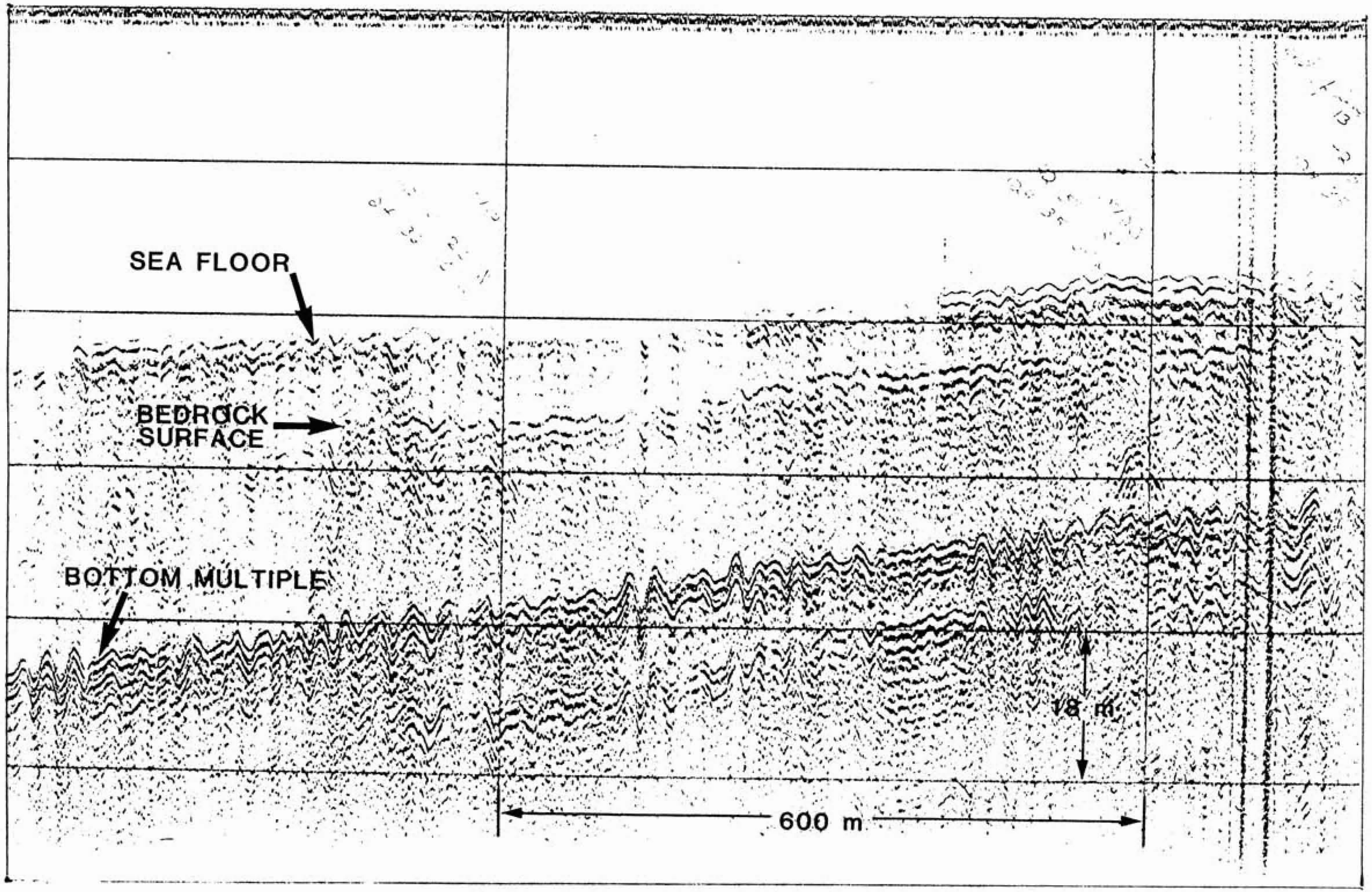



**FIGURE 2.49. SEISMIC PROFILE, LINE 13, CAPE BLANCO WEST**

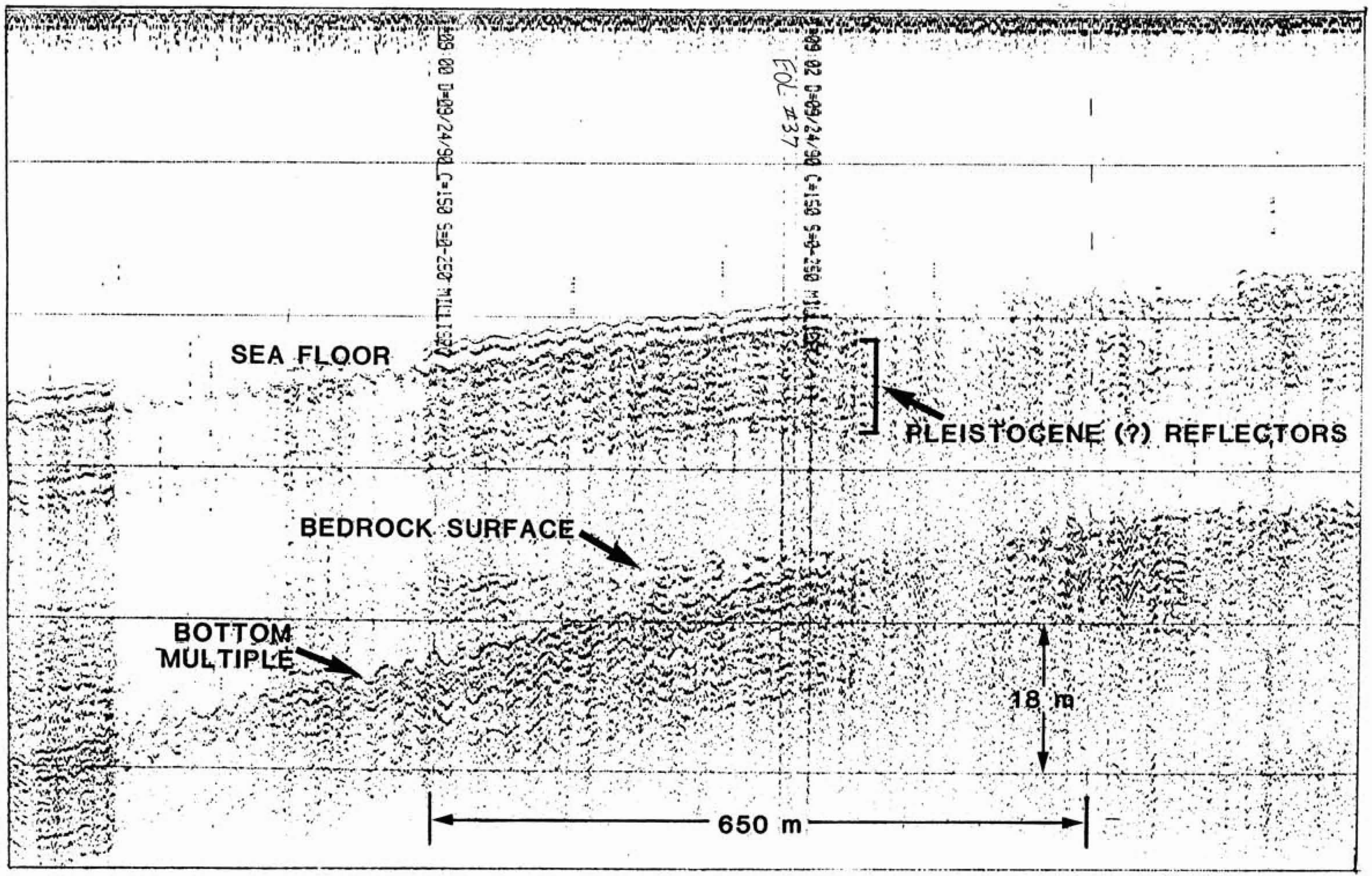



**FIGURE 2.50. SEISMIC PROFILE, LINE 37, GOLD BEACH SOUTH**

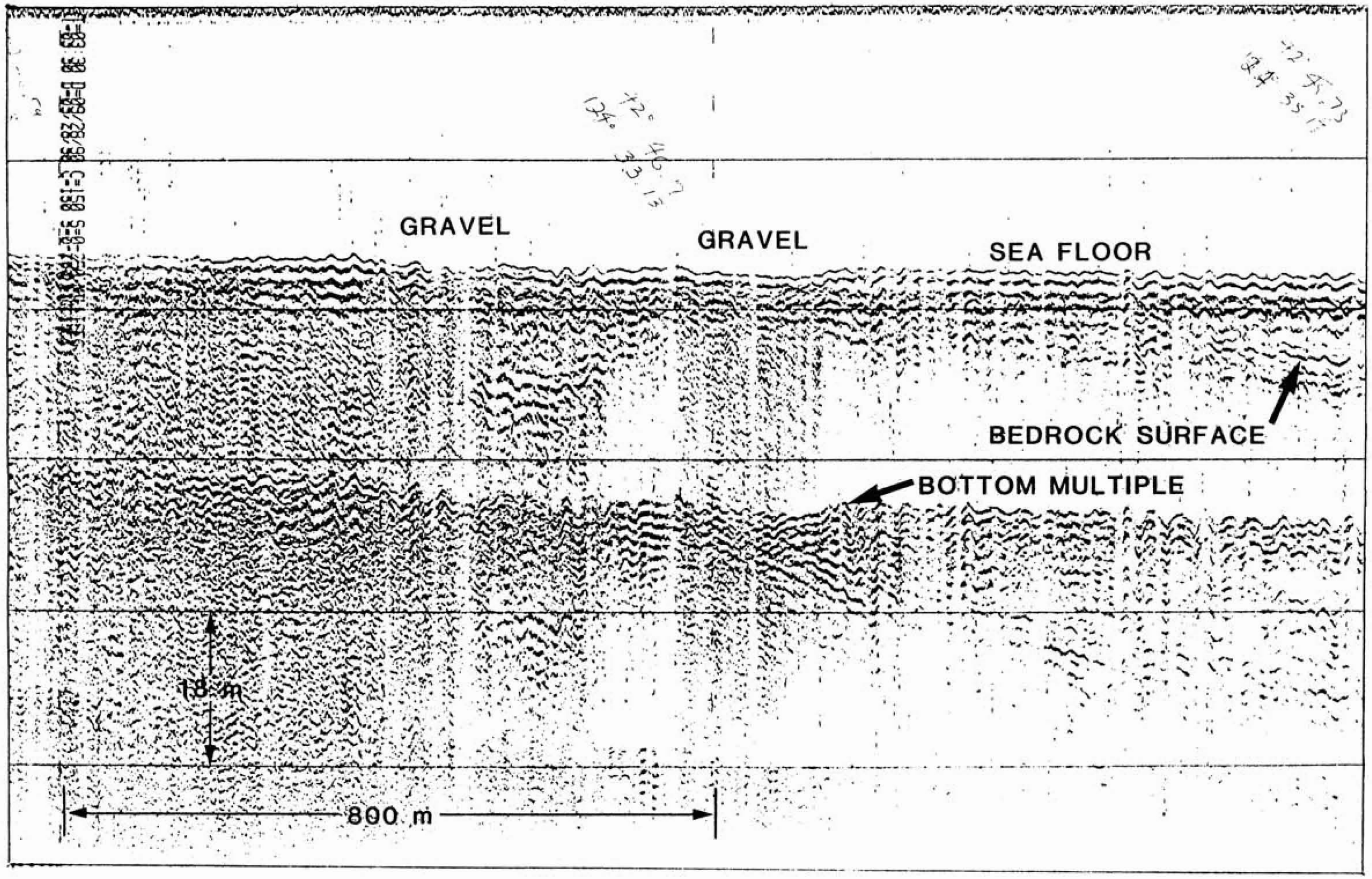



**FIGURE 2.51. SEISMIC PROFILE, LINE 30, CAPE BLANCO SOUTH**

material. This sediment probably represents a complex history, in which Holocene shelf sediment overlies Pleistocene deposits of diverse origins. In a few places, internal reflectors within probable Pleistocene deposits appear on the profiles (Fig. 2.50).

In the Gold Beach west area, the seismic profiles delineated a system of ancient channels beneath the sea floor (Figs. 2.17 and 2.52). These channels are cut into bedrock and almost certainly represent pathways of the Rogue River across the inner shelf at earlier lowstands of the sea. The width of the channels ranges from 0.5 to about 2 km, and their axes lie between 25 to 50 m below the present sea floor. Most of the channels are capped by a horizontal reflector that probably represents a wave-cut platform This reflector is overlain by an additional 15 to 20 m of sediment. These stratigraphic relations imply that the channels were cut prior to marine transgression of the past 20,000 years, possibly during much earlier lowstands of the sea. The configuration of the channels is complex and may represent multiple episodes of incision. For example, about 8 km west of the mouth of the Rogue River, the channel system bifurcates into north- and south-trending segments (Fig. 2.52). It seems unlikely that both of these branches formed during the same lowstand. More probably, the river, during a lowstand, partly re-exhumed a pre-existing, filled, east-west channel to the point of bifurcation, where it turned to the north (or south) and incised a new channel. The records do not indicate the sequence in which these channels were cut.

### 2.3.3. Side-scanning sonar surveys

The side-scanning sonar provides an image of the sea floor that can delineate rock outcroppings or the texture of the bottom sediment. Waves and currents shape unconsolidated sand and gravel into ripples and dunes. The size and shape of these bedforms depends on both the nature and velocity of the current and the grain size of the sediment. Waves, in particular, generate relatively straight-crested ripples on the shelf that are oriented with crests more or less parallel to the shoreline. The size of these ripples depends strongly on the size of the material moved by the wave-generated currents. In fine sand, the ripples typically have a spacing of no more than a few decimeters and are no more than a centimeter or two high. Such ripples are too small to be resolved with the side-scanning sonar systems used in this cruise. In contrast, under the action of waves, gravel typically is shaped into much larger bedforms, spaced a meter or more apart and several decimeters high. Ripples of this size are readily resolved on a side-scanning sonar image (Fig. 2.53), and the instrument can be used to delineate the distribution of the coarser sediment, which has relevance not only to the

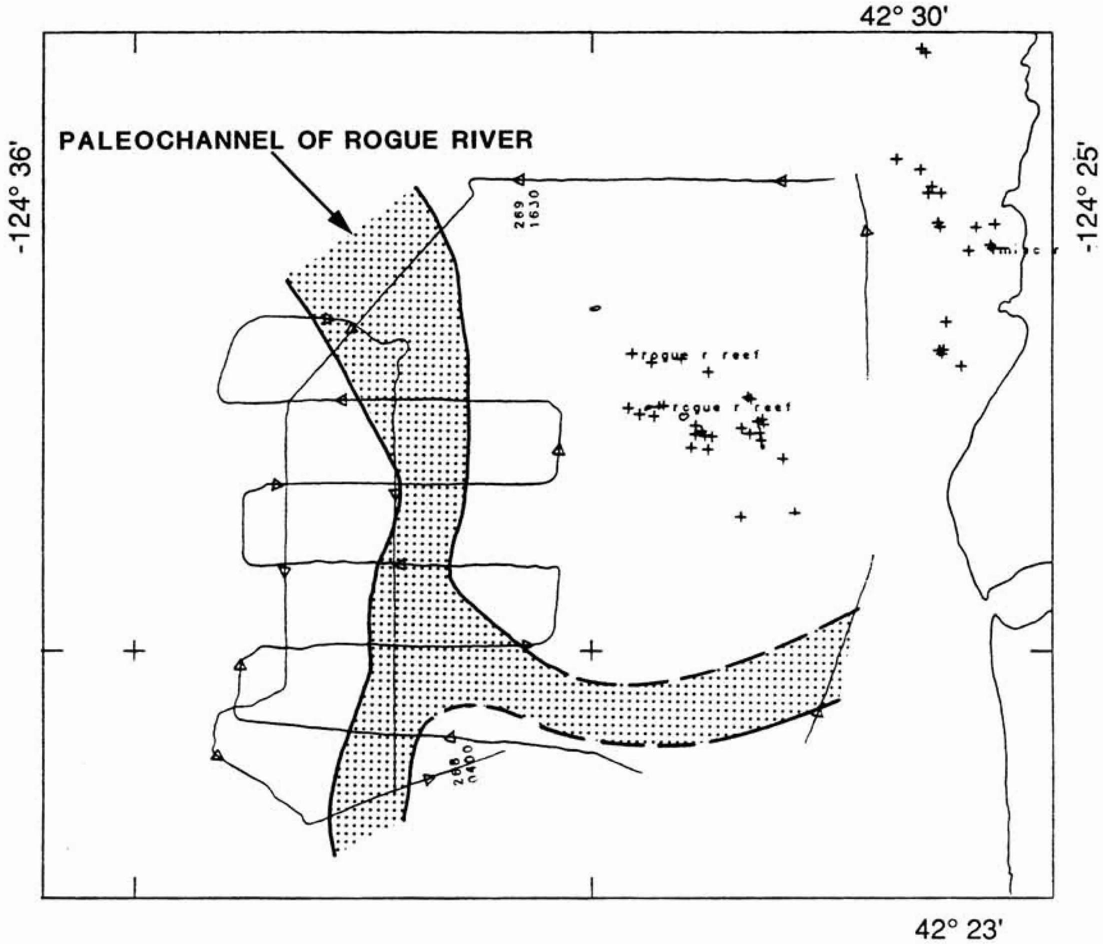



**FIGURE 2.52. SEISMIC LINES, GOLD BEACH WEST AND LOCATION OF BURIED PALEO-CHANNELS**

MAP SCALE 1:100,000

0 — 10 km

0 — 5 nm

MERCATOR PROJECTION STANDARD PARALLEL = 42.5000°

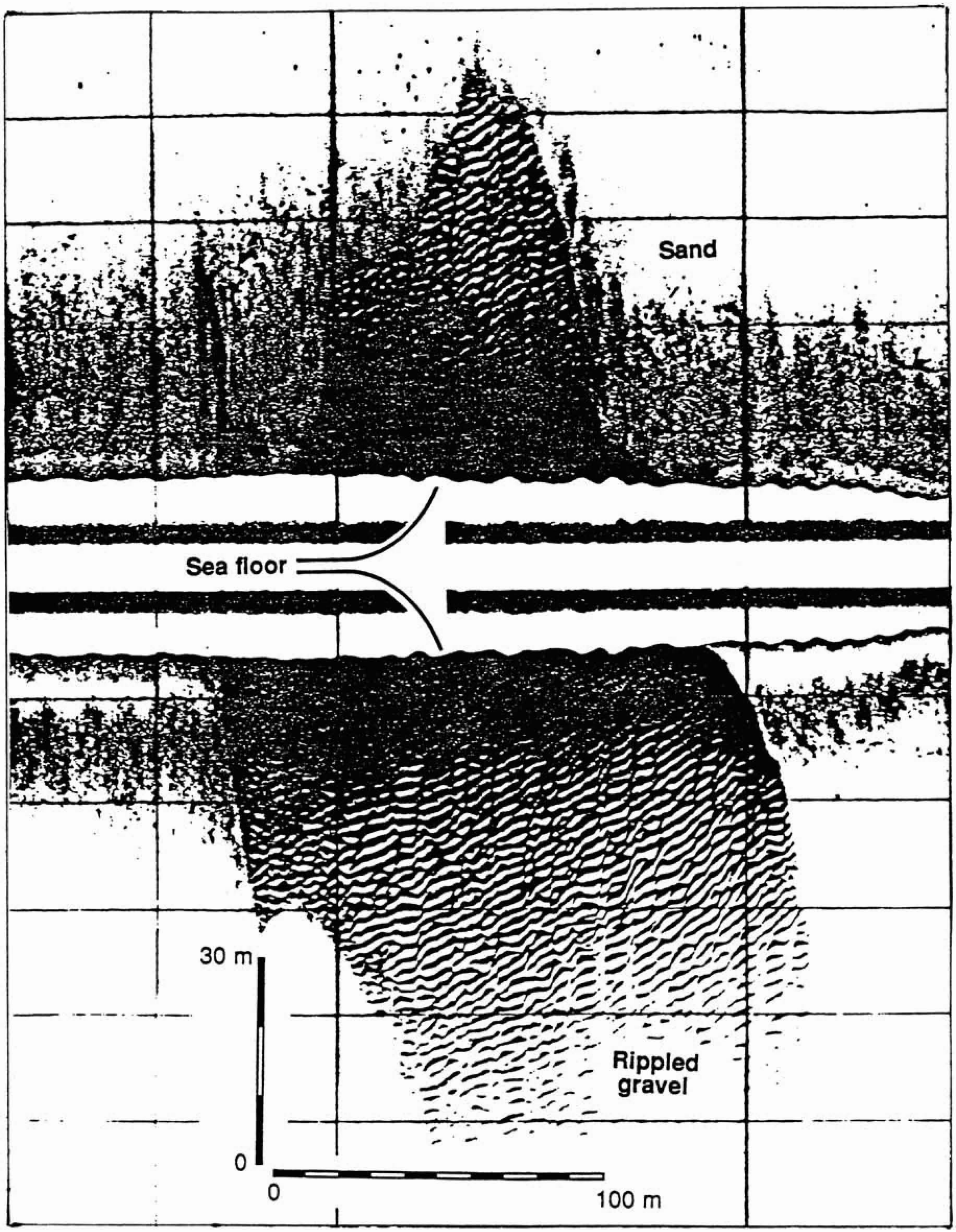



FIGURE 2.53. PORTION OF A SIDE-SCANNING SONAR RECORD, CAPE BLANCO SOUTH

occurrence of placer minerals but also to the distribution of bottom fauna.

A side-scanning sonar survey confirmed the earlier observations that large patches of gravel cover the sea floor in the Cape Blanco south area (Fig. 2.54). In parts of the area, the gravel is continuous for a kilometer or more; in other parts, it is more discontinuous, occurring in patches less than 100 m wide. From the bathymetry recorded on seismic and side-scanning sonar profiles (Figs. 2.51 and 2.53), the gravel appears to occupy shallow depressions on the sea floor. Adjacent, slightly higher, parts of the sea floor are mantled by a layer of fine sand; ripples on the surface of this sand are too small to be resolved with side-scanning sonar. Grab samples and collection from trawls indicates that the gravel consists of well-rounded clasts 0.5 to 7 cm across. Abraded shell fragments are an abundant constituent, and coarse to very-coarse sand was present in some of the samples.

Several aspects of the gravel indicate that it is a relict deposit that is rarely disturbed under present conditions. Barnacles or barnacle scars typically occur on only one side of the pebbles or shells, indicating that they were not routinely rolled about. The distribution of the gravel far from the present shoreline suggests that it accumulated at a much lower stand of the sea. Much of it may have been deposited near the mouth of the Elk River where it crossed the shelf during the latest Pleistocene. If so, its presence indicates that sand presently accumulates in this area very slowly, and that the modern sand on this part of the shelf forms only a thin veneer over older deposits.

The limited side-scanning sonar survey in the Cape Blanco West area (Fig. 2.22) detected no large ripples indicative of gravel.

### 2.3.4. Geological sampling

The samples collected during the cruise provide details of geology not available from the geophysical records. Samples were collected at four vibralift sites in the Rogue River area and at one site off Cape Blanco (Fig. 2.55). Mineralogic data reported in another section of this report bears on the nature and origin of the substrate beneath the shelf. The vibralift samples yield some stratigraphic information that indicates the age and environment of accumulation of the sediment penetrated. Small intact slabs of the uppermost sand collected from the Smith-McIntyre grabs document the nature of processes presently active in the areas of sampling.

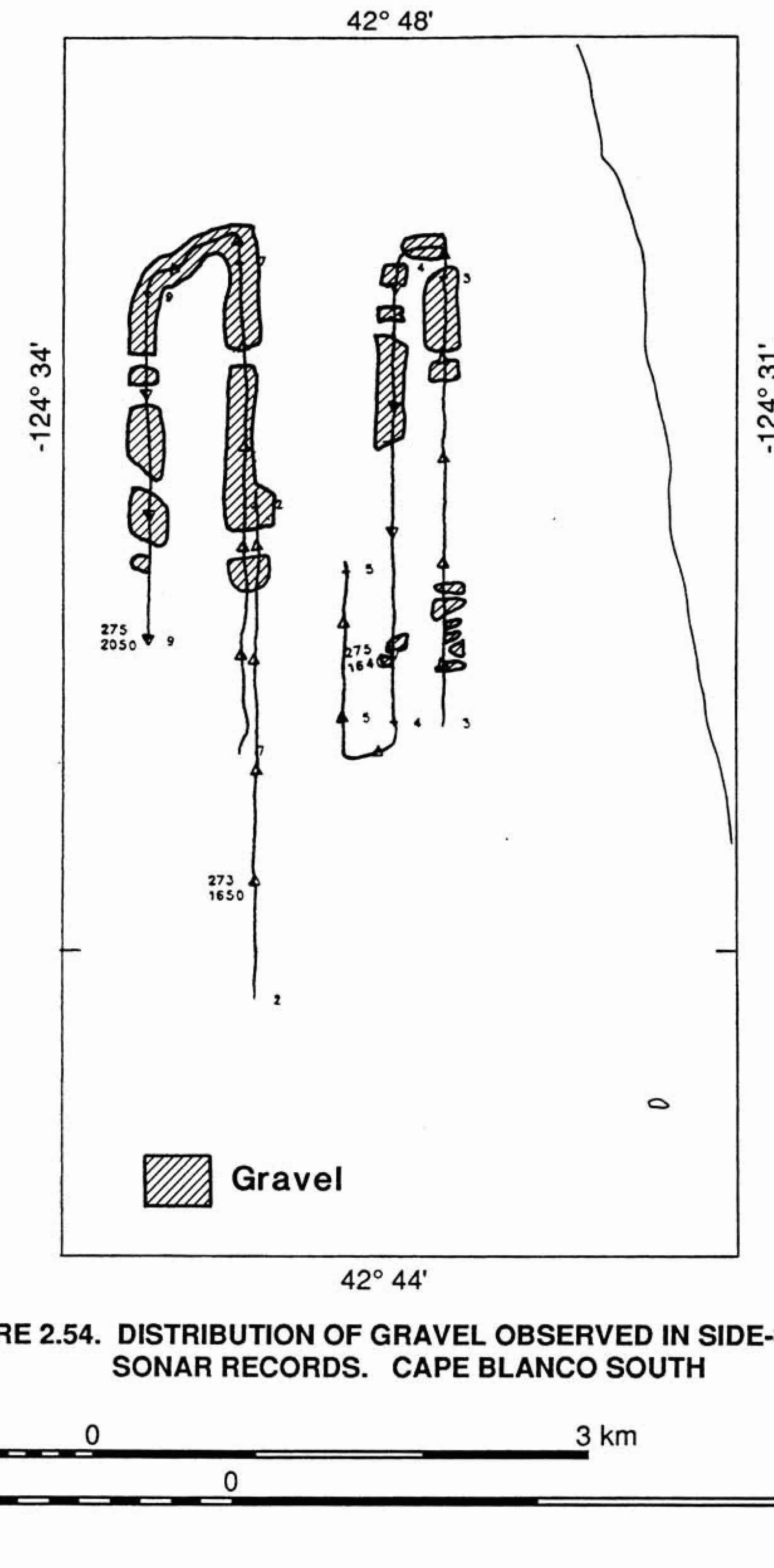
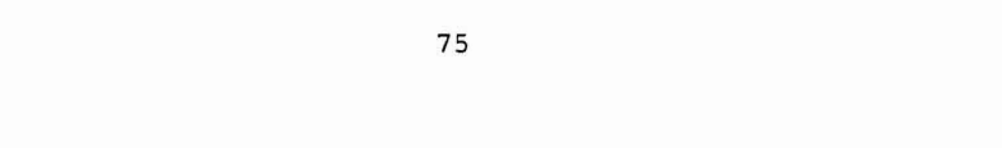



**FIGURE 2.54. DISTRIBUTION OF GRAVEL OBSERVED IN SIDE-SCANNING SONAR RECORDS. CAPE BLANCO SOUTH**



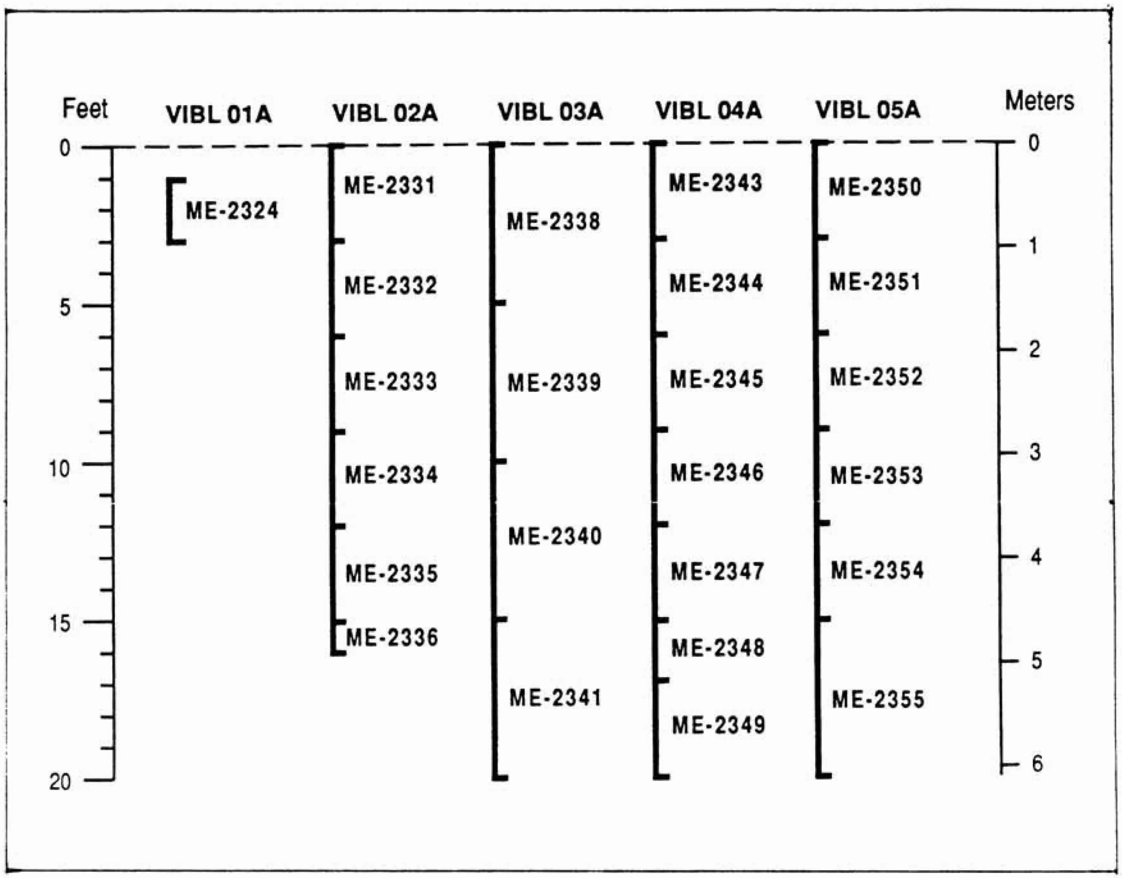



FIGURE 2.55. LOCATION AND DEPTH OF PENETRATION OF VIBRALIFT SAMPLES

Mineralogically, the vibralift samples showed no rich concentrations of heavy minerals beneath the sea floor that would suggest buried fossil beach deposits. Vibralift 04A (Fig. 2.37) yielded shell fragments that were dated using C-14 methods by the Portland State University Geology Department. Three dates were obtained. The lowermost sample, collected from the 17-20 foot (5-6 m) interval has an age in the range of 5500 to 6000 years BP. An intermediate sample, from the 9-12 foot (3-4 m) interval, has an age in the range of 3700 to 4200 years BP, and the uppermost sample, collected from the 1-3 foot (<1 m)interval has an age of 2100-2500 years BP. These dates indicate a middle to late Holocene age for the upper 20 feet(6 m) of sediment in the Cape Sebastian area. Holocene sea-level curves for the U. S. west coast suggest that all of this sediment accumulated as a shelf deposit in water depths that approached the present shelf values. The similarity of grain-size distributions at depth in the vibralift samples, as reported in another section of this report, supports the conclusion that all of the sediment sampled at depth with the vibralift system was deposited in a shelf setting.

Vibralift 03A (Fig. 2.35) encountered a layer of gravel at the deepest penetration (20 feet) that probably represents the base of the Holocene section at this location. In sections of Pleistocene deposits exposed in uplifted terraces onshore, as well as in cores taken from the inner shelf in other areas, layers of gravel mark the surface of transgression where the rising sea crossed the surface of the land. Typically, deposits that accumulate along the shoreline during a transgression are eroded, and inner shelf sediment blankets the erosional surface as sea level continues to rise. The nature of Pleistocene deposits between this surface and the underlying bedrock surface is unknown.

The absence of 3-dimensional sampling precludes analysis of sediment beneath the sea floor off Cape Blanco. Small subsamples of intact sediment from the Smith-McIntyre grabs provides some insight into the geological processes currently active in this area. The samples were taken by inserting rectangular plastic containers into the surface of the sand collected within the Smith-McIntyre sampler, effectively providing small box cores about 9 cm wide, 1.5 cm thick and 7-8 cm deep. X-ray radiographs of these cores show an upper, well-stratified layer of sand, 1-5 cm thick, overlying bioturbated sand. The stratification, which is unmarked by any faunal activity, almost certainly represents very active reworking of the sediment by physical processes. In one core (SMAC-08A, Fig. 2.24), the stratified sand is enriched in heavy minerals. Although the other cores have no similar surficial concentration of heavy minerals, concentrations 1-2 cm thick, partly disrupted by faunal burrowing occur sporadically in the underlying sand. It is likely that these concentrations resulted from winnowing by wave-generated currents during storms at some earlier, but relatively recent, time.

## SECTION 3.0

## MINERALOGY AND GEOCHEMISTRY

Cheryl Mardock, U.S. Bureau of Mines

## SECTION 3.0

## MINERALOGY AND GEOCHEMISTRY

### 3.1. Objectives

The primary objective of this mineralogical investigation was to assess offshore heavy placer mineral assemblages for possible value to the Nation and to the State of Oregon. The U.S. Bureau of Mines was involved with this investigation to assess the potential for significant resources of strategic minerals within the Nation's Exclusive Economic Zone (EEZ). Bureau personnel functioned as part of the research team by conducting microscopic mineralogic characterization of samples on board the research vessel to assist with on-site mineral evaluations and to provide complete sample characterization by performing in-depth mineralogic, chemical, and processing tests in laboratories located at the Bureau's Albany, Oregon and Salt Lake City, Utah Research Centers.

The mineralogical and geochemical evaluations in this study are also intended for use by the State of Oregon in development of land-use policies for its offshore domains. State and federal entities have the responsibility to manage land under their control fairly. Most lands are managed to provide multiple-use areas and mineral use data is required to make informed decisions. Mineralogical characterization and geochemical analyses of samples taken during the research expedition (see Tables 3.1-3.4) helped to determine the significance of potentially valuable mineral deposits along the continental shelf of the western United States.

Previous research studies of on-shore beach terrace deposits that contain heavy-mineral concentrations confirmed the presence of notable amounts of ilmenite, chromite, magnetite, zircon, garnet, gold, and the PGM-bearing minerals along coastal areas of southwestern Oregon. (Binney and Peterson, 1989, p. 130-134; Pardee, 1934, p. 23-30; Martinez and others, 1981, 14 p.). Geologic interpretation (Kulm and Peterson, 1989, p. 14-27; Peterson and others, 1987, p. 203-229; Smith, and Hopkins, 1972, p. 143-180; and Twenhofel, 1943 p. 16-25) indicated that rich deposits of similar mineralization could logically occur on the adjoining continental shelf. As a result of that information, this mineralogical study was performed in the interest of the Nation and the State of Oregon to determine if extensive deposits of these strategic, critical, and precious minerals lie off the southwest coast of Oregon.

Strategic minerals contain the critical metals titanium, chromium, zirconium, and the platinum-group metals (PGM). Titanium is the primary constituent of light-weight, high-strength alloys used in the aerospace industry, and, in its oxide form, is a white pigment that became particularly important for use in paint when the use of lead was restricted. Chromium, a widely used metal in the metallurgical, chemical, and refractory industries, is a component in stainless steels that makes the alloy resistant to corrosion. Zirconium is a metal that is used in highly corrosive environments such as those found in the chemical industry. Zirconium is also used as a structural material for nuclear reactors because it does not interact with neutrons in the reactor environment. The platinum-group metals are chemically inert at high temperatures and display excellent catalytic activity. They are in demand for use in automobile emissions catalysts as well as for their use in the chemical, electrical, glass, and dental-medical industries. The Nation now depends solely or significantly upon imports for these strategic metals (U.S. Bureau of Mines Bulletin 675, 1985).

## 3.2. Methods

### 3.2.1. Mineralogical Characterization

Mineralogical evaluation of the sediments was performed aboard ship and at the Bureau's Albany Research Center (ALRC) by binocular and optical polarized-light microscopy. On the ship, samples were panned and microscopically examined to obtain an estimate of valuable mineral composition in order to evaluate on-site mineralization at each sampling location. At ALRC, representative splits of samples taken at 3-ft depth intervals by a vibralift technique were panned to separate three weight fractions, a heavy fraction, a mid-weight fraction, and a light fraction to determine the presence of valuable mineral constituents. The heavy fraction, with a specific gravity greater than 4.0, contained minerals such as chromite, ilmenite, magnetite, garnet, zircon, rutile, monazite, gold, and PGM. The mid-weight fraction, with a specific gravity less than 4.0 but greater than 3.0, separated pyroxenes and amphiboles which are common minerals with varying amounts of calcium, magnesium, iron, aluminum, and silica. The light fraction, with a specific gravity less than 3.0, contained rock fragments, shell fragments, quartz, feldspar, and muscovite.

At ALRC, selected representative sample splits were screened, air-dried, and magnetically separated on a Franz Isodynamic Separator[1] to isolate constituents for

[1]Reference to specific products does not imply endorsement by the Bureau of Mines.

characterization. All samples were examined using optical and electron microscopy and by X-ray diffraction to determine chemical and mineralogical composition. X-ray diffraction analysis on selected gravity and magnetic fractions verified optical interpretations of mineral species. Scanning-electron microscopy (SEM) with energy-dispersive X-ray analysis (EDX) using backscatter- and secondary-electron imaging was used to determine the physical and chemical nature of individual whole and cross-sectioned minerals.

It is the intent of this study to determine the merit of the minerals discovered which includes not only determining the quantity of valuable elemental constituents, but also the quality of the minerals in which the valuable elements are found. Liberation, grain size, overall mineralogy, processibility, and accessibility are major factors in determining the value of a mineral deposit (Martinez and others, 1981, 14 p.). Unique or economically pertinent information on the chemistry of the individual minerals found in this study are listed in Table 3.1.

### 3.2.2 Geochemical Analysis

Representative splits from unconcentrated samples were analyzed at ALRC for their chemical content. Each element was tested by the most appropriate method to insure accuracy of the analysis. Additional confirming analyses of strategic and precious elements were done by the Bureau's Salt Lake City Research Center (see Section 4.0).

Samples were also solubilized using a sodium-peroxide fusion for analyses of vanadium, lead, arsenic, zirconium, hafnium, cerium, and lanthanum by inductively coupled plasma atomic emission spectrophotometry (ICP).

Samples were also solubilized by a sodium-peroxide fusion for analyses of chromium, iron, and titanium. Analysis of these elements was done by classical volumetric methods.

For sodium, calcium, magnesium, potassium, and aluminum analyses, samples were solubilized by acid digestion in a closed teflon vessel heated with microwave energy. These five elements were analyzed by flame atomic absorption spectrophotometry. Mercury was determined by the U.S. Environmental Protection Agency method for solids using cold-vapor atomic absorption spectrophotometry.

Gold, silver, and PGM were analyzed by fire assay/ICP at the Bureau's Reno Research Center.

## 3.3 Results and Discussion

### 3.3.1 Mineralogical Characterization

Mineralogical characterization includes grade estimation, mineral species categorization, grain-size analysis, physical characteristics, liberation data, mineral associations, inclusions, chemical variations and contaminants, alteration products, hazardous material evaluation, nonmineral constituent analysis, and commodity classification. These determinations depict a deposit's mineral nature, geologic history, processibility, economic viability, strategic importance, and, in conjunction with other studies done by the research team, profiles environmental concerns and biological settings[2].

Optical and SEM-EDX characterization indicated that sediments collected offshore of the Rogue River, Gold Beach, and Cape Sebastian are predominantly composed of a few percent heavy minerals, about 25 percent (pct)[3] mid-weight minerals, and the remainder light constituents. Analysis indicated no significant change with depth, to 20-ft, in the concentration of heavy minerals in samples taken from these southern sites.

Samples collected to 3-ft penetrations west and north of Cape Blanco contained greater proportions of heavy mineral fractions (up to 15 pct) and mid-weight mineral fractions (up to 50 pct) than samples from south of Cape Blanco. Incomplete sampling at this site due to harsh sea conditions and equipment failures precluded determination of changes in concentration of heavy minerals with depth. The heavy portions had higher concentrations of ilmenite, chromite, zircon, and gold than those in sediments collected south of Cape Blanco. Sand size, angularity, and alteration characteristics of these sediments were comparable to those of the sands collected south of Cape Blanco.

Although the mineral concentrations varied between individual samples and sample sites, the minerals of strategic or precious value were all found in the heavy fraction and were limited to ilmenite, chromite, zircon, and gold (Table 3.1). Abundant magnetite, small amounts of garnet, and barely detectable traces of monazite and rutile were also found in the heavy fraction in the majority of the samples. No PGM minerals were detected.

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[2]See applicable sections elsewhere in this report for interpretative work using mineralogical data.

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[3]All reported percentages in this Section are based on weight.

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Table 3.1. Offshore sample mineralogy

| Mineral | Ideal formula[1] | Chemical notes[2] |
|---|---|---|
| Ilmenite | $FeTiO_3$ | Contains 1-3 pct Mn, |
| Chromite | $FeCr_2O_4$ | High Al and Mg, low Fe, |
| Zircon | $ZrSiO_4$ | No Th detected. |
| Native Gold | Au | No chemistry available. |
| Magnetite | $Fe_3O_4$ | No substitutions for Fe noted. |
| Garnet | $FeAl_2Si_3O_{12}$ | Almandine variety. |
| Rutile | $TiO_2$ | |
| Monazite | $(Ce,La,Nd,Th)PO_4$ | 5-8 pct Th, some Y present. |
| Biotite | $K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$ | |
| Muscovite | $KAl_2(Si_3Al)O_{10}(OH,F)_2$ | |
| Hornblende | $Ca_2(Mg,Fe)_4Al(Si_7Al)O_{22}(OH,F)_2$ | |
| Hypersthene | $(Mg,Fe)_2Si_2O_6$ | |
| Serpentine | $(Mg,Fe)_3Si_2O_5$ | |
| Plagioclase Feldspar | $(Na,Ca)Al(Al,Si)Si_2O_8$ | |
| Alkali Feldspar | $(K,Na)(AlSi_3O_8)$ | |
| Quartz | $SiO_2$ | |
| Rock Fragments | schist, andesite/diorite | |
| Shell Fragments | $CaCO_3$ | |
| Manmade Lead Material | Pb or PbO | No natural lead compounds detected. |

[1]From Fleischer, M., 1987.

[2]Chemistry derived from SEM-EDX analyses of individual mineral grains.

The highest concentration of ilmenite, approximately 9 pct, was found in the Cape Blanco surface samples. Samples taken south of Cape Blanco at the Rogue River, Gold Beach, and Cape Sebastian study sites averaged 1 pct ilmenite. Although ilmenite, an iron-titanium oxide, is sometimes mined on land at a grade of 9 pct, it presents both economic and environmental difficulties for the production of titanium metal. It is found in dry-land domestic deposits in sufficient quantities to relegate similar, but more inaccessible, offshore deposits of ilemenite to a nonessential-resource status. Only traces of rutile were found in some of the samples. If rutile had been present in large quantities, the deposit might have had strategic significance for the Nation's needs for titanium (U.S. Bureau of Mines Bulletin 675, Titanium Chapter.)

Chromite was also concentrated (up to 2 pct) in the Cape Blanco surface samples. It averaged 0.3 pct in samples from other sites. Chromite is the primary ore of chromium and is one of the Nation's most important critical minerals. If the Cape Blanco deposit has this mineral at depth in greater quantities, the deposit could be classified as one of possible strategic interest.

Zircon, when present, occurs only in very small to trace amounts, and averages 0.02 pct in the Cape Blanco samples and 0.04 pct in samples from the other sites.

Traces of gold were observed in panned concentrates from surface samples collected from the Cape Blanco site. The gold was near-micrometer in size and scarce enough to be undetectable in a fire assay of unconcentrated material splits.

Potentially toxic elements were also studied. Numerous micrometer-size pieces of elemental lead and lead oxide were noted in the SEM-EDX study of the heavy fractions. These forms of lead do not occur in nature. No native minerals containing mercury or arsenic were observed. The source of trace amounts of arsenic detected in the chemical analysis of the samples (see table 3.3) is unknown. A few grains of the rare-earth- and thorium-bearing mineral, monazite, were detected in highly concentrated fractions of the sand. However, quantities of these elements were so low that they could not be detected by standard analytical methods (table 3.2).

Noneconomic or gangue minerals were concentrated in mid-weight and light fractions which included significant quantities of quartz; feldspar; amphiboles and pyroxenes; muscovite and biotite (two varieties of mica); various sizes of sedimentary, igneous, and metamorphic rock fragments; and shell fragments.

The sand grains are sharply angular and relatively unaltered, another indication that the material is of primary and local origin. With the exception of the larger rock fragments, the sand grains are composed of separate minerals. The sand is fine-grained, with the bulk of the sediments in the 70- by 140-mesh (212- by 106-micrometer) fraction. Wave action, especially during the winter storm months, and longshore currents actively disturb and transport sediments at the 300- to 500-ft water depths sampled (Smith and Hopkins, 1972, p. 143-180). There is little sediment in the deposits that is less than 200 mesh (75 micrometer), the size range of particles that tend to remain in suspension (Table 4.2). However, the micas are in the form of very thin flakes that remain in suspension, and they are the primary concern as a source of water clouding.

### 3.3.2. Geochemical Analysis

Geochemical analysis pinpoints each sample's total elemental makeup, thereby presenting a picture of the makeup of each site sampled. With the exception of the Cape Blanco location where only surface samples were collected, the chemical makeup of samples at varying depths gave a three dimensional view of each site. The analyses are used to model the deposit's generalized stratigraphy and its overall value as well as to predict potential environmental concerns.

Chemical analyses of the samples correlate well with the mineralogical findings. Tables 3.2-3.4 list the analyses (see also section 5 results for confirmation of targeted strategic element percentages). Sample numbers in Table 3.2-3.4 correspond to the sample numbers in Figure 2.55 with the prefix "ME".

Titanium (Ti) is the most abundant element of interest. The maximum percent of titanium attained in a near-surface sample from Cape Blanco was approximately 3 pct Ti, which calculates to approximately 5 pct $TiO_2$. Samples from sites south of Cape Blanco ranged from less than 0.01 to 0.75 pct Ti and averaged 0.3 pct Ti, an order of magnitude less than those taken at Cape Blanco. There was no relevant change in Ti values with increases in the depth down to 20-ft.

Chromium (Cr) is second in quantity of the strategic and precious metals present. As in the case of titanium, chromium content was higher (averaging 0.5 pct Cr) in the Cape Blanco near-surface samples. Cape Blanco chromium content was four times higher than the chromium content in samples from sites to the south, which averaged 0.14 pct Cr. No change in chromium values was found to correspond with changes in depth.

Table 3.2. Primary metal analyses, percent

| Sample | Description/Depth | Cr | Ti | Zr | Hf | V | Ce | La |
|---|---|---|---|---|---|---|---|---|
| 2321 | Cape Blanco/1 ft | .78 | 3.01 | .06 | <.01 | .02 | 0.01 | <0.01 |
| 2324 | Cape Blanco/2 ft | .28 | 1.15 | .08 | .02 | .01 | .01 | <.01 |
| 2331 | Gold Beach/3 ft | .10 | .74 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2332 | Gold Beach/6 ft | .13 | .67 | .01 | <.01 | .02 | <.01 | <.01 |
| 2333 | Gold Beach/9 ft | .14 | .50 | .01 | <.01 | .02 | <.01 | <.01 |
| 2334 | Gold Beach/12 ft | .14 | .60 | .02 | <.01 | .02 | .01 | .02 |
| 2335 | Gold Beach/15 ft | .06 | .45 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2336 | Gold Beach/16 ft | .13 | .39 | .01 | <.01 | .01 | <.01 | <.01 |
| 2338 | Rogue River/5 ft | .12 | .55 | .01 | <.01 | .02 | <.01 | <.01 |
| 2339 | Rogue River/10 ft | .13 | .54 | <.01 | <.01 | .02 | <.01 | <.01 |
| 2340 | Rogue River/15 ft | .17 | .69 | <.01 | <.01 | .02 | <.01 | <.01 |
| 2341 | Rogue River/20 ft | .19 | .41 | .01 | <.01 | .02 | <.01 | <.01 |
| 2342 | Cape Sebastian/1 ft | .50 | .74 | .03 | <.01 | .02 | <.01 | <.01 |
| 2343 | Cape Sebastian/3 ft | .20 | .47 | .01 | <.01 | .02 | <.01 | <.01 |
| 2344 | Cape Sebastian/6 ft | .11 | .24 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2345 | Cape Sebastian/9 ft | .14 | .38 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2346 | Cape Sebastian/12 ft | .12 | .56 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2347 | Cape Sebastian/15 ft | .08 | .43 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2348 | Cape Sebastian/17 ft | .22 | .61 | <.01 | <.01 | .02 | <.01 | <.01 |
| 2349 | Cape Sebastian/20 ft | .13 | .55 | <.01 | <.01 | .02 | <.01 | <.01 |
| 2350 | N Cape Sebastian/3 ft | .23 | .37 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2351 | N Cape Sebastian/6 ft | .15 | .36 | <.01 | <.01 | .01 | <0.01 | .01 |
| 2352 | N Cape Sebastian/9 ft | .10 | .51 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2353 | N Cape Sebastian/12 ft | .12 | .47 | <.01 | <.01 | .01 | <.01 | <.01 |
| 2354 | N Cape Sebastian/15 ft | .13 | .61 | .01 | <.01 | .02 | <.01 | <.01 |
| 2355 | N Cape Sebastian/20 ft | .16 | .48 | <.01 | <.01 | .02 | <.01 | <.01 |

Table 3.3. Precious and toxic metal analyses

| Sample | Description/Depth | Au[1] | Ag[1] | PGM*[1] | Pb[2] | As[2] | Hg[3] |
|---|---|---|---|---|---|---|---|
| 2321 | Cape Blanco/1 ft | ND | 0.3 | <.002 | 0.06 | 0.02 | <0.2 |
| 2324 | Cape Blanco/2 ft | ND | .1 | <.002 | .09 | .03 | <.2 |
| 2331 | Gold Beach/3 ft | ND | .1 | <.002 | .11 | .01 | <.2 |
| 2332 | Gold Beach/6 ft | ND | ND | <.002 | .11 | .02 | <.2 |
| 2333 | Gold Beach/9 ft | ND | .1 | <.002 | .06 | .04 | <.2 |
| 2334 | Gold Beach/12 ft | ND | .1 | <.002 | .07 | .03 | <.2 |
| 2335 | Gold Beach/15 ft | ND | ND | <.002 | <.01 | <.01 | <.2 |
| 2336 | Gold Beach/16 ft | ND | .2 | <.002 | .03 | .04 | <.2 |
| 2338 | Rogue River/5 ft | ND | .2 | <.002 | <.01 | <.01 | <.2 |
| 2339 | Rogue River/10 ft | ND | ND | <.002 | .03 | .03 | <.2 |
| 2340 | Rogue River/15 ft | ND | .1 | <.002 | <.01 | <.01 | <.2 |
| 2341 | Rogue River/20 ft | ND | ND | <.002 | .05 | <.01 | <.2 |
| 2342 | Cape Sebastian/1 ft | ND | .1 | <.002 | <.01 | .02 | <.2 |
| 2343 | Cape Sebastian/ ft | ND | ND | <.002 | <.01 | <.01 | <.2 |
| 2344 | Cape Sebastian/6 ft | ND | ND | <.002 | .07 | .03 | <.2 |
| 2345 | Cape Sebastian/9 ft | ND | .1 | <.002 | <.01 | <.01 | <.2 |
| 2346 | Cape Sebastian/12 ft | ND | .1 | <.002 | .12 | <.01 | <.2 |
| 2347 | Cape Sebastian/15 ft | ND | .1 | <.002 | .21 | .05 | <.2 |
| 2348 | Cape Sebastian/17 ft | ND | .2 | <.002 | .01 | <.01 | <.2 |
| 2349 | Cape Sebastian/20 ft | ND | .1 | <.002 | .12 | <.01 | <.2 |
| 2350 | N Cape Sebastian/3 ft | TR | .1 | <.002 | <.01 | <.01 | <.2 |
| 2351 | N Cape Sebastian/6 ft | ND | ND | <.002 | .04 | <.01 | <.2 |
| 2352 | N Cape Sebastian/9 ft | ND | .2 | <.002 | <.01 | .01 | <.2 |
| 2353 | N Cape Sebastian/12 ft | ND | .1 | <.002 | .07 | .02 | <.2 |
| 2354 | N Cape Sebastian/15 ft | ND | ND | <.002 | .06 | <.01 | <.2 |
| 2355 | N Cape Sebastian/20 ft | ND | ND | <.002 | .09 | .02 | <.2 |

ND-Not detected.
TR-Trace
*Includes Pt, Pd, and Rh.
[1]troy ounces/short ton.
[2]percent.
[3]milligram/kilogram.

Table 3.4. Additional elemental analyses, percent

| Sample | Description/Depth | Fe | Na | Ca | Mg | K | Al |
|---|---|---|---|---|---|---|---|
| 2321 | Cape Blanco/1 ft | 8.42 | 1.41 | 2.64 | 1.43 | 0.69 | 4.33 |
| 2324 | Cape Blanco/2 ft | 4.68 | 1.61 | 1.87 | 1.19 | 1.08 | 4.66 |
| 2331 | Gold Beach/3 ft | 5.08 | 1.53 | 1.99 | 3.24 | .81 | 5.28 |
| 2332 | Gold Beach/6 ft | 5.03 | 1.64 | 2.02 | 3.29 | .74 | 5.30 |
| 2333 | Gold Beach/9 ft | 5.32 | 1.61 | 2.11 | 3.10 | .71 | 5.01 |
| 2334 | Gold Beach/12 ft | 5.11 | 1.55 | 2.03 | 3.01 | .70 | 5.01 |
| 2335 | Gold Beach/15 ft | 4.22 | 1.62 | 1.76 | 2.93 | .65 | 4.87 |
| 2336 | Gold Beach/16 ft | 4.82 | 1.48 | 1.78 | 3.02 | .67 | 4.89 |
| 2338 | Rogue River/5 ft | 4.97 | 1.50 | 1.96 | 3.09 | .80 | 4.90 |
| 2339 | Rogue River/10 ft | 4.74 | 1.50 | 2.13 | 2.94 | .70 | 4.83 |
| 2340 | Rogue River/15 ft | 5.17 | 1.40 | 2.12 | 2.94 | .71 | 4.47 |
| 2341 | Rogue River/20 ft | 5.50 | 1.38 | 2.88 | 2.96 | .61 | 4.46 |
| 2342 | Cape Sebastian/1 ft | 7.74 | 1.46 | 2.64 | 3.20 | .65 | 4.54 |
| 2343 | Cape Sebastian/3 ft | 4.98 | 1.36 | 2.32 | 2.52 | .61 | 4.26 |
| 2344 | Cape Sebastian/6 ft | 4.29 | 1.64 | 2.03 | 2.14 | .67 | 4.27 |
| 2345 | Cape Sebastian/9 ft | 4.59 | 1.65 | 2.09 | 2.18 | .66 | 4.27 |
| 2346 | Cape Sebastian/12 ft | 5.05 | 1.61 | 2.07 | 2.20 | .76 | 4.18 |
| 2347 | Cape Sebastian/15 ft | 4.03 | 1.68 | 1.95 | 2.20 | .83 | 4.25 |
| 2348 | Cape Sebastian/17 ft | 6.60 | 1.58 | 2.53 | 2.48 | .54 | 4.61 |
| 2349 | Cape Sebastian/20 ft | 5.79 | 1.86 | 2.64 | 2.80 | .62 | 5.26 |
| 2350 | N Cape Sebastian/3 ft | 4.91 | 1.62 | 2.04 | 2.56 | .66 | 4.43 |
| 2351 | N Cape Sebastian/6 ft | 4.03 | 1.34 | 1.78 | 2.16 | .76 | 4.40 |
| 2352 | N Cape Sebastian/9 ft | 3.66 | 1.55 | 1.35 | 1.56 | .82 | 4.01 |
| 2353 | N Cape Sebastian/12 ft | 4.92 | 1.56 | 1.77 | 1.76 | .60 | 4.21 |
| 2354 | N Cape Sebastian/15 ft | 5.76 | 1.43 | 1.73 | 1.72 | .56 | 4.21 |
| 2355 | N Cape Sebastian/20 ft | 6.23 | 1.41 | 1.50 | 1.45 | .59 | 4.27 |

## SECTION 4.0

## MINERAL PROCESSING

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## SECTION 4.0

## MINERAL PROCESSING

### 4.1. Objectives and Technical Approach

The U.S. Bureau of Mines, Salt Lake City Research Center, conducted an investigation of 24 southwest Oregon placer samples to assess the potential for recovery of titanium-, chromium-, and zirconium-bearing heavy minerals and gold, silver, and platinum group metals (PGM) by mineral separation techniques.

The samples received from the Bureau's Albany Research Center were labeled Stations 1 through 5 and were collected from five locations, as follows:

Station 1 - Near Cape Blanco
Station 2 - Near Gold Beach
Station 3 - Near the Rogue River
Station 4 - Near Cape Sebastian
Station 5 - North of Cape Sebastian

All samples were recovered from the sea bottom by vibralift. The samples from Stations 2 through 5 were taken from sediment depths of approximately 1, 2, 3, 4, 5, and 6 meters (3, 6, 9, 12, 15, and 20 ft). Because the samples were collected by vibralift, some gold and platinum, if present, may have been lost because of their high specific gravities. Details of the sampling are provided elsewhere in this report.

Each sample was quantitatively analyzed for titanium, chromium, zirconium, and iron. Particle-size analysis was conducted on each sample to determine the size variability with regard to depth and location since this could impact on choices for physical separation techniques. The individual depth samples for each station were combined to form station composites. Each station composite was subjected to gravity concentration using a shaking table (Deister Table[1]) to recover the heavy minerals, e.g., ilmenite ($FeTiO_3$), rutile ($TiO_2$), zircon ($ZrSiO_4$), chromite ($Fe(Cr,Fe)_2O_4$), magnetite ($Fe_3O_4$), hematite ($Fe_2O_3$), etc, and heavy metals, e.g., gold, silver, and PGM. The table products were analyzed for the elements of interest.

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[1]Reference to specific products does not imply endorsement by the U.S. Bureau of Mines.

Gravity concentration was selected as the primary means to evaluate the potential for heavy mineral recovery from the sands. Gravity concentration methods utilize the differences in specific gravity between minerals to make the separations. No reagents or chemicals are used in the separation process. The heavier minerals usually contain the more valuable metals such as titanium, chromium, zirconium, gold, silver, and the PGM.

The shaking table is a bed-type gravity-separation machine for treatment of relatively fine materials and may be thought of as a mechanized continuous "gold pan" for producing high-grade gravity concentrate. The table consists of a rectangular or rhomboidal deck which is adjusted to a slight slope. The table, operated by a motor-driven cam, reciprocates in its own plane and imparts a pulsating action to the minerals as they flow across the table in a film of water. The heavy minerals gravitate toward the upper end of the table while the lighter material, in this case sand, is washed down and across the table and is removed as rejects or tailings. An intermediate specific gravity fraction, or middlings, is also commonly obtained which may be recycled for additional recovery. Table separation is also influenced by the size consistency of the mineral particles as well as specific gravity. In general, tabling is quite effective in concentrating heavy minerals down to about 270 mesh.

Recovery of titanium minerals usually involves separation of the heavy titanium-bearing minerals from lighter minerals such as quartz, feldspar, and mica by wet-gravity-separation methods. Equipment used includes spirals and pinched sluice separators of various designs, followed by tabling as described above. Ilmenite is the most abundant titanium mineral and has a specific gravity of 4.3 to 5.5. Pure ilmenite concentrates contain about 53 pct $TiO_2$; weathered ilmenites may contain up to 70 pct $TiO_2$. Rutile concentrates generally contain 95 pct $TiO_2$ (Lynd, 1985).

Titanium concentrates, produced from sand deposits in the United States, contain about 60 to 65 pct $TiO_2$, and concentrates produced from rock deposits in the United States contain 45 to 50 pct $TiO_2$ (Lynd, 1985). An approximate minimum requirement for an economic deposit of titanium minerals in the southeastern United States is an average grade (raw ore) of 1 pct $TiO_2$ and 3 to 4 pct total heavy mineral content. The average depth of the ore is 15 ft. In western Australia, where the deposits are much larger, the average grade of the ore is 0.5 pct $TiO_2$. In 1983, world production of titanium metal came 37 pct from rutile and 63 pct from ilmenite. Titanium dioxide pigment was produced mainly from ilmenite with significant amounts produced from other materials such as rutile and other nonmetal titanium-bearing products (Lynd, 1985).

Chromite is the major chromium-bearing mineral and has a specific gravity of 4.3 to 4.6. There is no primary production of chromium in the United States, and the United States has no economic chromium ore reserves. However, the United States has a reserve base and resources on land that could be exploited (Papp, 1988). The Bureau has conducted metallurgical tests on materials from these sources containing 5.2 to 20 pct $Cr_2O_3$. Gravity separation was able to produce a market-grade concentrate containing greater than 48 pct $Cr_2O_3$ from these sources (McDonald, 1990).

Zircon is the major zirconium-bearing mineral. The high specific gravity of zircon, 4.6 to 4.7, enables it to be concentrated with other heavy minerals such as ilmenite or rutile by gravity-separation methods. A clean zircon concentrate is produced from heavy-mineral concentrates using drying, screening, electrostatic, and electromagnetic separation processes. Zircon is nonconductive and can be separated from ilmenite, rutile, and other heavy minerals by electrostatic methods. A 99-pct $ZrSiO_4$ product is usually obtained (Adams, 1985).

Gold is recoverable from land-based deposits containing an average of 0.04 tr oz/st, and placer gravels yielding an average of 0.03 tr oz/$yd^3$ washed (about 0.02 to 0.04 tr oz/st depending on the density of the gravel) (Lucas, 1988).

PGM deposits are mostly associated with magmatic intrusions of mafic and ultramafic rock in which they occur in lode deposits. Placer deposits are fewer. In most of the deposits that are mined, the PGM values are co-recovered with nickel, copper, and cobalt. The Stillwater mine, located near Billings, MT, is the only PGM operation in the United States, and the concentrates are smelted and refined in Belgium (Loebenstein, 1985; Loebenstein, 1988).

## 4.2. Methods

The methods described in this section were used for characterization of the samples to determine the chemistry, mineralogy, size consistency, and beneficiation (physical concentration of the mineral values) potential. In general, the amenability of the sample to conventional mineral processing can be assessed from the results of these tests.

### 4.2.1. Chemistry and Mineralogy

Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) was used for titanium and zirconium analysis, and Atomic Absorption Spectrophotometry (AAS) was used for chromium and iron analysis. Assays were completed on all as-received samples and on table test products.

X-ray diffraction analysis was done on the table test concentrates to aid in determining the minerals present in the sands. The table test concentrates were assayed for gold, silver, and PGM by fire assay.

### 4.2.2. Size Distribution of Samples

Screen analyses were performed to determine the size distribution of each sample. A 200-g (wet weight) split of each sample was first wet screened at 270-mesh (53 %m). After drying the products, the plus 270-mesh fraction was dry screened on a nest of standard Tyler mesh sieves. The screen sizes were, in mesh size (in micrometers), 35 (420), 48 (297), 65 (210), 100 (149), 150 (105), 200 (74), and 270 (53). The minus 270-mesh (53 %m) products were combined, and the individual weight distributions and cumulative weight distributions were calculated.

The individual screen fractions for all depths at each station were combined to provide a sized composite product for each station hole. This was done because there was only a slight variation in size and chemistry between samples taken at various depths (for clarification, see discussion in Section 4.3.1 Results and Discussion - Chemical Analyses of Individual Samples), and because some of the screen fractions (of each sample) contained too little material to analyze separately. Chemical analysis was done on each composite screen fraction. This showed if the heavy minerals (metals) were contained predominately in specific screen fractions.

### 4.2.3. Preparation of Samples for Beneficiation Testing

Composite samples for the Deister Table tests were prepared by combining samples from all depths at each station to produce station composites. These composite samples were then split in half (Figure 4.1) for beneficiation testing. One split was beneficiated using a laboratory shaking table (Figure 4.2). The second split was reserved for potential future flotation testing.

### 4.2.4. Table Concentration Testing

A laboratory-size Deister Table and the procedure shown in Figure 4.2 were used to evaluate the potential for separation of the heavy minerals by gravity concentration. Approximately 14 kg (30 lb) of material was fed to the table in a water slurry for each test. A rougher concentrate containing predominantly heavy minerals was obtained, along with a middling fraction containing intermediate specific gravity minerals and sand tailings containing the light

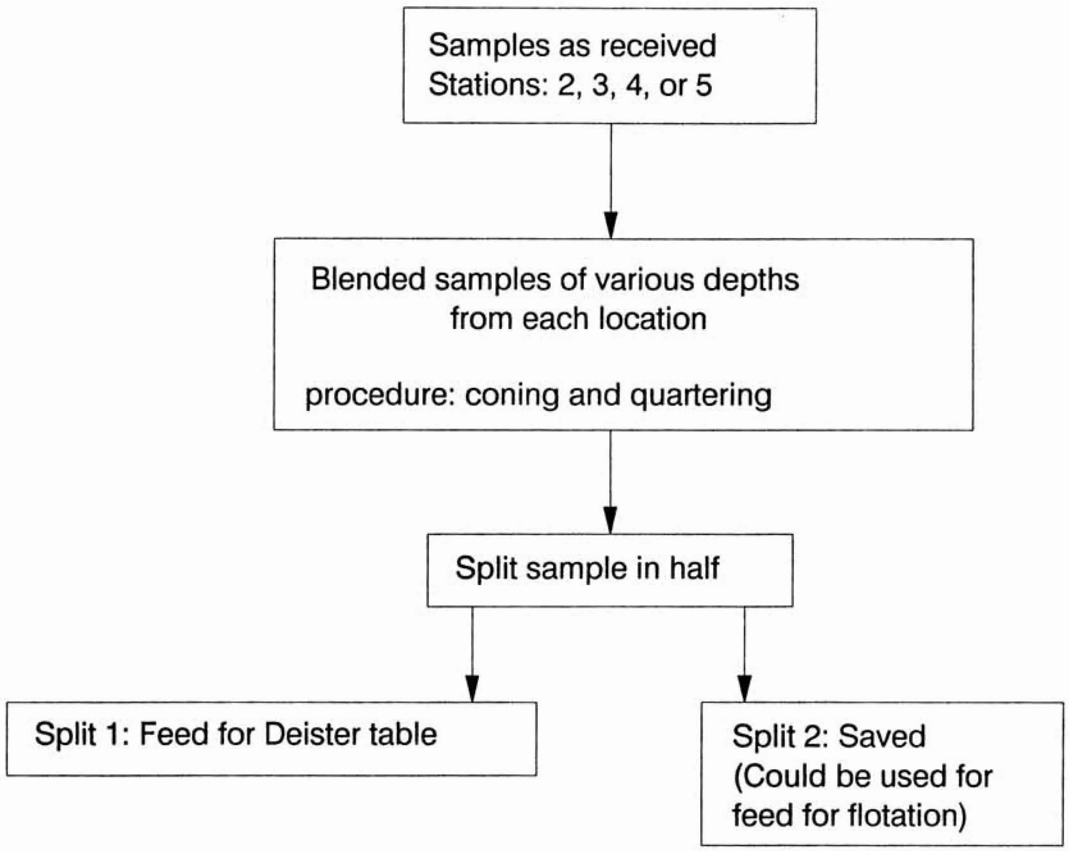


**FIGURE 4.1. Preparation of samples for processing.**

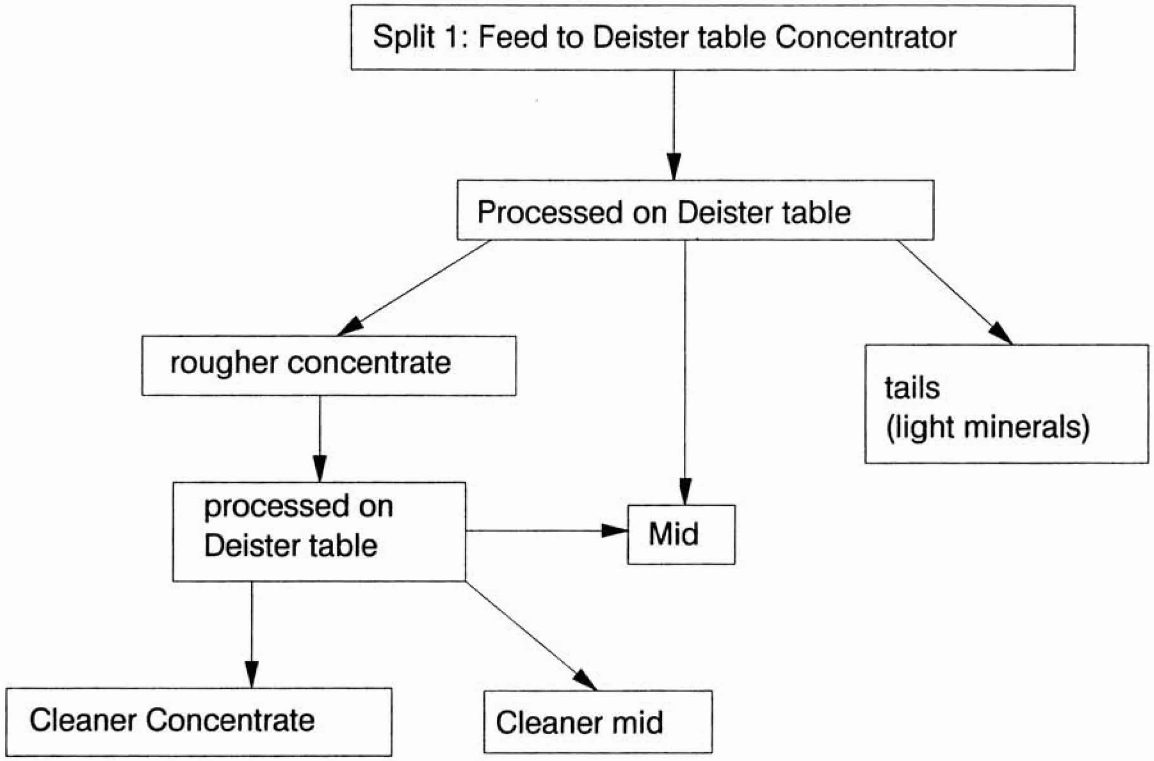


**FIGURE 4.2. Processing samples using the Deister table.**

minerals. The rougher concentrate was repassed on the table to produce a final heavy mineral concentrate product (cleaner concentrate product), a cleaner middling product, and cleaner tailings. The cleaner tailings and the rougher middling were combined to form a middling product. In practice, the middling products would generally be recirculated back to the circuit for additional minerals recovery.

#### 4.2.5. Magnetic Separation

The potential of using low-intensity magnetic separation to beneficiate the material was assessed by using the Davis Tube. This device has an electromagnet which holds the magnetic fraction in the tube. Water is passed continuously through the tube. The tube agitates the sample in a rotating and up-and-down action. The nonmagnetic fraction is carried out of the tube with the water.

In this test work, a 10-g charge was placed in the tube. The products, a magnetic and a nonmagnetic fraction, were assayed for titanium, chromium, and iron.

### 4.3. Results and Discussion

This section gives the results of the physical and chemical characterization of the samples and an assessment of their amenability to mineral processing techniques.

#### 4.3.1. Chemical Analysis of Individual Samples

Bulk assays for each sample, as received, are shown in Table 4.1. The only sample containing potentially commercial amounts of heavy minerals is the Cape Blanco sample which analyzed 3.3 pct Ti or 5.5 pct $TiO_2$. All other samples have much lower amounts of titanium with $TiO_2$ content ranging between 0.33 to 0.63 pct. The chromium and zirconium content are too low in all samples to be of interest.

In studying samples from Stations 2 through 5, there is little variation in the analysis of $TiO_2$ with depth. The largest variation was in samples from Station 4 with $TiO_2$ ranging from 0.63 to 1.07 pct. It was concluded that the samples representing various depths could be combined and used as a single sample for the Deister Table separation study.

It should be noted that the sum of the bulk assays for $TiO_2$ reported in this chapter differ from those obtained on separate sample splits which were reported in the Mineralogy and Geochemistry chapter, Chapter 3. The reason is not known at this time, but work is in progress to resolve the discrepancies. However, the assays reported in Table 4.1 compare favorably with the calculated head assays in

# Table 4.1. Chemical Analysis of Oregon Placer Samples

Station 1: Cape Blanco

| ID number | Depth, ft | Analysis, pct | | | | Calculated analysis, pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ti | Cr | Zr | Fe | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| ME-2321 | 2 | 3.32 | 0.83 | 0.038 | 8.09 | 5.54 | 1.21 | 0.05 | 11.57 |

Station 2: Gold Beach

| ID number | Depth, ft | Analysis, pct | | | | Calculated analysis, pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ti | Cr | Zr | Fe | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| ME-2331 | 3 | 0.49 | 0.15 | 0.011 | 5.6 | 0.82 | 0.22 | 0.01 | 8.01 |
| ME-2332 | 6 | 0.42 | 0.12 | <0.008 | 4.58 | 0.71 | 0.18 | <0.01 | 6.55 |
| ME-2333 | 9 | 0.47 | 0.15 | <0.008 | 4.99 | 0.78 | 0.22 | <0.01 | 7.14 |
| ME-2334 | 12 | 0.41 | 0.15 | <0.008 | 4.67 | 0.69 | 0.22 | <0.01 | 6.68 |
| ME-2335 | 15 | 0.34 | 0.08 | <0.008 | 4.06 | 0.57 | 0.12 | <0.01 | 5.81 |
| ME-2336 | 16 | 0.33 | 0.08 | 0.011 | 3.87 | 0.56 | 0.12 | 0.01 | 5.53 |

Station 3: Rogue River

| ID number | Depth, ft | Analysis, pct | | | | Calculated analysis, pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ti | Cr | Zr | Fe | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| ME-2338 | 5 | 0.42 | 0.14 | 0.008 | 4.09 | 0.69 | 0.20 | 0.01 | 5.85 |
| ME-2339 | 10 | 0.46 | 0.19 | <0.008 | 5.16 | 0.77 | 0.28 | <0.01 | 7.38 |
| ME-2340 | 15 | 0.50 | 0.22 | 0.008 | 5.39 | 0.84 | 0.32 | 0.01 | 7.71 |
| ME-2341 | 20 | 0.51 | 0.19 | 0.008 | 5.57 | 0.85 | 0.28 | 0.01 | 7.97 |

Station 4: Cape Sebastian

| ID number | Depth, ft | Analysis, pct | | | | Calculated analysis, pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ti | Cr | Zr | Fe | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| ME-2343 | 3 | 0.44 | 0.19 | <0.008 | 4.63 | 0.73 | 0.28 | <0.01 | 6.62 |
| ME-2344 | 6 | 0.38 | 0.12 | 0.01 | 3.96 | 0.63 | 0.18 | 0.01 | 5.66 |
| ME-2345 | 9 | 0.50 | 0.16 | <0.008 | 4.97 | 0.83 | 0.23 | <0.01 | 7.11 |
| ME-2346 | 12 | 0.45 | 0.12 | <0.008 | 4.49 | 0.75 | 0.18 | <0.01 | 6.42 |
| ME-2347 | 15 | 0.38 | 0.12 | <0.008 | 4.19 | 0.64 | 0.18 | <0.01 | 5.99 |
| ME-2348 | 17 | 0.63 | 0.17 | <0.008 | 6.16 | 1.06 | 0.25 | <0.01 | 8.81 |
| ME-2349 | 20 | 0.64 | 0.17 | 0.01 | 5.78 | 1.07 | 0.25 | 0.01 | 8.27 |

Station 5: North Cape Sebastian

| ID number | Depth, ft | Analysis, pct | | | | Calculated analysis, pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Ti | Cr | Zr | Fe | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| ME-2350 | 3 | 0.34 | 0.1 | <0.008 | 3.83 | 0.57 | 0.15 | <0.01 | 5.48 |
| ME-2351 | 6 | 0.35 | 0.11 | 0.017 | 3.87 | 0.59 | 0.16 | 0.02 | 5.53 |
| ME-2352 | 9 | 0.48 | 0.25 | 0.009 | 4.8 | 0.79 | 0.37 | 0.01 | 6.86 |
| ME-2353 | 12 | 0.46 | 0.11 | 0.009 | 4.86 | 0.77 | 0.16 | 0.01 | 6.95 |
| ME-2354 | 15 | 0.60 | 0.17 | 0.008 | 5.79 | 1.01 | 0.25 | 0.01 | 8.28 |
| ME-2355 | 20 | 0.55 | 0.15 | 0.011 | 5.61 | 0.93 | 0.22 | 0.01 | 8.02 |

Note: Assays for Ti and Zr by inductively coupled plasma-atomic emission spectroscopy
assays for Cr and Fe by atomic absorbtion spectrophotometry

subsequent tables, Table 4.3 and 4.4, and thus, the results in this chapter appear to be internally consistent.

### 4.3.2. Size Distributions of Individual Samples

Each of the "as is" received samples was screened, and the size distributions are given in Table 4.2. Figures 4.3 through 4.8 present the data graphically. These figures, with the exception of Station 1 which was not sampled by depth, show that the size distribution at each station varies only slightly with depth. Further, Stations 2 through 5 have very similar size distributions with the bulk of the material in the 48 x 200-mesh size range (see Figure 4.8). Typical heavy minerals in sands of this size consistency would be ideally suited for gravity concentration. All samples, as received, contained only about 1 wt pct finer than 270 mesh. However, it is conceivable that the fines may have been lost during vibralift sampling. Because so little minus 270-mesh material was present, the decision was made not to conduct froth flotation testing for fine gold, silver, or PGM.

Figures 4.3 and 4.8 (Station 1 - Cape Blanco sample) show that the size distribution of this sample is somewhat finer than the samples from the other four stations with most of the material being 65 x 200 mesh. This is still well within the range where gravity-separation techniques should be effective. Only 0.86 pct of the material is finer than 270 mesh.

### 4.3.3. Chemistry of Size Fractions

Analyses on the composite samples (depth samples were combined for each station) show that the $TiO_2$ values are concentrated in the 150 X 200-mesh and 200 X 270-mesh fractions, Table 4.3. The assays of the 150 X 200-mesh fraction for the Cape Blanco station were 16 pct $TiO_2$ and 4.1 pct $Cr_2O_3$, and the assays of the 200 X 270-mesh fraction for Cape Blanco was 25.2 pct $TiO_2$, and 5.0 pct $Cr_2O_3$. These assays were much higher than were the other four stations. These stations ranged between 2.77 to 4.78 pct $TiO_2$, and 1.17 to 4.07 pct $Cr_2O_3$. These results suggest that the Cape Blanco sample could be beneficiated by sizing and gravity concentration.

### 4.3.4. Gravity Concentration

Deister Table tests were performed on the Station 1 sample and on composite samples from Stations 2 through 5. The composite samples were made by combining the individual samples taken at different depths from each station. The results of the Deister Table tests are shown in Table 4.4. Station 1 contained a larger quantity of heavy minerals than the other four stations. The cleaner concentrate for

# Table 4.2. Size Distributions of Oregon Placer Samples

Station 1: Cape Blanco

| Sample No. | ME-2321 | |
|---|---|---|
| Screen size, mesh | Wt pct | Wt dist'n pct finer |
| +35 | 0.01 | 99.99 |
| 35X48 | 0.07 | 99.92 |
| 48X65 | 0.92 | 99.00 |
| 65X100 | 32.46 | 66.54 |
| 100X150 | 49.78 | 16.77 |
| 150X200 | 13.99 | 2.78 |
| 200X270 | 1.91 | 0.86 |
| -270 | 0.86 | 0.00 |

Station 2: Gold Beach

| Sample No. | ME-2331 | | ME-2332 | | ME-2333 | | ME-2334 | | ME-2335 | | ME-2336 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample depth | 3 ft | | 6 ft | | 9 ft | | 12 ft | | 15 ft | | 16 ft | |
| Screen size, mesh | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer |
| +35 | 0.81 | 99.19 | 0.44 | 99.56 | 0.63 | 99.37 | 0.71 | 99.29 | 0.51 | 99.49 | 0.36 | 99.64 |
| 35X48 | 0.15 | 99.03 | 3.20 | 96.37 | 2.99 | 96.38 | 3.03 | 96.26 | 2.45 | 97.05 | 1.75 | 97.89 |
| 48X65 | 10.80 | 88.24 | 21.20 | 75.17 | 19.37 | 77.01 | 20.79 | 75.47 | 18.67 | 78.37 | 15.79 | 82.10 |
| 65X100 | 48.19 | 40.05 | 50.68 | 24.48 | 49.84 | 27.17 | 52.32 | 23.15 | 55.39 | 22.99 | 55.59 | 26.51 |
| 100X150 | 32.54 | 7.52 | 21.28 | 3.20 | 22.30 | 4.87 | 20.66 | 2.49 | 20.51 | 2.48 | 23.05 | 3.46 |
| 150X200 | 6.13 | 1.39 | 2.49 | 0.71 | 3.65 | 1.22 | 1.89 | 0.60 | 2.02 | 0.45 | 2.45 | 1.01 |
| 200X270 | 0.12 | 1.26 | 0.29 | 0.42 | 0.46 | 0.77 | 0.34 | 0.25 | 0.15 | 0.30 | 0.37 | 0.64 |
| -270 | 1.26 | 0.00 | 0.42 | 0.00 | 0.77 | 0.00 | 0.25 | 0.00 | 0.30 | 0.00 | 0.64 | 0.00 |

Station 3: Rogue River

| Sample No. | ME-2338 | | ME-2339 | | ME-2340 | | ME-2341 | |
|---|---|---|---|---|---|---|---|---|
| Sample depth | 5 ft | | 10 ft | | 15 ft | | 20 ft | |
| Screen size, mesh | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer |
| +35 | 0.20 | 99.80 | 0.16 | 99.84 | 0.51 | 99.49 | 1.53 | 98.47 |
| 35X48 | 0.46 | 99.34 | 0.25 | 99.58 | 0.57 | 98.92 | 1.44 | 97.02 |
| 48X65 | 6.30 | 93.04 | 3.21 | 96.37 | 3.72 | 95.20 | 3.10 | 93.92 |
| 65X100 | 63.30 | 29.74 | 53.21 | 43.16 | 52.83 | 42.37 | 48.32 | 45.60 |
| 100X150 | 24.43 | 5.31 | 36.18 | 6.98 | 35.25 | 7.13 | 37.61 | 7.99 |
| 150X200 | 4.28 | 1.03 | 5.60 | 1.38 | 5.72 | 1.41 | 6.61 | 1.38 |
| 200X270 | 0.51 | 0.52 | 0.62 | 0.76 | 0.65 | 0.76 | 0.80 | 0.57 |
| -270 | 0.52 | 0.00 | 0.76 | 0.00 | 0.76 | 0.00 | 0.57 | 0.00 |

## Table 4.2. Size Distributions of Oregon Placer Samples continued

Station 4: Cape Sebastian

| Sample No. | ME-2343 | | ME-2344 | | ME-2345 | | ME-2346 | | ME-2347 | | ME-2348 | | ME-2349 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample depth | 3 ft | | 6 ft | | 9 ft | | 12 ft | | 15 ft | | 17 ft | | 20 ft | |
| Screen size, mesh | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer |
| +35 | 0.13 | 99.87 | 0.09 | 99.91 | 0.07 | 99.93 | 0.03 | 99.97 | 0.04 | 99.96 | 0.18 | 99.82 | 0.17 | 99.83 |
| 35X48 | 0.55 | 99.31 | 0.42 | 99.49 | 0.53 | 99.40 | 0.57 | 99.40 | 0.59 | 99.38 | 0.62 | 99.20 | 0.42 | 99.40 |
| 48X65 | 8.25 | 91.06 | 7.50 | 91.99 | 8.17 | 91.23 | 9.42 | 89.98 | 9.76 | 89.61 | 8.65 | 90.54 | 5.26 | 94.14 |
| 65X100 | 54.88 | 36.18 | 55.69 | 36.29 | 51.79 | 39.44 | 52.13 | 37.85 | 55.74 | 33.87 | 48.67 | 41.87 | 45.90 | 48.25 |
| 100X150 | 30.51 | 5.67 | 31.07 | 5.22 | 33.31 | 6.13 | 31.70 | 6.14 | 28.39 | 5.48 | 34.31 | 7.56 | 39.33 | 8.92 |
| 150X200 | 4.78 | 0.88 | 4.45 | 0.78 | 5.20 | 0.94 | 5.13 | 1.01 | 4.45 | 1.03 | 6.49 | 1.07 | 7.53 | 1.39 |
| 200X270 | 0.38 | 0.50 | 0.35 | 0.43 | 0.51 | 0.42 | 0.53 | 0.48 | 0.48 | 0.55 | 0.72 | 0.35 | 1.14 | 0.25 |
| -270 | 0.50 | 0.00 | 0.43 | 0.00 | 0.42 | 0.00 | 0.48 | 0.00 | 0.55 | 0.00 | 0.35 | 0.00 | 0.25 | 0.00 |

Station 5: North Cape Sebastian

| Sample No. | ME-2350 | | ME-2351 | | ME-2352 | | ME-2353 | | ME-2354 | | ME-2355 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample depth | 3 ft | | 6 ft | | 9 ft | | 12 ft | | 15 ft | | 20 ft | |
| Screen size, mesh | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer | Wt pct | Wt dist'n pct finer |
| +35 | 0.15 | 99.85 | 0.06 | 99.94 | 0.21 | 99.79 | 0.11 | 99.89 | 0.08 | 99.92 | 0.17 | 99.83 |
| 35X48 | 0.48 | 99.37 | 0.32 | 99.62 | 0.80 | 98.99 | 0.42 | 99.47 | 0.44 | 99.48 | 0.41 | 99.42 |
| 48X65 | 8.03 | 91.34 | 8.56 | 91.06 | 11.36 | 87.63 | 8.80 | 90.67 | 7.66 | 91.82 | 8.95 | 90.47 |
| 65X100 | 54.01 | 37.33 | 55.47 | 35.58 | 54.46 | 33.17 | 56.56 | 34.11 | 53.81 | 38.01 | 55.67 | 34.79 |
| 100X150 | 30.87 | 6.46 | 30.47 | 5.11 | 28.10 | 5.06 | 29.71 | 4.40 | 31.67 | 6.34 | 29.26 | 5.53 |
| 150X200 | 4.93 | 1.53 | 3.95 | 1.16 | 4.24 | 0.82 | 3.60 | 0.80 | 5.35 | 0.98 | 4.68 | 0.85 |
| 200X270 | 0.84 | 0.70 | 0.55 | 0.61 | 0.43 | 0.39 | 0.37 | 0.43 | 0.64 | 0.34 | 0.47 | 0.38 |
| -270 | 0.70 | 0.00 | 0.61 | 0.00 | 0.39 | 0.00 | 0.43 | 0.00 | 0.34 | 0.00 | 0.38 | 0.00 |

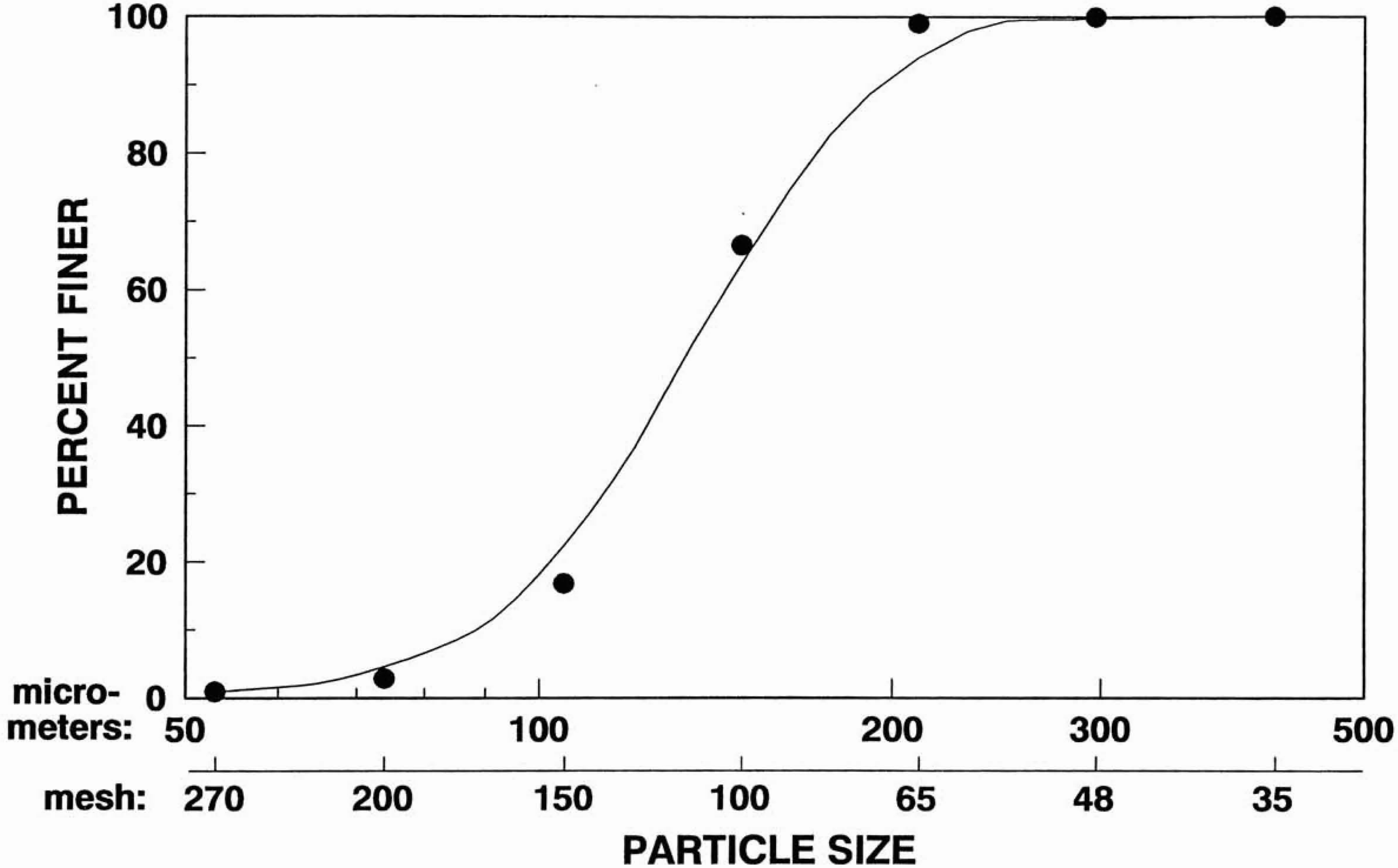


FIGURE 4.3 Particle size distribution of the sample taken from Station 1 (Cape Blanco).

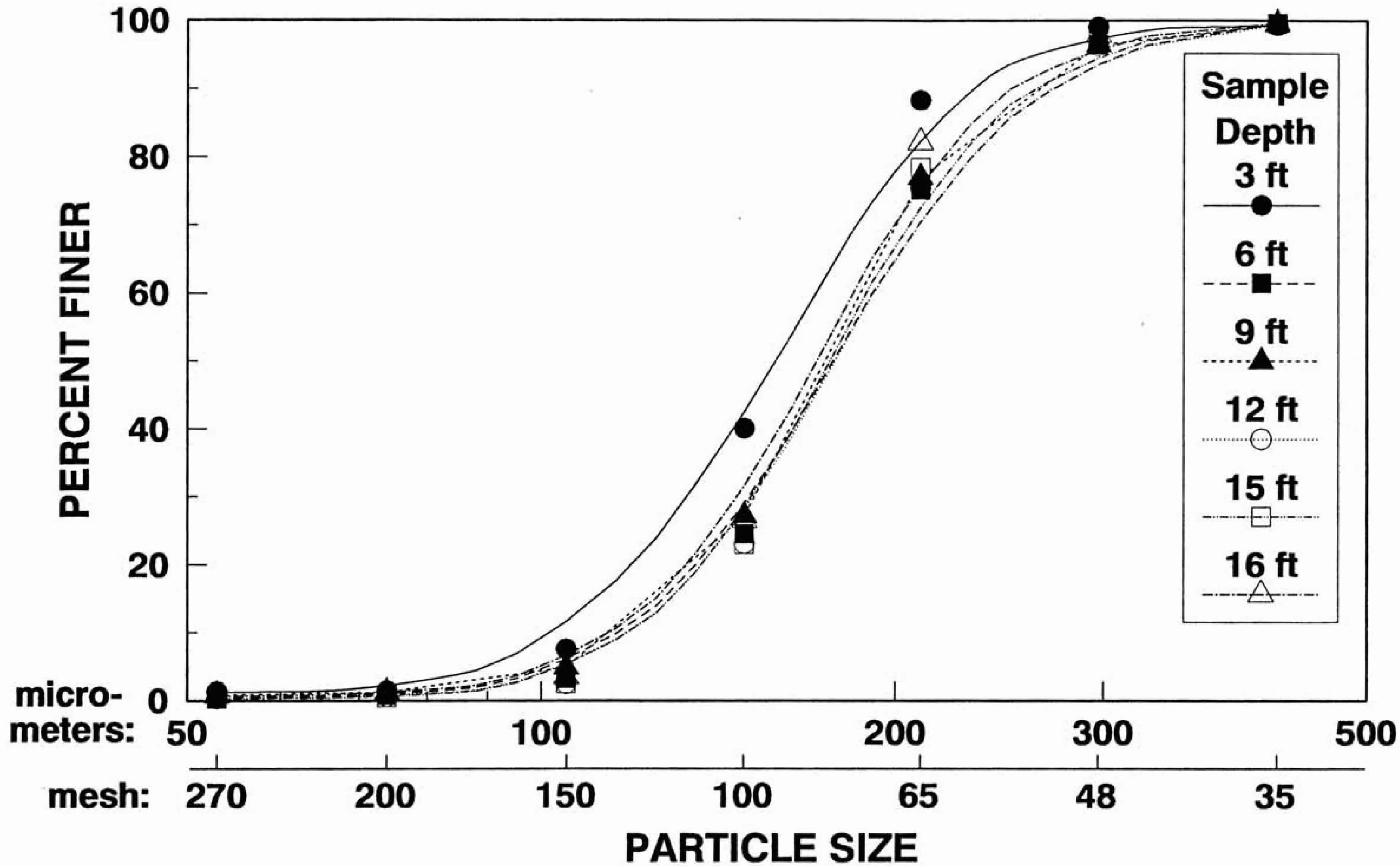


**FIGURE 4.4 Particle size distributions for the samples taken from Station 2 (Gold Beach).**

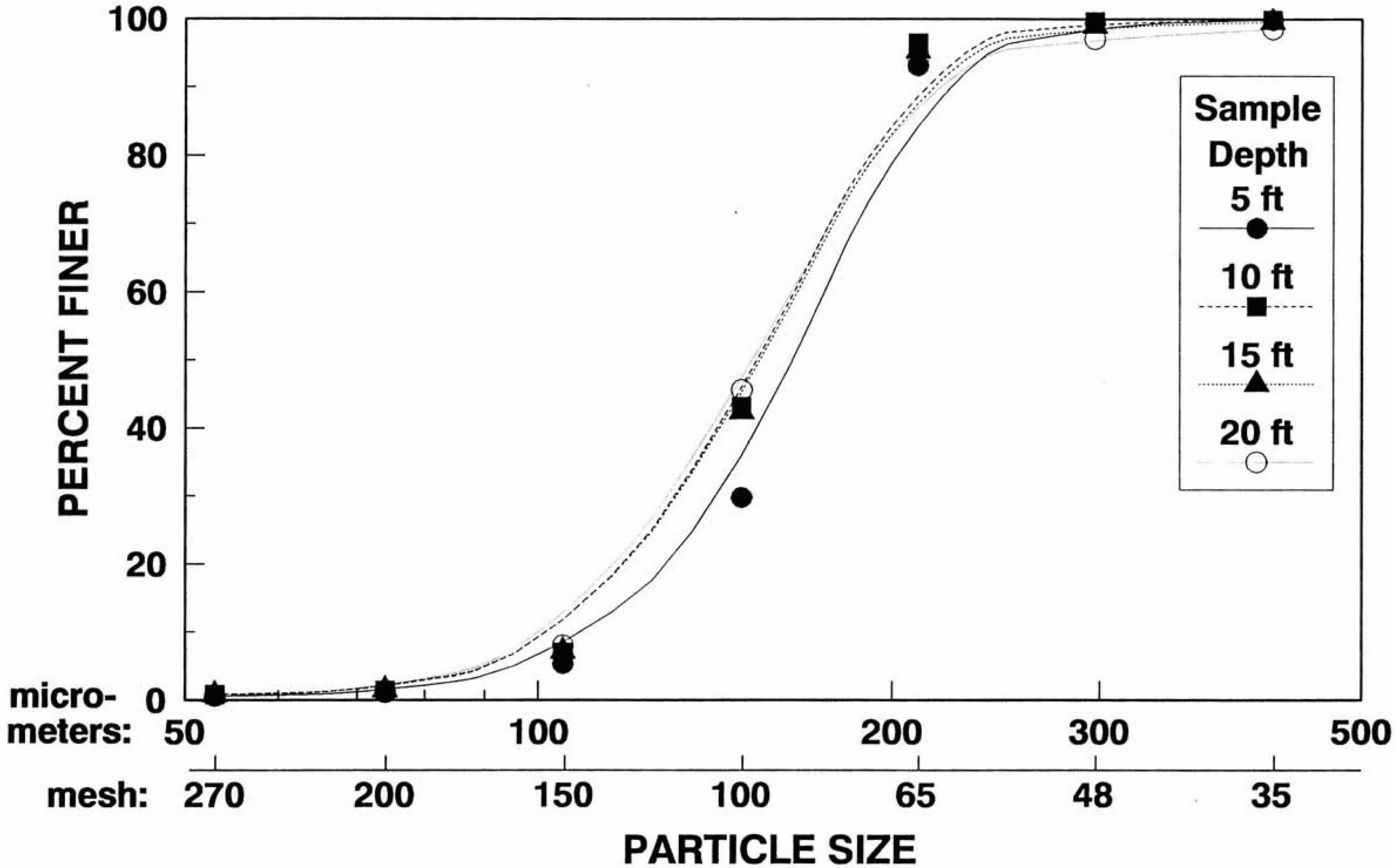


**FIGURE 4.5 Particle size distributions for the samples taken from Station 3 (Rogue River).**

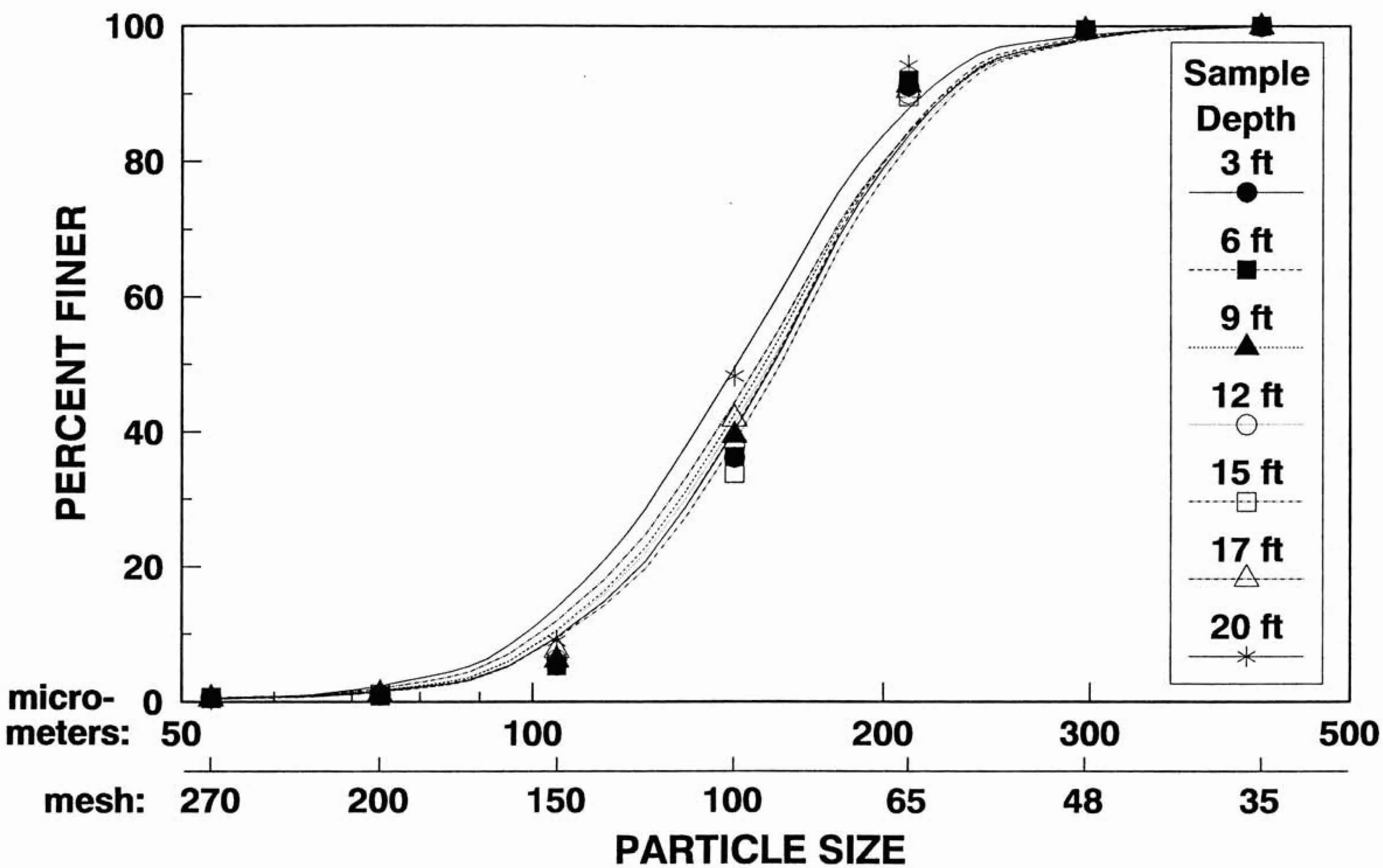


**FIGURE 4.6. Particle size distributions for the samples taken from Station 4 (Cape Sebastian).**

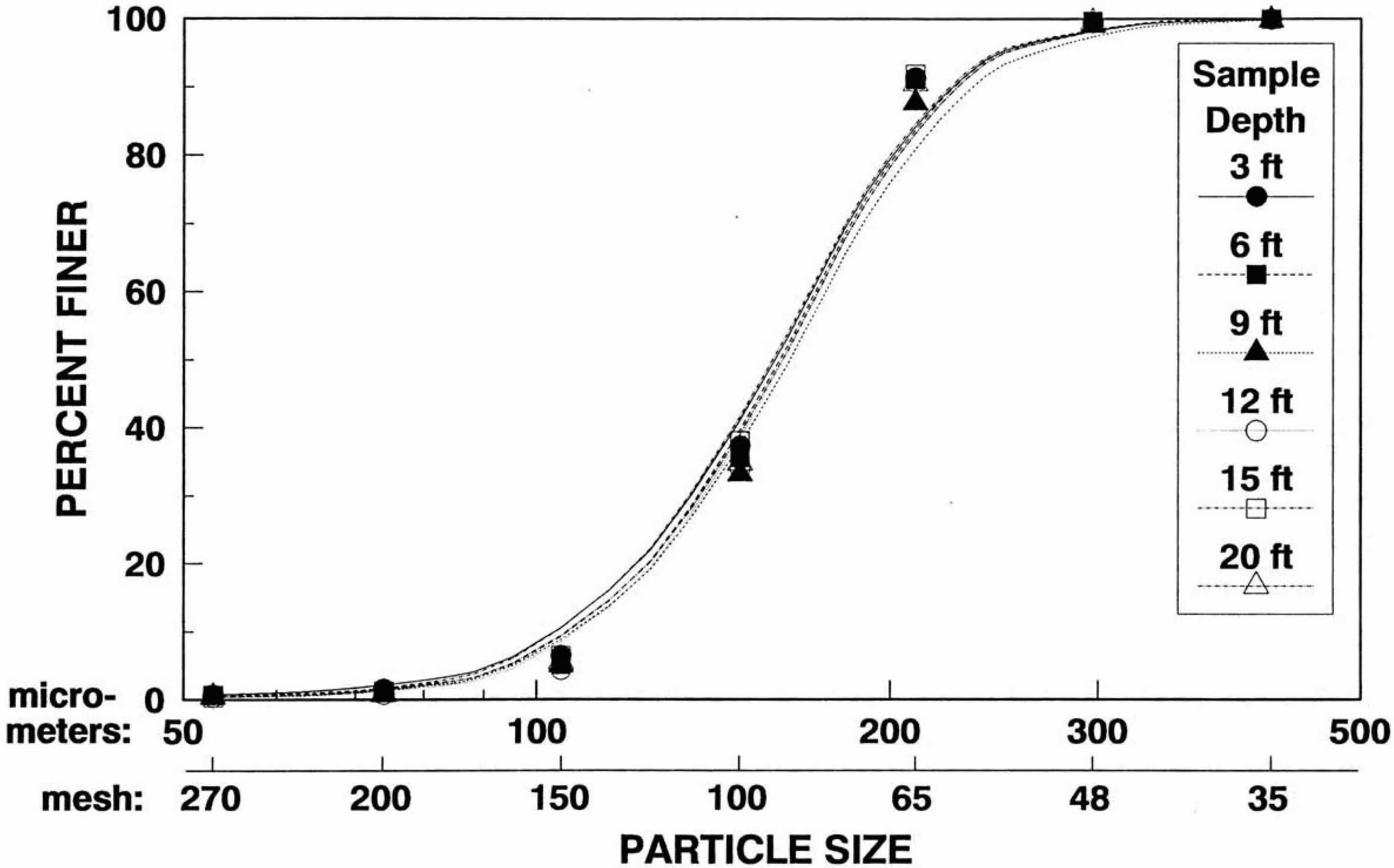


**FIGURE 4.7 Particle size distributions for the samples taken from Station 5 (North Cape Sebastian).**

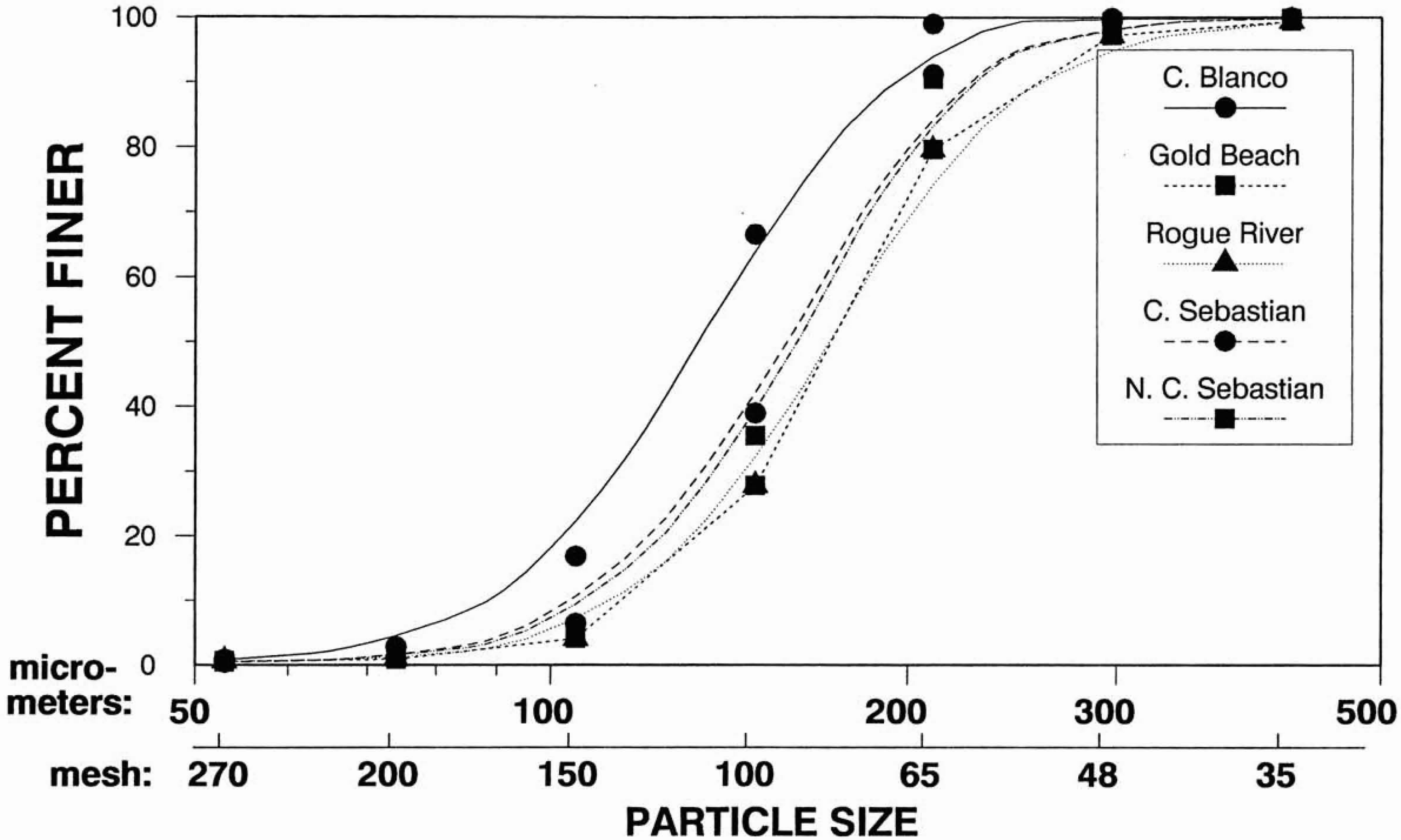


**FIGURE 4.8 Comparison of Particle size distribution for all stations**

## Table 4.3. Chemistry of Size Fractions

Station 1: Cape Blanco
Sample No. ME-2321

| Screen size, mesh | Wt pct | Analysis, pct | | | | Unit distribution,pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | TiO2 | Cr2O3 | ZrO2 | Fe2O3 | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| 35X65 | 1.00 | 0.21 | 0.05 | 0.00 | 1.17 | 0.06 | 0.05 | 0.00 | 0.17 |
| 65X100 | 32.46 | 0.30 | 0.04 | 0.00 | 2.06 | 2.57 | 1.26 | 0.00 | 9.78 |
| 100X150 | 49.78 | 1.89 | 0.44 | 0.00 | 5.18 | 24.77 | 24.10 | 0.00 | 37.69 |
| 150X200 | 13.99 | 16.03 | 4.09 | 0.07 | 19.73 | 59.14 | 63.24 | 63.28 | 40.39 |
| 200X270 | 1.91 | 25.22 | 5.02 | 0.28 | 39.04 | 12.71 | 10.61 | 34.91 | 10.92 |
| -270 | 0.86 | 3.31 | 0.77 | 0.03 | 8.34 | 0.75 | 0.74 | 1.80 | 1.05 |
| Totals | 100.00 | 3.79 | 0.90 | 0.02 | 6.84 | 100 | 100 | 100 | 100 |
| Head assay | | 5.54 | 1.21 | 0.05 | 11.57 | | | | |

Station 2: Gold Beach - Composite
Sample No. ME-2331 to ME-2336

| Screen size, mesh | Wt pct | Analysis, pct | | | | Unit distribution,pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | TiO2 | Cr2O3 | ZrO2 | Fe2O3 | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| +35 | 0.57 | 0.37 | 0.06 | 0.00 | 3.83 | 0.34 | 0.22 | 0.00 | 0.45 |
| 35X48 | 2.26 | 0.38 | 0.07 | 0.00 | 4.06 | 1.39 | 1.04 | 0.00 | 1.87 |
| 48X65 | 17.77 | 0.36 | 0.05 | 0.00 | 3.60 | 10.36 | 5.45 | 0.00 | 13.07 |
| 65X100 | 52.00 | 0.45 | 0.08 | 0.00 | 3.93 | 37.56 | 25.91 | 0.00 | 41.74 |
| 100X150 | 23.39 | 0.90 | 0.25 | 0.00 | 6.38 | 33.67 | 38.10 | 0.00 | 30.45 |
| 150X200 | 3.11 | 2.79 | 1.17 | 0.00 | 14.87 | 13.88 | 23.81 | 0.00 | 9.43 |
| 200X270 | 0.29 | 3.72 | 2.34 | 0.01 | 33.18 | 1.73 | 4.44 | 100.00 | 1.96 |
| -270 | 0.61 | 1.11 | 0.26 | 0.00 | 8.22 | 1.08 | 1.05 | 0.00 | 1.02 |
| Totals | 100 | 0.62 | 0.15 | 0.00 | 4.90 | 100.00 | 100.00 | 100.00 | 100.00 |
| Head assay | | 0.67 | 0.18 | 0.01 | 6.42 | | | | |

## Table 4.3. Chemistry of Size Fractions
## Continued

Station 3: Rogue River - Composite
Sample No. ME-2338 to ME-2341

| Screen size, | | Analysis, pct | | | | Unit distribution,pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| mesh | Wt pct | TiO2 | Cr2O3 | ZrO2 | Fe2O3 | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| +35 | 0.60 | 0.34 | 0.18 | 0.01 | 4.33 | 0.31 | 0.38 | 3.76 | 0.37 |
| 35X48 | 0.68 | 0.45 | 0.45 | 0.00 | 5.36 | 0.45 | 1.12 | 0.00 | 0.52 |
| 48X65 | 4.08 | 0.38 | 0.13 | 0.00 | 5.02 | 2.29 | 1.94 | 0.00 | 2.93 |
| 65X100 | 54.41 | 0.42 | 0.05 | 0.00 | 4.79 | 33.59 | 9.21 | 0.00 | 37.21 |
| 100X150 | 33.37 | 0.71 | 0.18 | 0.00 | 7.25 | 35.10 | 21.19 | 0.00 | 34.53 |
| 150X200 | 5.55 | 2.77 | 2.79 | 0.02 | 24.31 | 22.76 | 56.13 | 65.26 | 19.27 |
| 200X270 | 0.65 | 4.78 | 4.07 | 0.05 | 45.62 | 4.56 | 9.54 | 19.74 | 4.21 |
| -270 | 0.65 | 0.98 | 0.20 | 0.03 | 10.40 | 0.94 | 0.48 | 11.24 | 0.97 |
| Totals | 100 | 0.68 | 0.28 | 0.00 | 7.01 | 100.00 | 100.00 | 100.00 | 100.00 |
| Head assay | | 0.78 | 0.27 | 0.01 | 7.1 | | | | |

Station 4: Cape Sebastian - Composite
Sample No. ME-2343 to ME-2349

| Screen size, | | Analysis, pct | | | | Unit distribution,pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| mesh | Wt pct | TiO2 | Cr2O3 | ZrO2 | Fe2O3 | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| +35 | 0.10 | 0.43 | 0.20 | 0.02 | 4.12 | 0.00 | 0.07 | 1.24 | 0.05 |
| 35X48 | 0.53 | 0.33 | 0.04 | 0.04 | 3.78 | 0.01 | 0.06 | 12.62 | 0.26 |
| 48X65 | 8.15 | 0.28 | 0.03 | 0.00 | 3.99 | 1.71 | 0.83 | 0.00 | 4.27 |
| 65X100 | 52.12 | 0.37 | 0.06 | 0.00 | 4.50 | 70.01 | 10.60 | 0.00 | 30.86 |
| 100X150 | 32.66 | 0.84 | 0.22 | 0.00 | 8.28 | 27.50 | 24.91 | 0.00 | 35.55 |
| 150X200 | 5.43 | 4.07 | 3.02 | 0.02 | 34.18 | 0.76 | 57.17 | 62.46 | 24.41 |
| 200X270 | 0.59 | 4.66 | 2.80 | 0.05 | 51.62 | 0.01 | 5.73 | 17.37 | 3.99 |
| -270 | 0.43 | 1.09 | 0.42 | 0.02 | 10.64 | 0.00 | 0.63 | 6.31 | 0.60 |
| Totals | 100 | 0.75 | 0.29 | 0.00 | 7.61 | 100.00 | 100.00 | 100.00 | 100.00 |
| Head assay | | 0.79 | 0.21 | 0.00 | 6.82 | | | | |

# Table 4.3. Chemistry of Size Fractions
## Continued

Station 5: North Cape Sebastian - Composite
Sample No. ME-2350 to ME2355

| Screen size, mesh | Wt pct | Analysis, pct | | | | Unit distribution,pct | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | TiO2 | Cr2O3 | ZrO2 | Fe2O3 | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
| +35 | 0.13 | 0.43 | 0.04 | 0.00 | 4.56 | 0.07 | 0.02 | 0.00 | 0.08 |
| 35X48 | 0.48 | 0.37 | 0.04 | 0.01 | 4.23 | 0.23 | 0.09 | 9.38 | 0.28 |
| 48X65 | 8.89 | 0.37 | 0.04 | 0.00 | 4.85 | 4.33 | 1.68 | 0.00 | 5.95 |
| 65X100 | 55.00 | 0.41 | 0.03 | 0.00 | 4.85 | 29.80 | 7.41 | 0.00 | 36.77 |
| 100X150 | 30.02 | 0.87 | 0.22 | 0.00 | 7.18 | 34.52 | 30.31 | 0.00 | 29.71 |
| 150X200 | 4.46 | 4.71 | 2.69 | 0.01 | 39.04 | 27.69 | 55.22 | 63.62 | 24.00 |
| 200X270 | 0.55 | 3.71 | 1.87 | 0.02 | 34.03 | 2.69 | 4.73 | 17.63 | 2.58 |
| -270 | 0.48 | 1.05 | 0.25 | 0.01 | 9.65 | 0.66 | 0.55 | 9.36 | 0.63 |
| Totals | 100 | 0.76 | 0.22 | 0.00 | 7.25 | 100.00 | 100.00 | 100.00 | 100.00 |
| Head assay | | 0.77 | 0.21 | 0.01 | 6.83 | | | | |

## Table 4.4. Oregon Placer Tabling Product Analyses

### Station 1: Cape Blanco

| Product | Wt. dist. pct | Analysis, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 | Distribution, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|---|---|---|---|---|
| Cleaner concentrate | 10.0 | 31.40 | 7.14 | 0.18 | 49.91 | 67.88 | 67.86 | 54.77 | 48.21 |
| Cleaner middlings | 2.0 | 21.21 | 8.67 | 0.09 | 32.32 | 9.17 | 16.49 | 5.31 | 6.24 |
| Middlings | 13.8 | 4.84 | 1.04 | 0.02 | 13.48 | 14.45 | 13.60 | 9.59 | 17.98 |
| Final tailings | 74.2 | 0.53 | 0.03 | 0.01 | 3.85 | 8.49 | 2.06 | 30.33 | 27.57 |

| | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|
| Calculated head | 4.62 | 1.05 | 0.03 | 10.35 |
| Analyzed head | 5.54 | 1.21 | 0.05 | 11.57 |
| Mass balance | 83.42 | 86.82 | 64.38 | 89.48 |

### Station 2: Gold Beach

| Product | Wt. dist. pct | Analysis, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 | Distribution, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|---|---|---|---|---|
| Cleaner concentrate | 1.1 | 9.32 | 7.74 | 0.06 | 66.07 | 15.83 | 58.24 | 3.82 | 11.18 |
| Cleaner middlings | 3.6 | 2.19 | 0.69 | 0.01 | 16.59 | 12.16 | 16.90 | 2.78 | 9.18 |
| Middlings | 66.8 | 0.52 | 0.04 | 0.02 | 5.61 | 53.57 | 18.02 | 67.01 | 57.58 |
| Final tailings | 28.5 | 0.42 | 0.04 | 0.02 | 5.03 | 18.45 | 6.83 | 26.39 | 22.06 |

| | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|
| Calculated head | 0.65 | 0.15 | 0.02 | 6.50 |
| Analyzed head | 0.67 | 0.19 | 0.02 | 6.82 |
| Mass balance | 96.00 | 77.00 | 71.99 | 95.34 |

### Station 3: Rogue River

| Product | Wt. dist. pct | Analysis, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 | Distribution, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|---|---|---|---|---|
| Cleaner concentrate | 1.6 | 8.88 | 8.60 | 0.05 | 69.07 | 20.12 | 55.95 | 4.84 | 16.06 |
| Cleaner middlings | 1.5 | 4.04 | 3.14 | 0.01 | 23.74 | 8.58 | 19.15 | 1.47 | 5.17 |
| Middlings | 51.9 | 0.64 | 0.09 | 0.01 | 6.55 | 46.73 | 18.49 | 41.59 | 49.40 |
| Final tailings | 45 | 0.39 | 0.04 | 0.02 | 4.49 | 24.57 | 6.41 | 52.09 | 29.37 |

| | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|
| Calculated head | 0.71 | 0.25 | 0.02 | 6.88 |
| Analyzed head | 0.69 | 0.20 | 0.01 | 7.02 |
| Mass balance | 101.95 | 120.31 | 112.30 | 98.00 |

### Station 4: Cape Sebastian

| Product | Wt. dist. pct | Analysis, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 | Distribution, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|---|---|---|---|---|
| Cleaner concentrate | 2.2 | 9.29 | 7.18 | 0.03 | 60.78 | 26.51 | 69.99 | 5.48 | 19.90 |
| Cleaner middlings | 4.1 | 2.25 | 0.70 | 0.01 | 16.16 | 12.00 | 12.73 | 4.08 | 9.86 |
| Middlings | 28.5 | 0.71 | 0.07 | 0.01 | 7.26 | 26.44 | 8.85 | 25.54 | 30.82 |
| Final tailings | 65.2 | 0.41 | 0.03 | 0.01 | 4.06 | 35.05 | 8.43 | 64.91 | 39.42 |

| | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|
| Calculated head | 0.77 | 0.23 | 0.01 | 6.72 |
| Analyzed head | 0.76 | 0.19 | 0.01 | 7.06 |
| Mass balance | 0.00 | 0.00 | 0.00 | 0.00 |

### Station 5: North Cape Sebastian

| Product | Wt. dist. pct | Analysis, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 | Distribution, pct TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|---|---|---|---|---|
| Cleaner concentrate | 2.5 | 10.29 | 7.69 | 0.06 | 69.21 | 31.38 | 73.23 | 8.05 | 24.40 |
| Cleaner middlings | 2.4 | 3.01 | 1.33 | 0.03 | 18.88 | 8.80 | 12.14 | 3.44 | 6.39 |
| Middlings | 31.7 | 0.74 | 0.07 | 0.02 | 7.36 | 28.68 | 8.99 | 29.50 | 32.91 |
| Final tailings | 63.4 | 0.40 | 0.02 | 0.02 | 4.06 | 31.14 | 5.64 | 59.01 | 36.30 |

| | TiO2 | Cr2O3 | ZrO2 | Fe2O3 |
|---|---|---|---|---|
| Calculated head | 0.82 | 0.26 | 0.02 | 7.09 |
| Analyzed head | 0.75 | 0.20 | 0.02 | 6.76 |
| Mass balance | 108.81 | 128.50 | 107.45 | 104.86 |

Station 1 represented 10 pct of the total sample weight. The cleaner concentrates for the other four samples ranged from 1.1 to 2.5 pct of the sample weights. The concentrate from Station 1 analyzed 31.4 pct $TiO_2$, and recovery was 67.9 pct. By repassing the middling fractions, recovery would increase. The 31.4-pct $TiO_2$ grade is reasonable for a table concentrate. Concentrate grades and recoveries for chromium and zirconium were low for Station 1.

The Deister Table results from the other locations were not promising (Table 4.4). The best of these is Station 5 with a concentrate containing 10.3 pct $TiO_2$. Recovery was only 31.4 pct $TiO_2$. Chromium and zirconium grades were also low.

The table concentrate samples were assayed for gold, silver, and PGM. Table 4.5 shows that there is essentially no silver or PGM. The highest gold assay was concentrated from the Cape Blanco sample. The gold content of the concentrate was 0.006 tr oz/st. From this result, the as-received sample is estimated to contain only 0.0006 tr oz/st Au.

### 4.3.5. X-ray Diffraction Analysis of Table Concentrate Products

The heavy minerals of interest in all concentrates are ilmenite, chromite, and zircon, as determined by X-ray diffraction analyses. Ilmenite, the titanium-bearing mineral, had stronger spectra than did chromite. The spectra for zircon were quite small indicating that only a trace was present. Other major minerals of high specific gravity were magnetite and hematite. No rutile, anatase, brookite, or garnet were detected. The X-ray data were consistent with the analytical data in Table 4.3.

### 4.3.6. Magnetic Separation

Low-intensity magnetic separation testing was conducted using the Davis Tube. Table 4.6 gives the results of the Davis Tube tests on the table cleaner concentrates (heavy mineral fraction). Both the magnetic and nonmagnetic fractions were assayed for $TiO_2$, $Cr_2O_3$, and $Fe_2O_3$.

Results from Davis Tube tests showed that the value of processing with low-intensity magnetic separation to be questionable. The best results showed only small increases in grade in the nonmagnetic fraction. The Cape Blanco sample showed the lowest upgrading of the cleaner concentrate from 31.4 (Table 4.4) to 31.9 pct $TiO_2$. The $Fe_2O_3$ content decreased from 49.9 to 40.8 pct. The biggest increase in grade occurred from 9.32 (Table 4.4) to 16.37 pct $TiO_2$ with the Gold Beach sample. The $Fe_2O_3$ content decreased from 66.1 to 29.2 pct.

Since the $TiO_2$ values were concentrated in the nonmagnetic fraction, it is likely that the $TiO_2$-containing minerals are

## Table 4.5. Precious Metals Assays of Deister Table Concentrates from Oregon Offshore Placer Samples

| | Assays, tr oz/st | | | | |
|---|---|---|---|---|---|
| Sample | Pt | Pd | Rh | Au | Ag |
| Station 1 - Cape Blanco | <0.003 | <0.003 | <0.003 | 0.006 | <.1 |
| Station 2 - Gold Beach | <0.003 | <0.003 | <0.003 | 0.003 | <.1 |
| Station 3 - Rogue River | <0.003 | <0.003 | <0.003 | 0.002 | <.1 |
| Station 4 - Cape Sebastian | <0.003 | <0.003 | <0.003 | 0.001 | <.1 |
| Station 5 - North Cape Sebastian | <0.003 | <0.003 | <0.003 | <0.001 | <.1 |

## Table 4.6. Low-Intensity Magnetic Separation (Davis Tube) Tests

| Sample I.D. Station No. | Total magnetic fraction, g | Wt pct | Analysis: TiO2 | Fe2O3 | Cr2O3 | Weight distribution, pct TiO2 | Fe2O3 | Cr2O3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.398 | 22.14 | 26.05 | 70.36 | 3.66 | 18.85 | 32.92 | 10.92 |
| 2 | 13.193 | 65.80 | 4.86 | 83.08 | 5.23 | 36.36 | 84.57 | 39.85 |
| 3 | 13.613 | 68.46 | 5.68 | 84.37 | 4.42 | 48.49 | 86.09 | 34.84 |
| 4 | 11.936 | 60.07 | 6.66 | 79.79 | 5.01 | 48.91 | 83.99 | 41.75 |
| 5 | 14.07 | 70.94 | 6.88 | 82.80 | 3.85 | 53.53 | 87.33 | 35.71 |

| Sample I.D. Station No. | Total nonmagnetic fraction, g | Wt. pct | Analysis: TiO2 | Fe2O3 | Cr2O3 | Weight distribution, pct TiO2 | Fe2O3 | Cr2O3 |
|---|---|---|---|---|---|---|---|---|
| 1 | 15.469 | 77.86 | 31.90 | 40.76 | 8.50 | 81.15 | 67.08 | 89.08 |
| 2 | 6.856 | 34.20 | 16.37 | 29.17 | 15.18 | 63.64 | 15.43 | 60.15 |
| 3 | 6.271 | 31.54 | 13.09 | 29.60 | 17.96 | 51.51 | 13.91 | 65.16 |
| 4 | 7.935 | 39.93 | 10.47 | 22.88 | 10.51 | 51.09 | 16.01 | 58.25 |
| 5 | 5.765 | 29.06 | 14.58 | 29.32 | 16.94 | 46.47 | 12.67 | 64.29 |

low in iron. The Davis Tube also concentrated the $Cr_2O_3$ values; however, the product grades were low. The nonmagnetic Cape Blanco concentrate contained 8.5 pct $Cr_2O_3$ with a recovery of 89 pct. The other four samples produced higher concentrates ranging from 10.5 to 18 pct $Cr_2O_3$ with recoveries from 58.3 to 65.1 pct. The grade of these concentrates were still much lower than the commercial grade of 48 pct $Cr_2O_3$.

## 4.4. Technical Assessment

Laboratory results suggest that ilmenite and chromite are the only heavy minerals of potential interest in the five samples. All samples also contained magnetite, hematite, and a trace of zircon. The table tests and Davis Tube results showed that only the ilmenite from the Cape Blanco sands may be concentrated to reasonable levels. The $TiO_2$ content of the Cape Blanco composite sample is 5.54 pct, and this suggests that the Cape Blanco area is worthy of further investigation as a possible titanium resource. Gravity concentration produced a 31.4-pct $TiO_2$ concentrate with a 67.9-pct recovery. Low-intensity magnetic separation (Davis Tube) did not appreciably upgrade this gravity concentrate product. The results of size-chemistry and gravity-separation tests suggests that a higher grade $TiO_2$ product could be produced from the Cape Blanco sample. A larger sample of this material would be needed to run these tests. Gravity concentrate grades and recoveries for chromium were low for all five samples, and only a trace of zircon was present in all of them.

## SECTION 5.0

## ENVIRONMENTAL SEDIMENT CHEMISTRY

Andy Schaedel, Oregon Department of Environmental Quality

## Section 5.0

## ENVIRONMENTAL SEDIMENT CHEMISTRY

### 5.1 Objectives

Sediment samples were collected at selected sites and analyzed for selected chemical and physical parameters. Given limited resources, screening level analyses were performed on a subset of these samples. Data were utilized as a means to screen for potential environmental concerns and to identify future study needs in the case that leasing and development activities are proposed in the black sand deposits.

### 5.2 Methods

Sediment samples were collected from benthic grab samples at the sites listed in Table 5.1. Three to five replicate benthic grab samples were generally taken at each site. A 500 ml pre-labeled polyethylene bottle was filled with the sediment and stored unpreserved in a cooler on ice. Date, time, depth, location and general observations were recorded on sample sheets developed for the cruise. Samples were delivered to the Department of Environmental Quality (DEQ) laboratory as soon as possible upon completion of the cruise.

All samples were analyzed for Total Organic Carbon (TOC). Due to financial constraints, one sample from each site was analyzed for the following:

- o Sediment Size (% gravel, % sand, % silt, % clay)
- o Total Metals.

At two sites, an additional sample was analyzed to assess variability for those sites.

Based on the results of sediment size and TOC analyses, additional organic chemical analyses could be made for selected pesticides, polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) using selection criteria listed in "Region X Dredged Material Testing Guidelines" (EPA, 1990). Based on this criteria, no additional organic analyses were made due to the low percentage of silts/clays (not greater than 20%) and low percentage of organic carbon (as indicated by the total organic carbon data) found in the samples. It should be noted that total organic carbon is not the same as volatile solids but does provide an indication of the organic content of the sediments.

Results and levels of detection are listed in Tables 5.2-5.4. All methods followed Methods for Chemical Analysis for Water and Wastewater, (EPA, 1991). All tests with the

Table 5.1 Sediment Collection Sites for Chemical Analyses

| Station | Latitude | Longitude | Date | Water | Grab # | Analysis[1] |
|---|---|---|---|---|---|---|
| 1 | 42 51.19 | 124 35.83 | 9/21/90 | 32 m | 3 (1C) | TMS |
| | 42 51.24 | 124 35.81 | 9/21/90 | 34 m | 4 (1D) | T |
| | 42 51.28 | 124 35.78 | 9/21/90 | 34 m | 5 (1E) | TMS |
| | 42 51.29 | 124 35.76 | 9/21/90 | 34 m | 6 (1F) | T |
| 2 | 42 23.70 | 124 26.18 | 9/22/90 | 9 m | 12 (2F) | TMS |
| | 42 23.77 | 124 26.24 | 9/22/90 | 10 m | 13 (2G) | T |
| | 42 23.56 | 124 26.28 | 9/22/90 | 12 m | 14 (2H) | T |
| | 42 23.54 | 124 26.37 | 9/22/90 | 12 m | 15 (2I) | T |
| | 42 23.56 | 124 26.36 | 9/22/90 | 13 m | 16 (2J) | T |
| 3 | 42 23.94 | 124 27.78 | 9/23/90 | 27 m | 23 (3B) | TMS |
| | 42 24.05 | 124 27.74 | 9/23/90 | 27 m | 24 (3C) | T |
| | 42 23.74 | 124 27.88 | 9/23/90 | 30 m | 26 (3E) | T |
| 4 | 42 20.22 | 124 26.94 | 9/23/90 | 25 m | 27 (4A) | T |
| | 42 20.23 | 124 26.92 | 9/23/90 | 24 m | 28 (4B) | TMS |
| | 42 20.27 | 124 26.91 | 9/23/90 | 24 m | 31 (4D) | T |
| | 42 20.29 | 124 26.94 | 9/23/90 | 24 m | 32 (4E) | T |
| 5 | 42 19.58 | 124 26.79 | 9/23/90 | 25 m | 33 (5A) | TMS |
| | 42 19.57 | 124 26.82 | 9/23/90 | 25 m | 34 (5B) | T |
| | 42 19.57 | 124 26.87 | 9/23/90 | 26 m | 35 (5C) | T |
| | 42 19.57 | 124 26.86 | 9/23/90 | 26 m | 36 (5D) | T |
| | 42 19.53 | 124 26.87 | 9/23/90 | 26 m | 37 (5E) | T |
| 13 | 42 50.41 | 124 37.13 | 9/27/90 | 43 m | 57 (13B) | TMS |
| | 42 50.41 | 124 37.13 | 9/27/90 | 42 m | 58 (13C) | T |
| | 42 50.41 | 124 37.13 | 9/27/90 | 42 m | 59 (13D) | T |
| | 42 50.40 | 124 37.11 | 9/27/90 | 42 m | 60 (13E) | T |
| 14 | 42 50.48 | 124 37.53 | 9/27/90 | 47 m | 61 (14A) | T |
| | 42 50.48 | 124 37.53 | 9/27/90 | 47 m | 62 (14B) | TMS |
| | 42 50.54 | 124 37.70 | 9/27/90 | 51 m | 63 (14C) | T |
| | 42 50.56 | 124 37.47 | 9/27/90 | 47 m | 65 (14E) | TMS |
| | 42 50.47 | 124 37.49 | 9/27/90 | 47 m | 66 (14F) | T |
| 17 | 42 45.70 | 124 33.26 | 9/30/90 | 31 m | 67 (17A) | TMS |

[1] Analysis: T = Total Organic Carbon
M = Metals
S = Sediment Size

exception of percent solids, TOC, sediment size, mercury and arsenic were made by Inductively Coupled Plasma (ICP) analysis. Mercury and Arsenic analyses were made using Graphite Furnace Methods. Total metal assays were made after nitric and hydrochloric acid digestions.

## 5.3 Results and Discussion

### 5.3.1 Results

Results of the Department of Environmental Quality sediment analyses are found in Tables 5.2 - 5.4. The State of Oregon does not have sediment quality standards as a means for assessing the quality of these results. Therefore, two methods were utilized to evaluate these data: 1) screening the data using dredge disposal guidelines and 2) screening the data using potential biological effects guidelines.

### 5.3.2 Dredge Guidelines

The first method followed the guidance offered in "Region X Dredged Material Testing Guidelines" (EPA, 1990). This methodology utilizes a tiered approach to evaluating sediment quality. This methodology utilizes technical and policy guidance for the evaluation and management of dredged material that was jointly produced by the Environmental Protection Agency and U.S. Army Corps of Engineers in the manual entitled, "Ecological Evaluation of Proposed Discharge of Dredge Material into Ocean Waters" (1978).

The three tiers of testing are: 1) physical characteristics (sediment size, volatile solids, oil and grease, available information); 2) chemicals of concern; and 3) bioassay and/or bioaccumulation testing. Using this methodology, samples are first screened based on physical/chemical tests. Those meeting all of the following criteria are considered acceptable for unconfined, open-water disposal (low risk) without further testing:

- sediment size (less than 20% silt/clay)
- volatile solids (less than 5% dry weight)
- oil and grease (less than 1,000 ppm by gravimetric method)
- available information indicates that sources of contaminants are low or absent.

Additional chemical screening (tier 2), consisting of metals and organics of concern and other indicator inorganic analyses, would be made based on concerns identified in tier 1. Several of the suggested chemicals of concerns were analyzed: antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. Total Organic Carbon and the percent solids were also recommended for

Table 5.2 Sediment Chemistry (all values mg/kg dry weight except as noted)

| Element | Detection Limit | Site 1C | 1E | 2F | 3B | 4B | 5A | 13B | 14B | 14E | 17A |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Percent Solids (%) | | 81% | 81% | 78% | 77% | 76% | 76% | 79% | 79% | 76% | 76% |
| Common Ions | | | | | | | | | | | |
| Aluminum | <5.0 | 8500 | 9000 | 14000 | 14000 | 14000 | 16000 | 7000 | 7000 | 15000 | 9200 |
| Calcium | <5.0 | 6500 | 7500 | 8000 | 9500 | 9500 | 9000 | 5000 | 4400 | 9500 | 5600 |
| Iron | <2 | 20000 | 20000 | 34000 | 32000 | 52000 | 30000 | 14000 | 13000 | 29000 | 14000 |
| Magnesium | <25 | 6000 | 6000 | 25000 | 24000 | 24000 | 25000 | 5500 | 5500 | 25000 | 6200 |
| Manganese | <0.5 | 200 | 210 | 360 | 390 | 420 | 720 | 170 | 150 | 400 | 150 |
| Potassium | <25 | 800 | 800 | 800 | 750 | 750 | 850 | 850 | 900 | 800 | 1100 |
| Sodium | <25 | 2500 | 2600 | 2600 | 2900 | 3000 | 36000 | 2800 | 3700 | 3400 | 3200 |
| Metals - Quantitative | | | | | | | | | | | |
| Antimony | <10 | - | - | - | - | - | - | - | - | - | - |
| Arsenic | <0.25 | 2.5 | 2.3 | 4.6 | 5.2 | 4.4 | 5.2 | 2.8 | 3.2 | 5.6 | 3.0 |
| Barium | <1.5 | 90 | 95 | 34 | 42 | 65 | 24 | 85 | 39 | 30 | 32 |
| Beryllium | <0.5 | - | - | - | - | - | - | - | - | - | - |
| Cadmium | <0.5 | - | - | - | - | .5 | - | - | - | - | - |
| Chromium | <1.5 | 140 | 170 | 170 | 170 | 340 | 170 | 85 | 55 | 160 | 82 |
| Cobalt | <3.0 | 5 | 5.5 | 16 | 16 | 19 | 15 | 4 | 4.5 | 14 | 4.6 |
| Copper | <1.0 | 3.5 | 3.0 | 15 | 10 | 14 | 14 | 2.5 | 2.5 | 11 | 3.1 |
| Lanthanum | <2.5 | 21 | 22 | 5 | 5 | 5 | 5 | 13 | 9 | 5 | 11 |
| Lead | <5.0 | - | - | - | - | - | - | - | - | - | - |
| Lithium | <2.5 | 11 | 11 | 17 | 18 | 17 | 19 | 11 | 11 | 19 | 13 |
| Mercury | <0.015 | - | - | - | - | - | - | - | - | - | - |
| Molybdenum | <2.5 | - | - | - | - | - | - | - | - | - | - |
| Nickel | <2.0 | 31 | 33 | 170 | 150 | 170 | 160 | 26 | 24 | 150 | 28 |
| Rubidium | <25 | - | - | - | - | - | - | - | - | - | - |
| Selenium | <12.5 | - | - | - | - | - | - | - | - | - | - |
| Silver | <0.5 | - | - | - | - | - | - | - | - | - | - |
| Strontium | <0.5 | 32 | 36 | 37 | 42 | 42 | 44 | 22 | 20 | 42 | 26 |
| Thallium | <25 | - | - | - | - | - | - | - | - | - | - |
| Titanium | <1.0 | 1000 | 1000 | 1000 | 950 | 1400 | 950 | 600 | 500 | 900 | 650 |
| Tungsten | <2.5 | - | - | - | - | - | - | - | - | - | - |
| Vanadium | <1.5 | 50 | 55 | 60 | 55 | 150 | 48 | 28 | 22 | 43 | 29 |
| Zinc | <1.0 | 34 | 34 | 50 | 49 | 60 | 50 | 27 | 25 | 50 | 28 |
| Zirconium | <0.5 | 6 | 6 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 5 |

- = not detected

Table 5.2 (contd) Sediment Chemistry (all values mg/kg dry weight except as noted)

| Element | Detection Limit 1C | Site 1E | 2F | 3B | 4B | 5A | 13B | 14B | 14E | 17A | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Additional Semiquantitative[1] Elemental Scan** | | | | | | | | | | | |
| Bismuth | <50 | - | - | - | - | - | - | - | - | - | - |
| Cerium | <25 | 35 | 40 | - | - | - | - | - | - | - | - |
| Cesium | <50 | - | - | - | - | - | - | - | - | - | - |
| Dysprosium | <5.0 | - | - | - | - | - | - | - | - | - | - |
| Erbium | <10 | - | - | - | - | - | - | - | 20 | - | - |
| Europium | <1.5 | - | - | - | - | - | - | - | - | - | - |
| Gadolinium | <2.5 | - | - | 9 | - | - | - | - | - | - | - |
| Gallium | <15 | - | - | - | - | - | - | - | - | - | - |
| Germanium | <50 | - | - | - | - | - | - | - | - | - | |
| Gold | <5.0 | - | - | - | - | 7 | - | - | - | - | - |
| Hafnium | <5.0 | 8.5 | 8.5 | 15 | 15 | 25 | 15 | 5 | 5 | 15 | 5 |
| Holmium | <2.5 | - | - | - | - | - | - | - | - | - | - |
| Indium | <25 | - | - | 25 | - | 35 | - | - | - | - | - |
| Iridium | <10 | - | - | - | - | - | - | - | - | - | - |
| Lanthanum | <5.0 | 20 | 20 | - | 5 | 5 | - | 15 | 10 | - | 10 |
| Lithium | <10 | 10 | 10 | 20 | 20 | 15 | 20 | 10 | 10 | 15 | 10 |
| Lutetium | <1.0 | - | - | 1 | 1 | 2 | 1 | - | - | - | - |
| Neodymium | <50 | - | - | - | - | - | - | - | - | - | - |
| Niobium | <5.0 | - | - | - | - | - | - | - | - | - | - |
| Palladium | <10 | - | - | - | - | - | - | - | - | - | - |
| Platinum | <25 | - | - | 30 | - | - | - | 25 | - | - | - |
| Praseodymium | <15 | - | - | - | - | - | - | - | - | - | - |
| Rhenium | <25 | - | - | - | - | - | - | - | - | - | - |
| Rhodium | <50 | - | - | - | - | - | - | - | - | - | - |
| Rubidium | <500 | - | - | - | - | - | - | - | - | - | - |
| Ruthenium | <10 | - | - | - | - | - | - | - | - | - | - |
| Samarium | <10 | - | - | - | - | - | - | - | - | - | - |
| Scandium | <0.5 | 3.5 | 3.8 | 4.0 | 4.5 | 4.5 | 4.5 | 3.0 | 2.5 | 4.5 | 3.0 |
| Sulfur | <25 | 270 | 270 | 280 | 270 | 290 | 310 | 360 | 420 | 300 | 400 |
| Tantalum | <15 | - | - | - | - | - | - | - | - | - | - |
| Tellurium | <50 | - | - | - | - | - | - | - | - | - | |
| Terbium | <15 | - | - | - | - | - | - | - | - | - | - |
| Thorium | <1.5 | 20 | 20 | 25 | 25 | 35 | 20 | 10 | 10 | 20 | 10 |
| Thulium | <1.5 | - | - | - | - | - | - | - | - | - | - |
| Tungsten | <50 | - | - | - | - | - | - | - | - | - | - |
| Uranium | <50 | - | - | - | - | 65 | - | - | - | - | - |
| Ytterbium | <1.0 | - | - | - | - | - | - | - | - | - | - |
| Yttrium | <0.25 | 7 | 8 | 5 | 5 | 6 | 5 | 6 | 5 | 5 | 5 |
| Zirconium | <1.5 | 4 | 4 | 3 | 3 | 2 | 3 | 4 | 4 | 3 | 4 |

1 Analyses have not been fully quality assured, interferences may be present.

- = not detected

Table 5.3 Sediment Size (all values are percent by weight)

| Size Range | Site 1C | 1E | 2F | 3B | 4B | 5A | 13B | 14B | 14E | 17A |
|---|---|---|---|---|---|---|---|---|---|---|
| Clay (<0.0039 mm) | 0.9 | 0.8 | 1.0 | 0.9 | 1.1 | 1.1 | 1.0 | 1.0 | 1.1 | 0.9 |
| Fine Silt (0.0039-0.0156 mm) | <0.1 | <0.1 | <0.1 | 0.1 | <0.1 | 0.1 | <0.1 | <0.1 | <0.1 | 0.1 |
| Coarse Silt (0.0156-0.0625 mm) | 0.1 | 0.1 | 0.2 | 0.5 | 0.8 | 0.5 | 0.1 | <0.1 | 0.5 | 0.5 |
| Very Fine Sand (0.0625-0.125 mm) | 40.3 | 43.7 | 11.2 | 29.9 | 34.0 | 20.6 | 21.5 | 15.1 | 27.3 | 20.1 |
| Fine Sand (0.125-0.25 mm) | 58.3 | 55.0 | 69.7 | 64.9 | 62.4 | 75.8 | 76.7 | 83.2 | 70.2 | 77.2 |
| Medium Sand (0.25-0.5 mm) | 0.3 | 0.3 | 17.2 | 3.6 | 1.7 | 1.7 | 0.7 | 0.6 | 0.8 | 1.1 |
| Coarse Sand (0.5-2.0 mm) | <0.1 | <0.1 | 0.7 | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Gravel (>2.0 mm) | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |

Table 5.4 Total Organic Carbon Results

| Site | Total Organic Carbon (mg/kg wet weight) |
|---|---|
| 1C | 1423 |
| 1D | 1260 |
| 1E | 1326 |
| 1F | 1225 |
| 2F | 1464 |
| 2G | 1592 |
| 2H | 1603 |
| 2I | 1804 |
| 2J | 1806 |
| 3B | 1832 |
| 3C | 2244 |
| 3G | 1565 |
| 4A | 1249 |
| 4B | 1608 |
| 4D | 1639 |
| 4E | 1561 |
| 5A | 1483 |
| 5B | 1633 |
| 5C | 1575 |
| 5D | 1926 |
| 5E | 1542 |
| 13B | 1365 |
| 13C | 1094 |
| 13D | 1186 |
| 13E | 1380 |
| 14A | 1796 |
| 14B | 1458 |
| 14C | 1542 |
| 14E | 1679 |
| 14F | 1575 |
| 17A | 1561 |

testing in order to further characterize the sediment and to assist in the interpretation of other chemical and biological testing. Lastly, when determined necessary, biological testing for toxicity and/or bioaccumulation may be required. Given limited resources, this level of testing was not part of this study.

None of the samples analyzed exceeded the sediment size criteria (more than 20% silt/clay) which would indicate a need for further organic testing. In addition, the Total Organic Carbon values indicated that the sediments were generally low in organic content. Therefore, based on sediment size, low organic content and limited analytical resources, further testing for organic priority pollutants was not made. These data indicated that the sediments in this area are primarily sand, in which case organics (which generally have an affinity for finer, organic particles) would not be of concern.

### 5.3.3 Biological Effects Criteria

Given that the sands may be of interest for their mineral content, metal analyses were screened relative to literature values for levels where there may be biological effects. Long and Morgan (1990), assembled and evaluated a wide variety of data to identify informal guidelines for use in evaluation of sediment data collected nationally. The purpose of their report was to assess the relative likelihood or potential for adverse biological effects occurring due to exposure of biota to toxicants in sediments.

Their approach was to: 1) assemble and review currently available information in which estimates of the sediment concentrations of chemicals associated with adverse biological effects have been determined or could be derived and 2) determine apparent ranges in concentration of individual chemicals in which effects are likely to occur. The lower 10 percentile and median concentrations [Effects Range-Low (ER-L) and Effects Range-Median (ER-M)] were identified along with an overall apparent effects threshold. Generally, the ER-L represent an approximation of the concentrations at which adverse effects were first detected. The ER-M values represent an estimate of the concentrations at or above which effects are often detected. This report evaluated data for 10 trace metals, 18 petroleum hydrocarbons and 11 synthetic organic compounds. Results for the trace metals are shown in Table 5.5.

Values in Table 5.2 were compared against guidelines shown in Table 5.5. None of the 10 samples exceeded any of the effects levels for Antimony, Arsenic, Cadmium, Copper, Lead, Mercury, Silver and Zinc. All samples exceeded both the ER-L and ER-M for Chromium and 7 out of 10 samples exceeded the ER-L and 5 out of 10 samples exceeded the ER-M for Nickel. It is recommended that, if further study occurs, further biological testing for potential biological effects from chromium and nickel be conducted.

Of the 70 metals analyzed, 33 were not detected. Limited information was available to determine potential environmental effects of the concentrations detected beyond that described for the 10 metals.

Generally, based on total elemental analyses of selected sediment samples, it appears that chromium and nickel concentrations may be of concern. It should be noted that concentrations were in the total form and may not reflect what could be biologically available. Therefore, if further study is conducted, it is recommended that additional biological testing be conducted, especially in the form of bioassays to determine what effect resuspension of the sediments would have on aquatic life.

Table 5.5

Summary of Effects Levels for Selected Chemicals in Sediments (dry weight) (from Long and Morgan, 1990)

| Element | ER-L1 (mg/kg) | ER-M2 (mg/kg) | Overall Apparent Effects Threshold |
|---|---|---|---|
| Antimony | 2 | 25 | 25 |
| Arsenic | 33 | 85 | 50 |
| Cadmium | 5 | 9 | 5 |
| Chromium | 80 | 145 | None |
| Copper | 70 | 390 | 300 |
| Lead | 35 | 110 | 300 |
| Mercury | 0.15 | 1.3 | 1 |
| Nickel | 30 | 50 | Insufficient Data |
| Silver | 1 | 2.2 | 1.7 |
| Zinc | 120 | 270 | 260 |

1 ER-L = Effects Range - Low (lower 10 percentile value in the effects data)

2 ER-M = Effects Range - Medium (median value in the effects data)

## SECTION 6.0

## BIOLOGICAL CHARACTERISTICS OF NEARSHORE SAND AREAS OFF SOUTHERN OREGON

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# BIOLOGICAL CHARACTERISTICS OF NEARSHORE SAND AREAS

## 6.1 Objectives

In the process of designing a research cruise, the Placer Minerals Task Force appointed a scientific subcommittee to determine what types of biological and geological information could be collected concurrently using one research vessel. The scientific subcommittee met and determined cruise priorities based on funding limitations and the needs of all principal investigators. Funding, ship time, space and gear constraints, and mineralogical, geological, and geophysical sampling needs all influenced the amount and type of biological sampling that could practically be completed.

A literature review funded in 1989 by the Placer Minerals Task Force provided the basis for setting sampling priorities for a study of the biota of nearshore sand areas in Southern Oregon. Ross (1990) described a general lack of information pertaining to the biota of nearshore habitats in Southern Oregon. The information that is available pertains to the species composition and relative abundance of commercially and recreationally caught groundfish and salmon, the location of seabird colonies on rocks and islands, and pinniped haul-out areas (Ross 1990). More recent work by the Oregon Department of Fish and Wildlife provides information about sea urchin distribution and relative abundances (McCrae 1989). Research recommendations presented by Bottom et al. (1989) helped define sampling objectives as well. In developing a research plan for the Washington and Oregon continental margin, they specifically addressed research needs for the areas in Southern Oregon thought to contain heavy minerals.

After reviewing the literature cited by Ross (1990), the recommendations of Bottom et al. (1989), and logistical limitations, we realized more than one cruise would be needed to characterize the biota of 'black sands'. Intensive sampling during different seasons over several years would be needed to adequately characterize the biota associated with heavy mineral deposits.

Since we could not define all biological characteristics of 'black sands', we thought it important to describe the spectrum of animals that live in nearshore sand areas at the time of the cruise. It also seemed valuable to use the 1990 cruise to help design more intensive studies of nearshore waters off southern Oregon. To maximize the value of the information acquired during the cruise, we developed three primary biological objectives:

1) Estimate species composition, diversity, and relative abundance of demersal fish, epibenthic invertebrates, benthic infauna, birds, and mammals in the study area,

2) Compare species composition, diversity, and relative abundance of fish and invertebrates living in areas containing deposits of heavy minerals with similar areas containing no deposits of heavy minerals, and

3) Collect and analyze samples in a manner that will help determine appropriate statistical sampling designs, should further studies be conducted.

Specific sampling objectives for each biological component included:

Invertebrates:
1) Describe species composition, relative abundances, and species diversity indices in target and control locations,
2) Evaluate infauna data to suggest appropriate sampling considerations for a future benthic infauna sampling program,
3) Describe the number of species and number of infaunal individuals retained by 1.0 mm and 0.5 mm sieves,
4) Describe infauna distributional patterns as a function of sediment characteristics,
5) Describe infauna distributional patterns as a function of depth, and
6) Evaluate the relative effectiveness of crab pots and trawl nets for sampling Dungeness crab (*Cancer magister*).

Fish:
1) Describe species composition, relative abundances, and species diversity indices in target and control locations,
2) Determine the number of replicate trawls needed to characterize species composition in the study area, and
3) Describe day/night variability in species composition at one location.

Birds and mammals:
1) Describe species composition, relative abundances, and species diversity indices in the study area, and
2) Determine the number of replicate transects needed to characterize species composition in the study area.

## 6.2 Methods

### 6.2.1 Invertebrate Sampling

A 0.1 $m^2$ Smith-McIntyre grab sampler was the primary tool used to sample benthic infauna. The sampling plan called for grab samples at geologic target stations and at control stations (Fig. 6.1, 6.2). Stations 2-5 were originally target locations; when geologic sampling there showed low concentrations of minerals, they were converted to control stations. Similarly, Station 17 was converted to a control station. Since the geologic sampling did not conclusively identify target sites at sea, we were unable

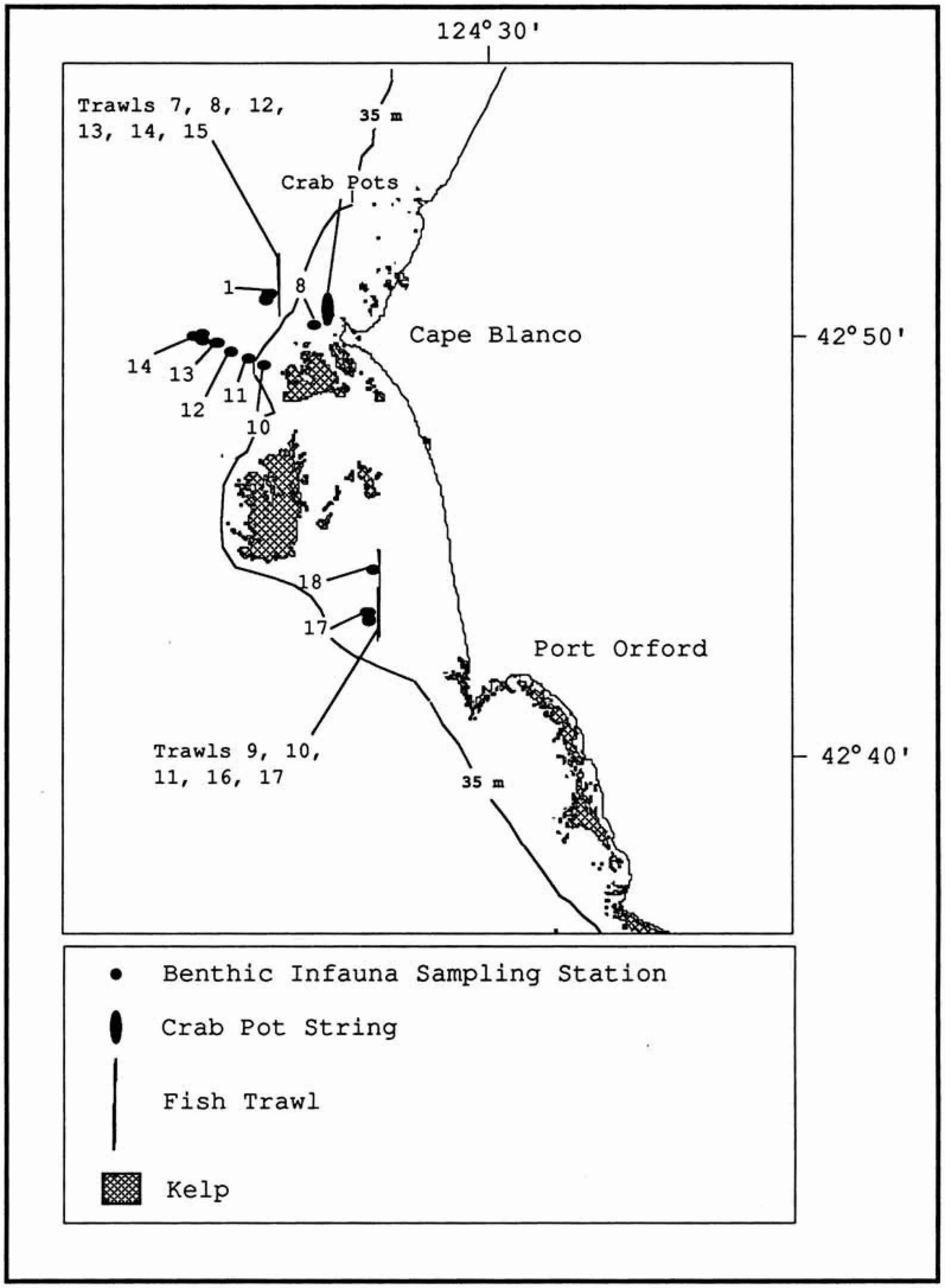



Figure 6.1. Benthic infauna stations, crab pot locations, and fish trawls. Northern portion of the study area.

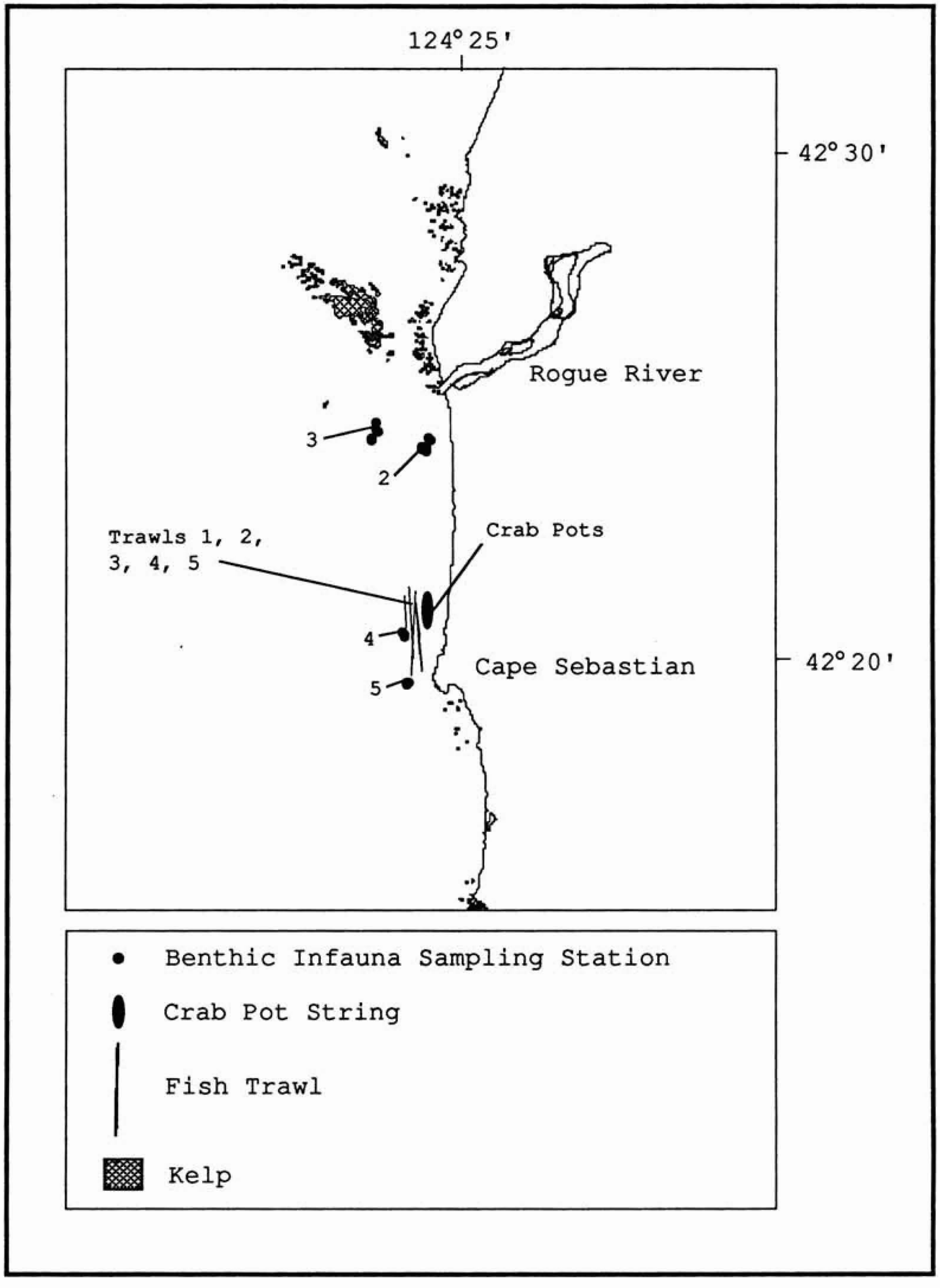



Figure 6.2. Benthic infauna stations, crab pot locations, and fish trawls. Southern portion of the study area.

to compare target sites to control locations. We collected grab samples at 13 stations; usually five grab samples were collected at each station (Fig. 6.1, 6.2). Analysis of 15 replicate grab samples at one station off the Rogue River helped predict the optimum number of sample replicates per station.

One study objective was to determine if species composition changed significantly with small changes in depth. Bathymetric contours in the study site were relatively evenly spaced, indicating the bottom had a regular slope. Stations 10-14 represent a transect of grab samples that was set up to evaluate infaunal changes along a narrow depth gradient. Water depth at Stations 10-14 ranged from 27-51 m. Data from some of these stations were later lumped together as a second way of estimating the optimum number of replicate samples per station.

We collected 68 successful grab samples during the cruise. Once the grab samples were aboard, we measured sample thickness to estimate volume and then sieved the samples at sea. The mean sediment penetration of the grabs was 8.7 cm and the mean sediment volume recovered was 5.7 liters. All 68 samples were passed through a 1.0 mm sieve. Since one sampling objective was to investigate species retention of different sieve sizes, we passed 11 of the 68 samples through a nested 1.0 and 0.5 mm sieve. The nested sieve technique was used both off the Rogue River and Cape Blanco. At one station meiofauna samples were collected from five grab samples by extracting a single core 2.88 cm wide by 5 cm deep from the undisturbed surface of each grab.

Material retained on the screen of the sieves and in the meiofauna cores was preserved immediately after collection in a buffered 5-10% formalin and seawater solution stained with rose bengal. The samples were transferred into 70% isopropyl alcohol one week after the cruise.

Six months after the cruise, the samples were analyzed by Marine Taxonomic Services of Corvallis, Oregon. Prior to sorting the samples, Marine Taxonomic Services resieved, washed and placed the samples in 70% isopropyl alcohol with rose bengal stain added to facilitate sorting animals from debris. After sorting, the animals were identified to species, or the lowest practical taxonomic level. After the samples were analyzed, all animals were placed in 70% alcohol and stored at Marine Taxonomic Services. Funding was not available for analysis of meiofauna samples, so they remain stored in sample jars.

Five commercial crab pots were used to catch adult Dungeness crab (*Cancer magister*). The pots contained two 11 cm wide escape ports and carried 900 g of squid in hanging bait containers. The cruise plan required a retrieval of crab pots after a 24 h soak. All crab caught in pots were counted, then weighed as a group to obtain mean weights. We measured carapace width (to the nearest millimeter) just anterior to the tenth anterolateral spines. Crab collected in beam trawls and otter trawls were also counted, weighed, and measured. We recorded other macroinvertebrate species collected in trawls and saved voucher specimens.

### 6.2.2 Fish Sampling

Commercial and recreational fishery catch data collected by the Oregon Department of Fish and Wildlife (Lukas and Carter 1990) and existing resource surveys (Demory et al. 1976) provide sufficient information about adult fish in the study area to design further sampling projects. In this study, our objective was to collect juvenile forms of commercially and recreationally caught species, and other species too small to be retained by commercial fisheries. We also wanted to estimate variability within and between stations, including day/night variation at one station.

A 3 m beam trawl with a liner was the primary fish sampling device. At one station we also used a 7.3 m otter trawl. The entire beam trawl and the bunt of the otter trawl were lined with 6.35 mm (1/4") mesh, and in addition, the bunt of the beam trawl was lined with 4.76 mm (1/8") mesh.

Tows were centered over heavy mineral target locations and at control stations. The vessel trawled parallel to isobaths to minimize variation caused by depth. Tow lengths were determined first by time, then by distance. Initial tows were set and retrieved at 10-30 min time intervals. The distances covered in initial trawl tows varied greatly due to wind and currents, so later trawls were set and retrieved at specified coordinates of latitude and longitude in an attempt to make consistent tow lengths of about 1.6 km.

Actual tow lengths were very consistent due to the precision of the Del Norte transponder ranging system used for navigation. The actual distance covered by the otter trawl was calculated based on vessel position when the trawl reached bottom and when the trawl left bottom. Towing distance for the beam trawl was determined by the number of revolutions of the two attached wheels as recorded by revolution counters (Carey and Heyamoto 1972). When the two wheel revolution counters disagreed, the larger of the two numbers was used. Thus, errors would tend to result in underestimates of abundance.

We completed 16 tows (Fig. 6.1, 6.2), covering a distance of 24 km. Areas swept were calculated differently for the two trawl types. The otter trawl was assumed to fish a swath a maximum of 4.9 m wide (0.67 times the headrope length of 7.3 m), based upon past experience with similar gear (D. Amos, Georgia Sea Grant, pers. comm., Feb. 28, 1991). The beam trawl fished a path 2.72 m wide, the distance between the insides of the skids.

All whole fish caught were identified, counted, and measured. All fish were identified to species or the lowest possible taxonomic level. Total length was measured to the nearest millimeter. In instances where more than 100 fish were caught, a subsample of over fifty was measured. Fish of each species were counted, then weighed as a group to obtain mean weights. Most specimens were discarded at sea. We preserved fish we could not easily identify in a buffered 10% formalin-sea water solution and identified and measured them ashore. Some voucher specimens were saved.

### 6.2.3 Seabird and Marine Mammal Observations

An observer, Robert O'Brien of Portland State University, surveyed birds and marine mammals along transects using protocols recommended by the United States Fish and Wildlife Service (Gould and Forsell 1989). We used the *M/V Aloha* to conduct 300 m wide belt transects at and between all stations. Most surveys were conducted while the research vessel was in transit or engaged in fish trawling or geophysical sampling; thus the shape of the transects reflects a sampling grid designed for another activity. This did not seem to pose a problem, though, as the study area was systematically covered by the geophysical sampling grid.

The observer, stationed on an upper deck of the *M/V Aloha*, about 5 m above the sea surface, counted and recorded all birds and marine mammals observed in a 30 min time period. Only birds viewed on one side of the ship were counted. Vessel location, vessel course and speed, time of day, and wind and sea conditions were recorded for each transect. Birds and marine mammals were counted and identified to species level where possible. Animal behavior was noted when possible.

An inflatable boat was used to conduct 300 m wide belt transects in the Rogue River to Cape Sebastian region as well. Nine transects were conducted with the inflatable boat. When using the inflatable boat, the observer stood in the bow and looked forward for birds and mammals out to 150 m on either side. The boat driver attempted to maintain a constant heading and speed for a 10 min time period.

We surveyed 351 km of track line during the cruise. Survey areas typically extended from shore to about 8 km offshore, and along shore for 15 km. In addition to the coastal transects in each sampling region, surveys were also conducted farther offshore when the *M/V Aloha* was transiting between study sites. Although the shortest transect covered 0.9 km and the longest covered 54.9 km, 90% of the transects were between 1.0 and 8.0 km in length.

## 6.3 Results and Discussion

### 6.3.1 Invertebrate Sampling

#### 6.3.1.1 Benthic Infauna

The objectives of the benthic grab sampling were to gain an initial understanding of soft-sediment benthic invertebrate communities in the study area, compare infauna assemblages at target stations with control stations, and to gather information needed for designing impact studies in the event of environmental disturbance. In addressing the first two objectives we describe the benthic community using a series of statistical and non-statistical methods. The third objective is addressed through analysis of sampling requirements for a possible impact study. Data analyzed in this section are from the 11 stations with five or more grabs per station (Fig. 6.1, 6.2). The results of statistical tests discussed in this section were considered significant at the $P < 0.05$ level. All analyses must be considered preliminary because this survey occurred in only one season. Benthic infauna typically show marked seasonal and year to year variation in density and species composition.

The benthic infauna sampling yielded 235 invertebrate taxa (Marine Taxonomic Services 1991). Of these, 149 taxa were identified to the species level and the remainder to genus or higher taxonomic level (Taxa are listed in the Appendix). Polychaetes (marine worms), gastropods (snails), pelecypods (clams), and amphipods accounted for most of the species. Table 6.1 shows the dominant taxa in terms of mean density (individuals/$m^2$) per station and frequency of occurrence in the grabs. The five most common species in terms of density included the polychaete *Spiophanes bombyx*, the amphipods *Eohaustorius sencillus, Foxiphalus major*, and *Rhepoxynius abronius*, and the gastropod *Olivella pycna* (Table 6.1). In addition, the polychaete *Scoloplos armiger* and the cumacean *Colurosylis* (*Anchicolurus*) *occidentalis* were common in terms of frequency of occurrence. All of these species are common in other sites along the Oregon coast that have comparable sediments, depth, and exposure (Hancock et al. 1980; Nelson et al. 1981; Sollitt et al. 1984; Emmett et al. 1987).

Mean benthic infauna densities ranged from 688 to 7598 individuals/$m^2$ (Fig. 6.3). Past surveys report similar infauna densities along the Oregon and Washington coasts (Lie and Kisker 1970; Carey 1972; Hancock et al. 1980; Nelson et al. 1981; Sollitt et al. 1984; Emmett et al. 1987). Stations 4 and 5 had significantly greater mean infauna densities ($P < 0.05$) than all other stations (Table 6.2). Mean densities at Stations 1, 2, and 10 through 14 were not significantly different from each other when evaluated with analysis of variance (Table 6.2). These stations had mean densities of about 1000 individuals/$m^2$ and

Table 6.1. High ranking taxa in terms of average density per station (individuals/$m^2$) and frequency of occurrence in grab samples (number) from stations with more than one grab. Plus marks indicate high ranking taxa in terms of density found in other areas off Oregon.

| Taxon | Density (No./$m^2$) | Frequency of Occurrence | Abundant Taxa Found in other Areas off Oregon | | | | |
|---|---|---|---|---|---|---|---|
| | | | Tillamook* | Depoe* | Siuslaw* | Umpqua* | Coos** |
| *Spiophanes bombyx* | 961.4 | 54 | + | + | | | + |
| *Eohaustorius sencillus* | 106.9 | 65 | + | + | + | + | + |
| *Foxiphalus major* | 88.9 | 64 | + | | | | + |
| *Olivella pycna* | 83.3 | 51 | + | + | + | + | |
| *Rhepoxynius abronius* | 69.0 | 42 | | + | + | + | |
| *Nemertinea* sp. Indet. | 58.5 | 62 | + | + | + | + | |
| *Nassarius* sp. Juv. | 53.9 | 46 | | | | | |
| *Olivella baetica* | 35.1 | 16 | | | | | + |
| *Monocludes spinipes* | 29.9 | 50 | | | | | |
| *Colurostylis occidentalis* | 26.5 | 53 | + | + | + | + | |
| *Cheirimedeia zotea* | 26.3 | 5 | | | | | |
| *Siliqua patula* | 26.2 | 22 | | | | | |
| *Scoloplos armiger* | 24.9 | 53 | + | + | + | + | + |
| *Mandibulophoxus gilesi* | 21.2 | 36 | + | | | + | |
| *Owenia fusiformis* | 20.5 | 15 | + | | | | |

* Emmett et al. (1987)

** Hancock et al. (1980); Nelson et al. (1981); and Sollitt et al. (1984)

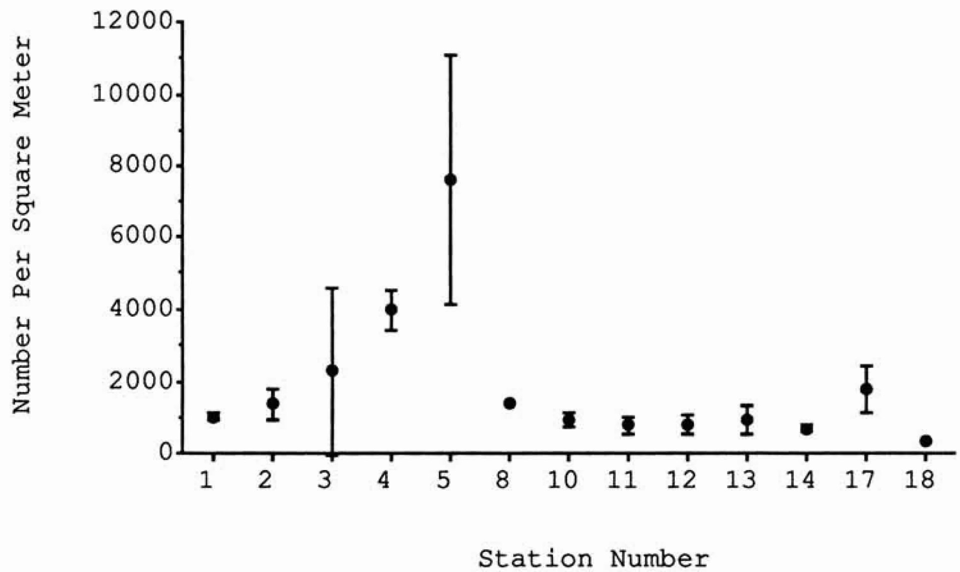



Figure 6.3. Mean benthic infauna densities (number/$m^2$). Error bars show range of one standard deviation.

relatively less variation in density than Stations 3 and 5 (Fig. 6.3). The mean density of Station 17 differed significantly from all other stations except Station 3. Variance was relatively high at Station 3, making comparison with other stations difficult. Generally, stations in close proximity to each other exhibited similar mean densities. Stations 1 and 10 through 14 had relatively low densities, Station 17 had intermediate densities, and Stations 4 and 5 had higher densities.

Table 6.2. Comparison of mean invertebrate densities at stations using analysis of variance. The '*' mark indicates stations where mean densities differed significantly at the 95% confidence level.

| Station | 1 | 2 | 3 | 4 | 5 | 10 | 11 | 12 | 13 | 14 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | * | * | | | | | | * |
| 2 | | | | * | * | | * | * | * | | * |
| 3 | | | | * | * | * | * | * | * | * | |
| 4 | * | * | * | | * | * | * | * | * | * | * |
| 5 | * | * | * | | | * | * | * | * | * | * |
| 10 | | | * | * | * | | | | | | * |
| 11 | | * | * | * | * | | | | | | * |
| 12 | | * | * | * | * | | | | | | * |
| 13 | | * | * | * | * | | | | | | * |
| 14 | | | * | * | * | | | | | | * |
| 17 | * | * | | * | * | * | * | * | * | * | |

The results of the analysis of variance are further interpreted by examining the most abundant species and their relative densities. Stations 1, and 10 through 13 had primarily amphipods, and invertebrate densities were relatively uniform among common species (Table 6.3). Stations 4 and 5 showed a clear preponderance of *Spiophanes bombyx* (Table 6.3). It was primarily this species that accounted for the significantly higher densities at these stations. Station 17 had relative high densities of *Olivella pycna* (Table 6.3), accounting for the relatively high overall density at this station.

A cluster analysis on the infauna data revealed two station cluster groups that included more than one station (Marine Taxonomic Services 1991). The first included Stations 1 and 10 through 13, and the second included Stations 2, 4, and 5. All other stations remained separate in the cluster analysis.

Species diversity values exhibited similar patterns as the analysis of variance and cluster analysis. We calculated the Shannon-Wiener index of diversity (H'), the Simpson Diversity

Table 6.3. Most abundant taxa in terms of mean density (individuals/$m^2$) at station cluster 1 (Stations 1,10,11,12,13), at Stations 4 and 5 combined, and at Station 17.

| Cluster 1 Taxa | Density | Stations 4 and 5 Taxa | Density | Station 17 Taxa | Density |
|---|---|---|---|---|---|
| *Foxiphalus major* | 102.0 | *Spiophanes bombyx* | 4475.0 | *Olivella pycna* | 440.0 |
| *Eohaustorius sencillus* | 98.8 | *Eohaustorius sencillus* | 158.0 | *Spiophanes bombyx* | 190.0 |
| Nemertinea sp. Indet. | 83.6 | *Nassarius* sp. Juv. | 156.0 | *Rhepoxynius abronius* | 165.0 |
| *Rhepoxynius abronius* | 72.8 | *Foxiphalus major* | 136.0 | *Nassarius* sp. Juv. | 133.3 |
| *Olivella baetica* | 57.6 | *Olivella pycna* | 79.0 | *Foxiphalus major* | 86.7 |
| *Spiophanes bombyx* | 46.0 | *Rhepoxynius abronius* | 76.0 | *Colurostylis occidentalis* | 53.3 |
| *Olivella pycna* | 42.4 | *Monocludes spinipes* | 75.0 | *Rhepoxynius vigitegus* | 51.7 |
| *Colurostylis occidentalis* | 28.4 | *Onuphis* sp. Juv. | 72.0 | *Lanassa venusta venusta* | 48.3 |
| *Psephidia lordi* | 25.6 | *Scoloplos armiger* | 40.0 | *Nephtys caecoides* | 46.7 |
| *Dendraster excentricus* | 20.0 | *Macoma indentata* | 34.0 | Nemertinea sp. Indet. | 46.7 |
| *Nephtys caecoides* | 15.6 | Nemertinea sp. Indet. | 30.0 | *Eohaustorius estuarius* | 45.0 |
| *Scoloplos armiger* | 14.8 | *Thalenessa spinosa* | 26.0 | *Scoloplos armiger* | 41.7 |
| Cirripedia | 14.4 | *Ampelisca careyi* | 26.0 | *Macoma indentata* | 40.0 |
| *Nassarius* sp. Juv. | 13.6 | *Grandifoxus* cf sp. R | 25.0 | *Monocludes spinipes* | 33.3 |
| *Mandibulophoxus gilesi* | 12.8 | *Phyllodoce hartmanae* | 24.0 | *Ampelisca careyi* | 28.3 |

Value (SD), Species Richness (SR), and Evenness (J) indices (Begon et al. 1986, Krebs 1972) for each station. Stations 4 and 5 had the lowest species diversity (Table 6.4), due to the large abundance of a single species (*Spiophanes bombyx*). The preponderance of this species also accounted for the low species evenness at stations 4 and 5 (Table 6.4). Stations 1, 10 through 14, and 17 had the highest diversities due to their relative high species richness and evenness (Table 6.4). The range of species richness and evenness indices was similar to other shallow sand areas along the coast (Table 6.5), but the Shannon-Wiener index of diversity was lower than other coastal sand areas, again due to the abundance of individual species.

We further explored patterns of benthic infauna distribution by examining possible relationships between infauna and depth and sediment grain size. We used linear regression analyses to examine mean invertebrate density versus depth for all stations combined and for the isobath-normal transect formed by Stations 10 through 14. There were no significant linear relationships between mean station density and depth in either case.

We examined counts of selected taxonomic groups and species to help elucidate trends along a depth gradient. A review of broad taxonomic groups showed no discernable trend in polychaete density with depth (Fig. 6.4). The spike in mean polychaete counts at 25 m was due to large numbers of *Spiophanes bombyx* at Stations 4 and 5 (Fig. 6.5). Amphipods showed a statistically significant linear tendency to decrease in numbers with depth (Fig. 6.4). The spike in amphipod counts at 25 m was due to relatively high counts of *Eohaustorius sencillus* and *Foxiphalus major* at Station 5. Pelecypods showed no discernable trends with depth (Fig. 6.4). The large spike in pelecypod counts at 11 m was due to high counts of juvenile razor clams (*Siliqua patula*) at Station 2 (Fig. 6.5).

A review of species density by depth showed that, of the seven most abundant taxa at Stations 10 through 14, only two, *Eohaustorius sencillus* and Nemertinea sp., showed a significant linear relationship with depth (Fig. 6.6). Densities in both of these taxa decreased with depth. Although not statistically significant, *Rhepoxynius abronius* and *Olivella baetica* appeared to decrease with depth. Of the taxa at Stations 2 through 5, two showed discernable trends with depth (Fig. 6.7). *Eohaustorius sencillus* appeared to decrease in abundance with depth and *Mandibulophoxus gilesi* showed a statistically significant linear decrease in abundance with depth (Fig. 6.7). Although not statistically significant, the prevalent *S. bombyx* appeared to increase with depth from Stations 2 through 5, then decrease from Stations 10 through 14. This trend may be entirely related to the high abundance at Stations 4 and 5.

Other researchers have examined trends in benthic infauna with depth and explained these trends in terms of the interrelated influences of wave and current exposure, sediment stability, and

Table 6.4. Diversity indices for benthic grab sample stations.

| Station | Diversity (H') | Richness (SR) | Evenness (J) |
|---|---|---|---|
| 1 | 2.96 | 6.92 | 0.78 |
| 2 | 2.71 | 7.22 | 0.67 |
| 3 | 2.44 | 9.24 | 0.58 |
| 4 | 1.27 | 7.24 | 0.32 |
| 5 | 1.20 | 7.28 | 0.29 |
| 10 | 3.05 | 10.27 | 0.73 |
| 11 | 3.23 | 9.25 | 0.80 |
| 12 | 3.06 | 7.87 | 0.79 |
| 13 | 2.91 | 8.64 | 0.73 |
| 14 | 3.36 | 10.79 | 0.83 |
| 17 | 3.18 | 11.33 | 0.73 |
| Mean | 2.67 | 8.73 | 0.66 |

Table 6.5. Indices of species diversity, richness, and evenness for different areas off the Oregon coast.

| Location | Diversity (H') | Richness (SR) | Evenness (J) |
|---|---|---|---|
| Cape Blanco* | 2.91-3.36 | 6.92-11.33 | 0.73-0.83 |
| Gold Beach* | 1.20-2.71 | 7.22- 9.24 | 0.29-0.83 |
| Tillamook Bay** | 0.71-4.72 | 5.48-10.04 | 0.13-0.84 |
| Depoe Bay** | 3.70-4.21 | 6.82- 8.98 | 0.66-0.74 |
| Siuslaw River** | 3.53-4.53 | 5.73- 9.00 | 0.61-0.83 |
| Umpqua River** | 2.61-4.40 | 5.15-11.24 | 0.53-0.75 |

* This study
** Emmett et al. (1987

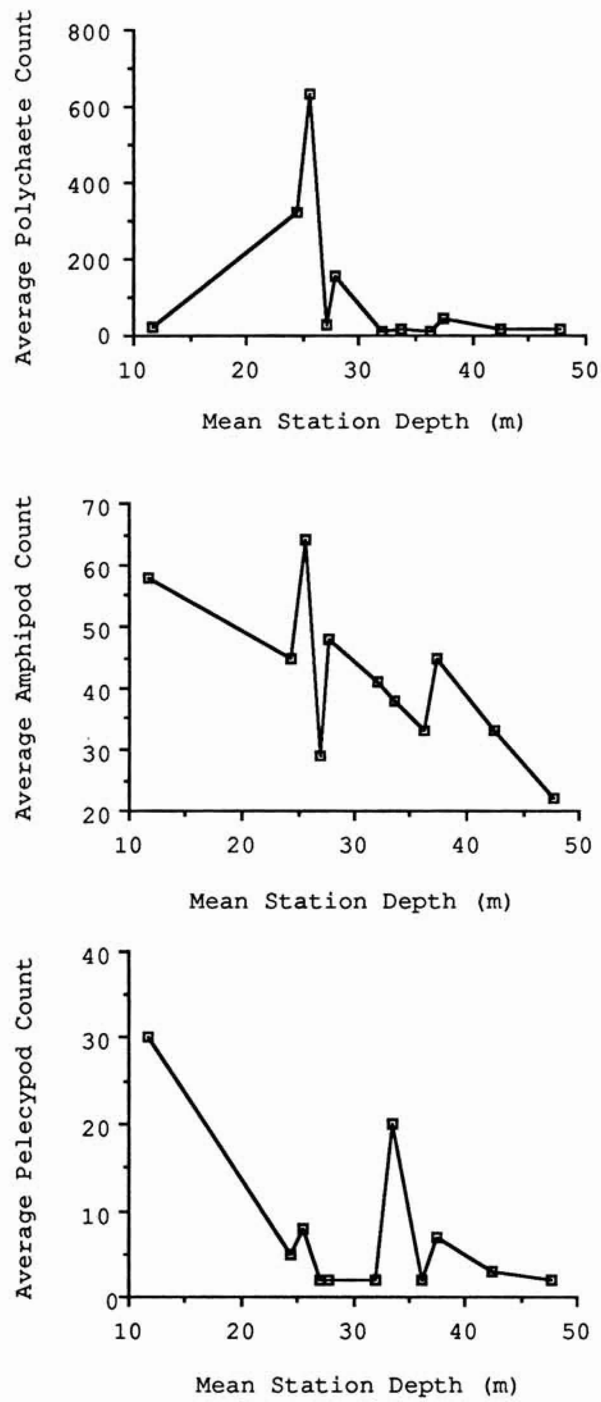



Figure 6.4. Average numbers of polychaetes, amphipods, and pelecypods caught versus mean station depth for all stations.

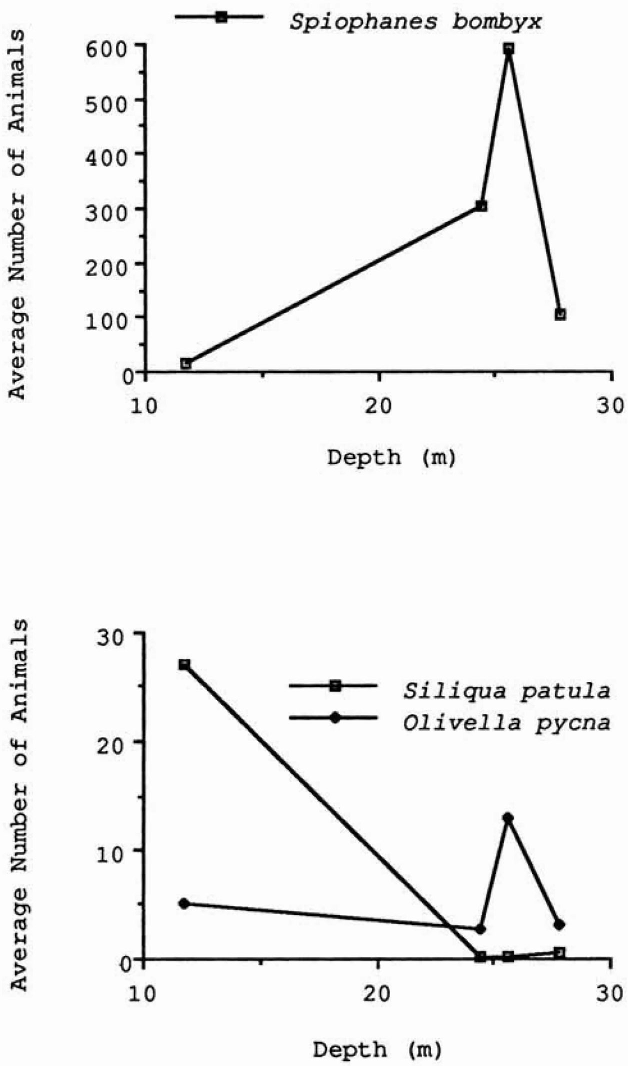



Figure 6.5. Average number of animals of selected species caught versus mean station depth for Stations 2-5.

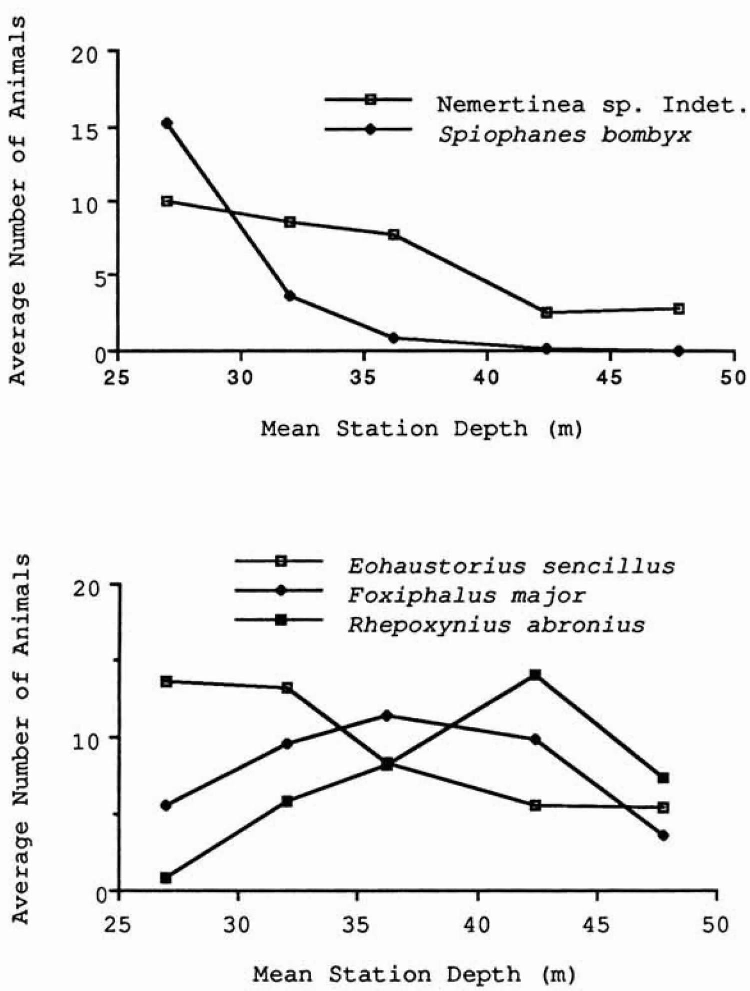



Figure 6.6. Average number of animals of selected species caught versus mean station depth for Stations 10-14.

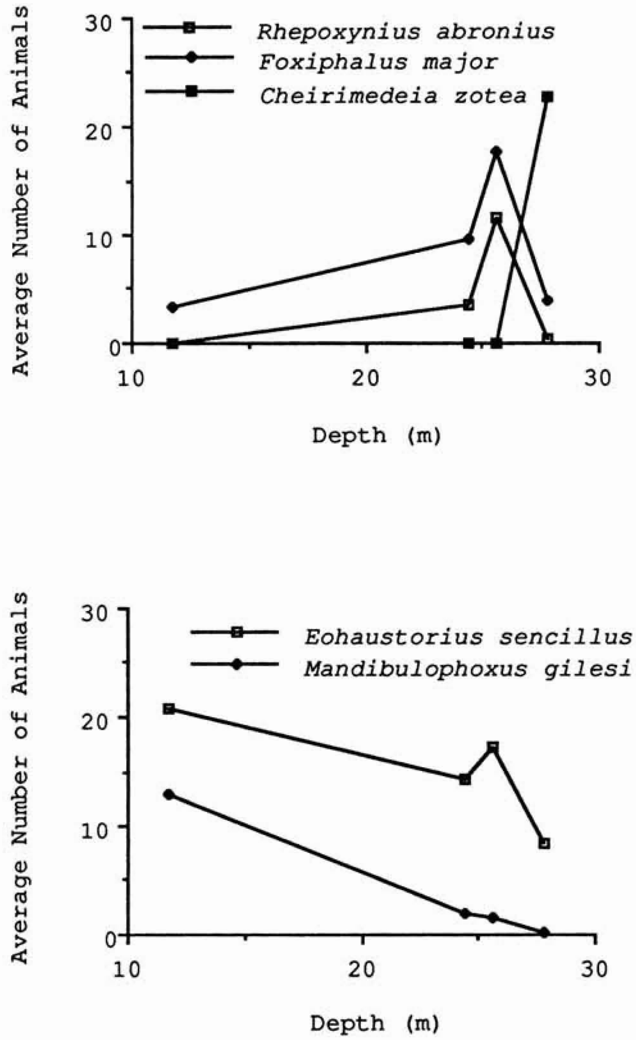



Figure 6.7. Average number of animals of selected species caught versus mean station depth for Stations 2-5.

sediment grain size. Lie and Kisker (1970) and Carey (1972) classified benthic communities off Oregon and Washington into three general categories. These included a shallow water sandy community out to about 100 m, an intermediate depth muddy-sand community, and a deep water mud community. The deeper, muddier areas generally have more species and higher densities than the shallow, sandy communities. All of our stations were within the area occupied by the shallow water sand community. Oliver et al. (1980) examined trends in infauna with depth in nearshore areas in Monterey Bay. The authors stated that their study area was similar in sediment type and wave exposure to the southern Oregon coast. They described a shallow water "crustacean zone" occupied by active free burrowing deposit feeding amphipods and ostracods. The crustacean zone is subject to frequent wave-induced sediment disturbance and occurs out to a depth of 10 - 20 m. Seaward of the crustacean zone is the "polychaete zone". This is a more stable environment with more tube dwelling and sedentary organisms such as polychaetes and bivalves.

Although some of the results are mixed, our data appear to follow the trends described by Oliver et al. (1980). Amphipods decreased with depth (Fig. 6.4) and, in the Rogue River area, we found an increase in polychaetes with depth (Fig. 6.5). Stations 2 through 5 cross the transition between zones described by Oliver et al. (1980). Station 2 is at about 11 m and is probably subjected to the greatest wave-induced sediment disturbance of any of our stations. This station had a relatively high proportion of free burrowing amphipods. Stations 3, 4, and 5 have the highest counts of tube dwelling polychaetes. These organisms require greater sediment stability and their presence tends to increase stability.

Infauna assemblages, sediment grain size distribution, and sediment stability are often interrelated. We examined possible relationships between infaunal density and grain size by running linear regressions between mean densities and medium and fine sand percentages. We found no statistically significant relationships. Station 2, apparently the most unstable station, exhibited a coarser grain size distribution and different fauna than other stations; however, all other stations had similar grain size distributions to each other. The sampling did not cover a wide enough gradient of sediment grain size distributions to allow further interpretation of trends in the benthic infauna. In addition, sediment grain size and stability vary over the year; benthic infauna most likely respond to the year-long patterns. Year-long patterns in such an exposed environment would not likely be well represented by sampling during a single point in the year.

The second objective of the infauna sampling was to compare target stations with control stations. The geologic sampling did not identify any target sites; therefore, a direct comparison could not be made. However, we were able to examine benthic infauna community patterns in relation to heavy metal concentrations in the sediment. Metal concentrations were analyzed at eight of the benthic infauna stations. Total metals analyzed quantitatively ranged from 719 mg/kg at Station 14 to 2,292 mg/kg at Station 4; most stations fell between 1,400 and 1,600 mg/kg.

We regressed total metal concentration against mean station density, number of species, and diversity measures. Density and number of species were not significantly related to total metals ($P > 0.05$). Species diversity and evenness did decrease significantly with total metals. This relationship is caused by Station 4 having high metal concentration and low species diversity. The low diversity and evenness at Station 4, however, resulted from the overwhelming relative abundance of *S. bombyx*. Since Station 5 exhibited similarly low diversity and evenness without the high metal concentration, the significant regression is thought to be a result of the way diversity and evenness are calculated, rather than reflect an environmental trend. Our analyses indirectly indicate that infauna community patterns were not strongly related to metal concentrations. Future work should be designed to examine relationships with metal concentrations and possible metal uptake by organisms. Also, if a target location is selected in future work, a more direct comparison between targets and controls should be made.

The third objective of the benthic infauna sampling was to gather information needed to design future impact studies. Sample design considerations examined included the number of sample replicates within a station, the distribution of stations in the study area, and sieve size appropriate for sampling the area. Other design variables evaluated included seasonality of sampling, depth of sampling into the substrate, and gear type. We only sampled soft sediment communities. The study area has significant areas of gravel sediment and rock reefs. Sampling schemes need to be developed for assessing impacts to invertebrates in these environments as well.

The number of replicate grabs taken per station is an important consideration in designing benthic infauna studies. Since infauna are often very patchy in distribution, a number of replicate samples are required to accurately describe a particular station. The typical recommended number of replicates for offshore infauna studies is five per station (McIntyre 1971). We performed several analyses to determine an optimum number of sampling replicates for future work. Station 2 was sampled with 15 grabs to evaluate the effects of different numbers of replicate samples on mean densities, variation, and taxa present. We also examined the same effects using the combined grabs from the clustered Stations 1, and 10 through 13. Power analyses and related calculations were performed to provide additional information on optimum number of replicates.

We randomly selected grab samples and plotted replicate grab combinations against mean density, coefficient of variation, and cumulative percent of species for Station 2 and the station cluster referred to above. At Station 2 and the station cluster, mean density reached a stable level at about 10 replicates (Fig. 6.8). The coefficient of variation reached a stable level at six replicates for Station 2 and at about 15 replicates for the station cluster (Fig. 6.9). Station 2 had a relatively low variance, leading to the low replicate sample size required to describe its variation. The cluster of 5 stations required a large number of replicates because of the between-station variation.

The analysis of taxa occurrence with replicate grab numbers gave similar results (Fig. 6.10). At Station 2, examination of 5 or 6 replicates yielded 80% of the taxa present while examination of 12 replicates yielded 90% of the taxa. The 80% and 90% taxa occurrence levels for the station cluster occurred at 15 and 17 replicate grabs, respectively. Sollitt et al. (1984) performed a similar taxa analysis off Coos Bay and found that, except in one case, three to five replicates were all that were needed to adequately describe taxa occurrence. None of the stations in their study were sampled with more than five grabs.

The number of replicates can be estimated for desired statistical tolerances given knowledge of the sampling means and variances. We used the mean density and number of species to calculate appropriate replicate numbers using three different approaches (Table 6.6). The first approach estimates replicates based on a tolerable percent error for the mean density and number of species at a station. The second approach estimates replicates based on tolerable 95% confidence limits around the mean (Table 6.6). The third approach estimates replicates based on a desired probability of showing a statistical difference (95% level) of sample means that differ by a given percentage. Presented are replicate number estimates for having a 95%, 90%, and 80% probability of showing a significant difference between means that vary by 20% and 40% (Table 6.6).

Decisions on replicates per station depend on the researcher's goals, total number of stations needed to characterize an area, and amount of money available. In an impact analysis, the researcher needs to be capable of making statistically supported conclusions about whether or not an activity has altered the environment significantly. It is difficult to define the level at which impacts constitute significant alterations to the environment. To do this, the researcher needs to consider the background level of natural variation in benthic infauna, the level at which alterations beyond this background level are ecologically significant, and the effects these changes may have on species that prey on the benthic infauna. Since many of these predator species are important in commercial and recreational fisheries, an indirect economic effect also needs to be considered. Ferraro et al. (1989) showed that five replicate samples per station was the optimum number for impact assessments designed to show effects of pollution at a location in Puget Sound. Lissner et al. (1989), using multivariate analytical techniques to describe the benthic

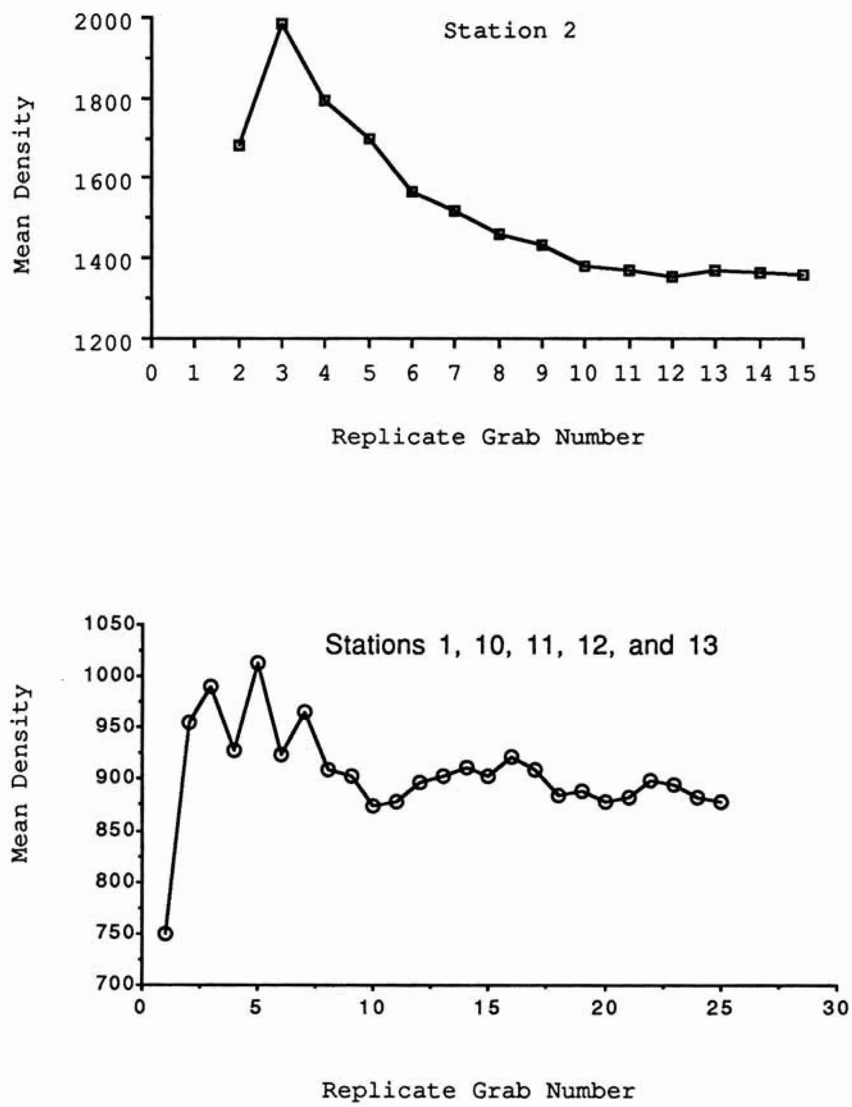
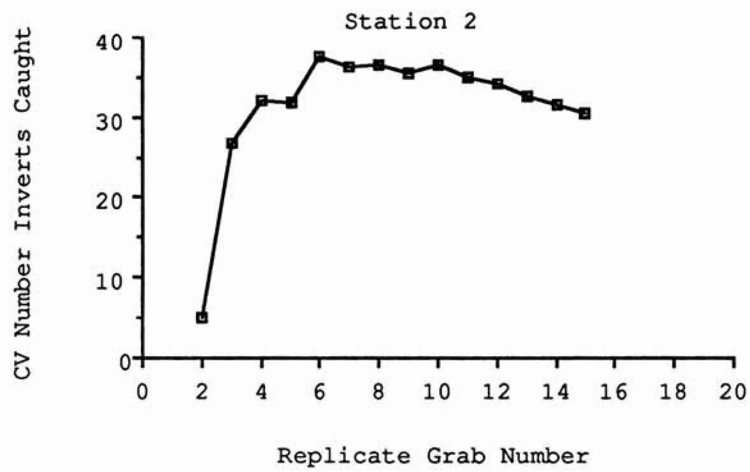



Figure 6.8. Mean density (number/$m^2$) of invertebrates caught versus replicate grab number for Station 2 and for Stations 1, 10, 11, 12, and 13 combined. Replicate grab samples were chosen randomly.



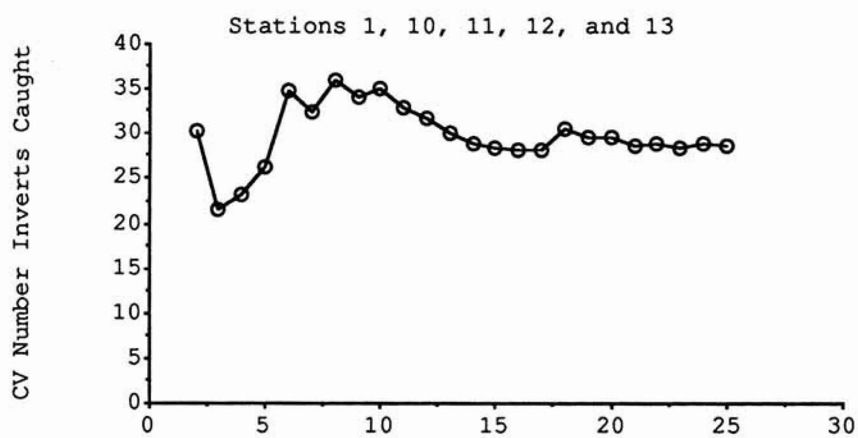
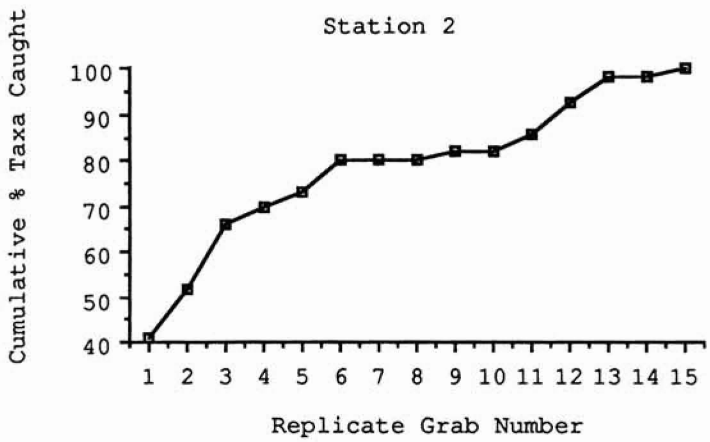




Figure 6.9. Coefficient of variation (CV) of numbers of invertebrates caught per grab versus randomly chosen replicate grab number for Station 2 and for Stations 1, 10, 11, 12, and 13 combined.



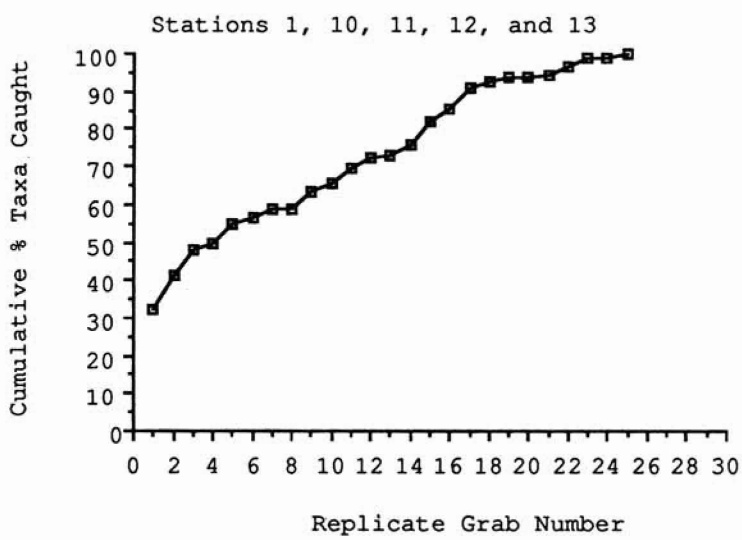




Figure 6.10. Cumulative percent taxa caught versus replicate grab number for Station 2 and for Stations 1, 10, 11, 12, and 13 combined.

Table 6.6. Estimated number of replicate grab samples (n) needed per station.

| | Mean n Based on Density | Mean n Based on Ln(Density+1) | Mean n Based on No.Taxa | Mean n Based on Ln(No. Taxa) |
|---|---|---|---|---|
| Estimated replicates based on tolerable percent error from the mean.* | | | | |
| 10% error | 9 | 50 | 4 | 2 |
| 20% error | 2 | 4 | 1 | 1 |
| 40% error | 1 | 1 | 1 | 1 |
| Estimated replicates based on tolerable range of 95% confidence limits.** | | | | |
| 10% range | 34 | 200 | 14 | 8 |
| 20% range | 9 | 13 | 4 | 2 |
| 40% range | 2 | 2 | 1 | 1 |
| Estimated replicates based on probability of showing significantly different means with a difference of *x*%.*** | | | | |
| 95% chance for 20% diff | 56 | 84 | 22 | 13 |
| 90% chance for 20% diff | 38 | 68 | 18 | 10 |
| 80% chance for 20% diff | 29 | 51 | 13 | 8 |
| 95% chance for 40% diff | 12 | 12 | 6 | 3 |
| 90% chance for 40% diff | 10 | 9 | 5 | 3 |
| 80% chance for 40% diff | 7 | 7 | 4 | 2 |

* $n = s^2/(D^2 \times mean^2)$ (Gonor and Kemp 1978)

** $n = (t^2 \times s^2)/(D^2 \times mean^2)$ (Gonor and Kemp 1978)

*** $n = multiplier \times ((2 \times s^2) / (D^2 \times mean^2))$ (Gonor and Kemp 1978; Snedecor and Cochran 1967)

n = number of replicates
$s^2$ = sample variance
D = desired percent variation from mean
t = Student's t statistic
multiplier = value given in Snedecor and Cochran (1967), Table 4.13.1

communities in a large area off California, demonstrated that one sample per station was adequate for describing benthic infauna distributional patterns.

There is currently no information in the study area on background level of variation in the benthic environment, or on the relationships between the infauna and their predators. Without this key information, it is difficult to recommend an optimum replicate sample number. Based on the results presented above, 10 grabs per station should be adequate to accurately estimate the station mean, describe the station variance, account for most of the species present, and have a good probability of showing changes in mean density. If demonstrating differences in number of species per station is all that is desired, then five replicates per station would be adequate.

A second important consideration in benthic sampling is the distribution of stations needed to characterize an area. Station distribution variables include the distance between stations, stratification of stations by depth or other environmental variables, and, in impact analysis, location of control stations and placement of stations along the gradient of impacts. The infauna in our study exhibited greater differences due to north-south geographic separation than depth gradient. Nearshore Oregon infauna sampling conducted by Hancock et al. (1980); Nelson et al. (1981); Sollitt et al. (1984); and Emmett et al. (1987) showed that infauna assemblages often exhibited greater differences within depth zones than across them. This may be due partially to the fact that these studies examined infauna off river mouths and within a narrow depth range. There were often distinct assemblages directly off a river mouth that differed from other assemblages north and south of the mouth. Where distinct assemblages did appear along a depth gradient, the breaks were at about 20-25 m, 30-35 m, and about 60 m (Hancock et al. 1980; Nelson et al. 1981; Sollitt et al. 1984; Emmett et al. 1987).

Based on our results and those of past studies, we recommend future sampling be stratified by both depth and geographic separation. Suggested depth strata would be 0-15 m, 15-35 m, and 35-60 m. The Blanco area should be a separate stratum from the Rogue Reef/Cape Sebastian area. An additional stratum should be located off the mouth of the Rogue River to adequately describe this river mouth area. Station locations should be chosen at random within the strata. Control stations should be in a similar stratum as the target stations but distant enough to ensure they are not disturbed. Since an activity such as mining would result in a plume of sediment moving with the prevailing currents, some sampling stations should be located downstream of the prevailing current.

The third sampling consideration, the size of the sieve openings used to separate invertebrates from sediment, has a large influence on the data obtained in any benthic infauna study. Most studies separate infauna with a 0.5 or 1.0 mm sieve (Ferraro et al. 1989). At two of our stations, we sieved the organisms in nested 1.0 and 0.5 mm sieves and analyzed the results separately. On the average the 1.0 mm sieve yielded 31 taxa while the 0.5 mm sieve yielded 15 additional taxa (Fig. 6.11). The total infauna density estimated with the 0.5 mm sieve was more than double that estimated with the 1.0 mm sieve. For species that were sampled in common by both sieves, the density obtained from the 0.5 mm sieve was more than triple that estimated from the 1.0 mm sieve.

Ferraro et al. (1989) showed that a 1.0 mm sieve was more efficient for analyzing pollution impacts at a site in Puget Sound. Processing samples from the 0.5 mm sieve is more costly and yields mainly juveniles that may not be important in describing impacts. However, these juveniles may be prey items for other species and may help to describe the recovery of an impacted area. We recommend that a 0.5 mm sieve be used in the study area for impact analysis. Because the sediments are sandy and relatively free of organic matter, the 0.5 mm screen did not require substantially more sieving and sorting effort than the 1.0 mm screen.

Other considerations when sampling infauna include seasonality of sampling, depth of sampling into the substrate, gear type, and abundance measures obtained. Sampling for this study was a one time effort during the fall months. Past studies have shown significant seasonal variation in benthic infauna (Hancock et al. 1980; Nelson et al. 1981; Sollitt et al. 1984; Emmett et al. 1987); we would expect substantial variation in our study area. Seasonal sampling is required to adequately describe the benthic community. Seasons can be defined as the four solar seasons (spring, summer, fall, winter), upwelling seasons (summer upwelling, winter downwelling, and spring transition), climatic seasons that affect sediment disturbance (winter storm, spring/summer NW winds, fall calm period), or some combination of these.

The Smith-McIntyre grab used in this study penetrated the substrate an average of 8.7 cm. This is not deep enough to sample deep dwelling organisms such as large clams. Other sampling devices would be needed to obtain a more complete list of benthic infauna. Some other types of quantitative infauna sampling gear that have been used successfully in Oregon include the Bouna-Reineck box corer (Carey and Heyamoto 1972) and the Gray-O'Hara box corer (Emmett et al. 1987). Both of these gear types will penetrate 15 or more centimeters into sandy substrate but are more difficult and time consuming to use than the Smith-McIntyre grab. The Bouna-Reineck box corer is very heavy and cumbersome, and can be dangerous to use in rough seas. The Gray-O'Hara represents a good compromise between ease of use and depth of sediment penetration. Neither of these devices would, however, sample deep-dwelling clams. These organisms would best be sampled with a venturi suction sampler similar to devices used by the Oregon Department of Fish and Wildlife and Washington Department of

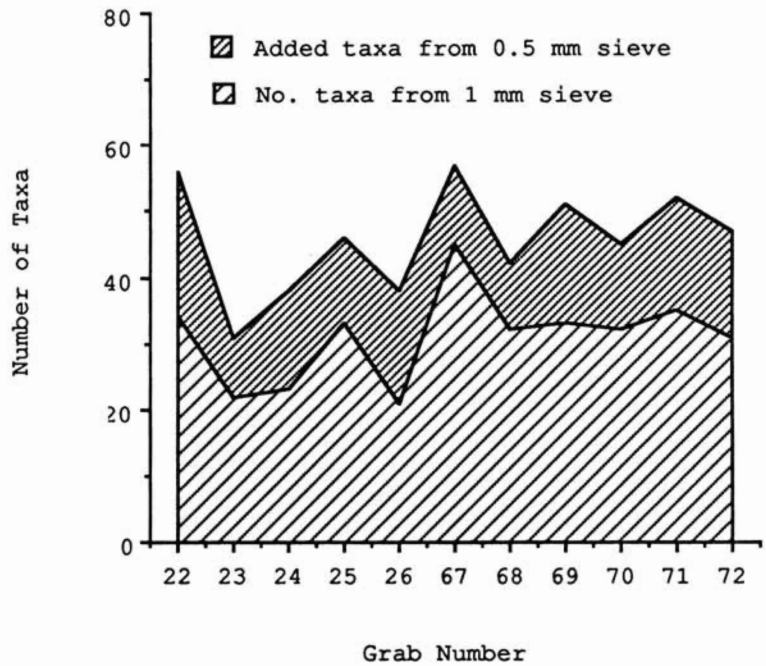



Figure 6.11. Comparison of species counts from 1.0 mm sieve and 0.5 mm sieve. Grab numbers 22-26 are from Station 3 and grab numbers 67-72 are from Station 17.

Fisheries for conducting clam surveys. This device is deployed by SCUBA divers and has a practical depth limitation of about 20 m (Tom Gaumer, Oregon Department of Fish and Wildlife, personal communication 1991).

This study identified and enumerated infauna species. Future projects should also weigh the biota so that biomass can be estimated. To describe the recovery of an impacted area, it would also be desirable to obtain life history information pertaining to recruitment, growth, and reproduction for the dominant species.

#### 6.3.1.2 Epibenthic Invertebrates

We counted and measured crab caught in pots and in trawls in an attempt to evaluate two gear types for sampling Dungeness crab (*Cancer magister*) populations. We twice set a string of five pots for a 24-26 h soak time (Fig. 6.1, 6.2), and caught a total of 67 Dungeness crab in pots. Pots located off Cape Sebastian caught an average of 13.2 crab per pot, whereas all pots retrieved off Cape Blanco were empty. The depth and substrate at which the pots were deployed was similar between the two areas, yet catches were vastly different. The number of times the gear was set was too small to determine if the difference in catch was due to a difference in abundance or was a sampling error. Cruise logistics prevented the deployment of enough gear to estimate Dungeness crab densities using crab pots. More work is necessary to determine the minimum number of sets or strings needed to adequately estimate adult crab populations.

The trawl catch of crab was more substantial. We caught 271 Dungeness crab in 16 trawls. All trawl tows in the Cape Blanco West area and the Gold Beach South area caught crab; trawl tows in both Cape Blanco South stations, however, caught no Dungeness crab. Although all tows in the Cape Blanco West area caught crab, no crab caught were larger than 34 mm. Crab caught in the Gold Beach South tows ranged from 10 to 190 mm in carapace width.

Pots and trawls caught different sized Dungeness crab. The frequency histogram of carapace widths of all crab caught shows several modes of size frequencies (Fig. 6.12). As expected, commercial crab pots caught only the larger crab (Fig. 6.13); trawls caught all size classes (Fig. 6.13). Analysis of the size frequencies of crab larger than the commercial size limit of 159 mm suggests that crab pots should be used if the purpose of a sampling project is to estimate the carapace width of commercial sized (greater than 159 mm) Dungeness crab in an area. In the Gold Beach South area where both pots and trawls caught crab, the mean carapace width of trawl caught crab (greater than 159 mm) was 169.3 mm; a width that is significantly smaller than the 172.3 mm mean carapace width of crab caught in pots (Student's 't' test, $P < 0.01$). Conversely, trawls should be used if the purpose is to estimate the numbers of all size classes of crab in the study area.

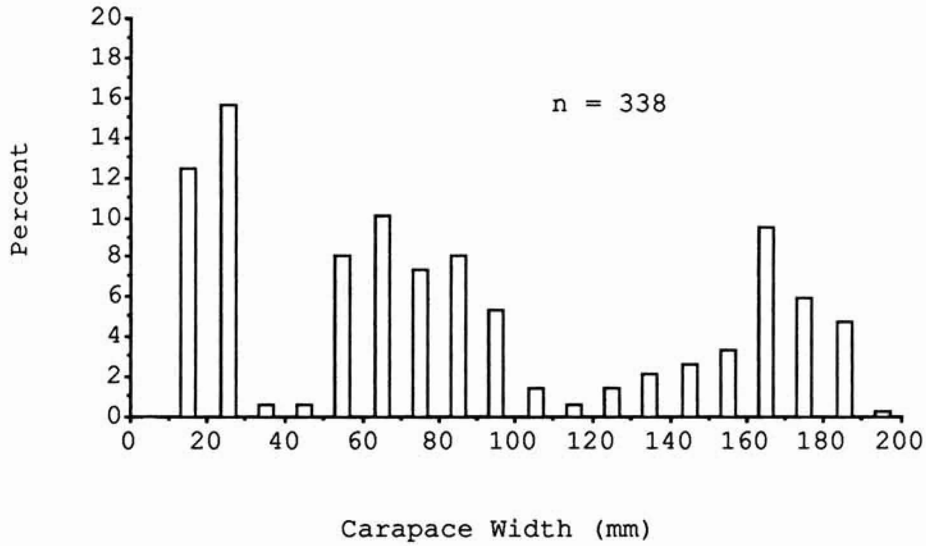



Figure 6.12. Histogram of carapace widths of all *Cancer magister* caught in trawls or pots.

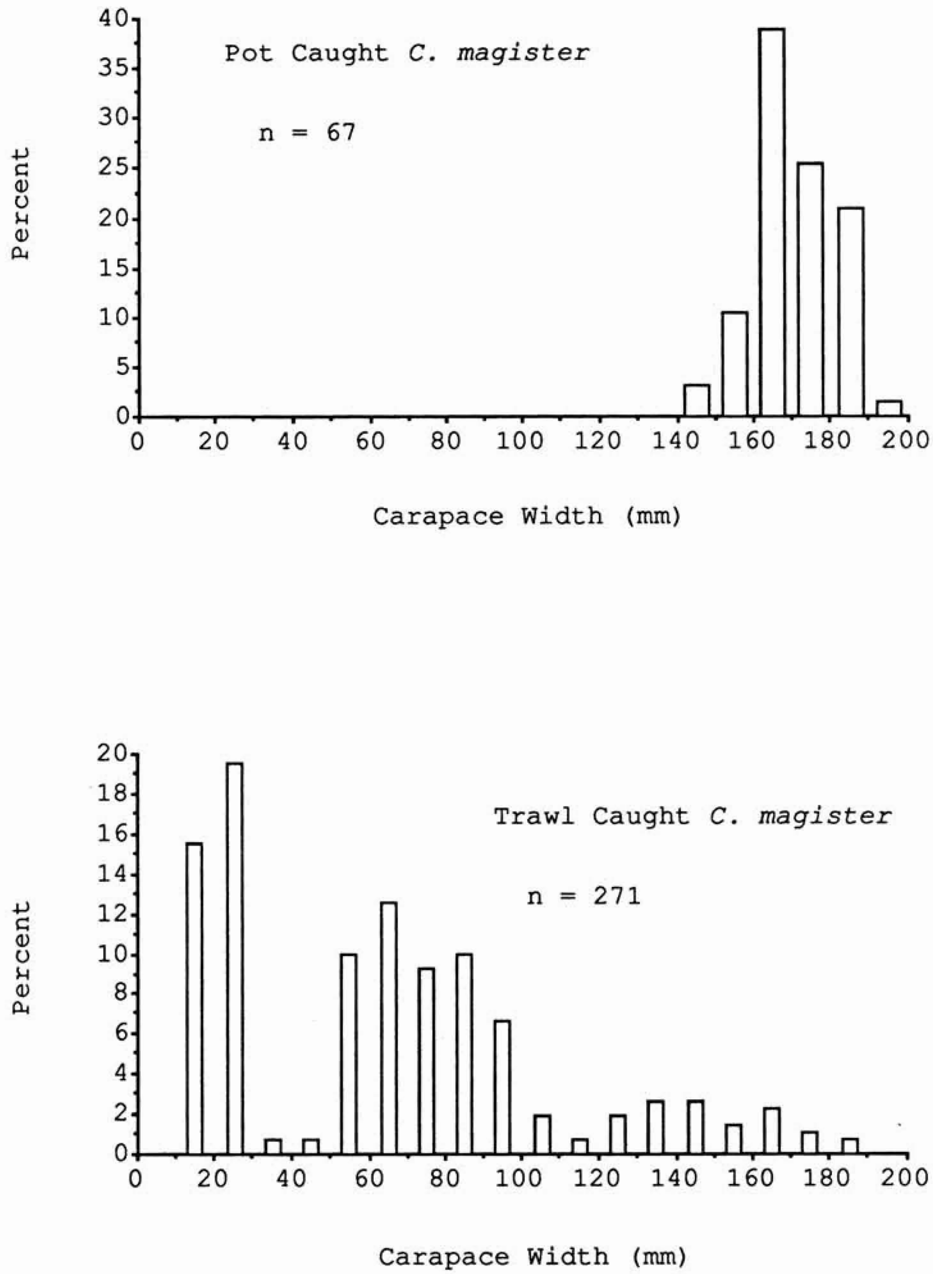



Figure 6.13. Histogram of carapace widths of *Cancer magister* caught in pots and in trawls.

Trawl tows in the Cape Blanco West region caught exclusively young of the year Dungeness crab (crab less than 30 mm carapace width). To adequately quantify the number of juvenile crab using an area, it may be important to sample at night. In two trawl tows at night, we caught 73 Dungeness crab, while the four day trawl tows averaged 5 crab per tow. It is likely that the juvenile crab burrow in the sand during the day and actively feed along the bottom at night; and thus are more susceptible to being captured by trawling during the night.

Each trawl collected large numbers of invertebrates not collected in the grab samples. The cruise sampling plan did not include quantification of invertebrates caught in trawls, but representative species were saved from most trawl tows (Table 6.7). A few species were very abundant in trawl catches. Ctenophores, crangonid shrimp, mysid shrimp, and amphipods were frequently caught in large numbers. Future studies should attempt to quantify these populations as they are important prey species.

### 6.3.2 Fish Sampling

Fifteen of the 17 trawl tows we conducted successfully caught fish. Tow number 6 was aborted. Tow number 5 caught no fish, possibly because the vessel was travelling too fast to keep the trawl on the bottom. At that location minimum vessel speed over ground was in excess of 6 km/hr (4 kt). In subsequent tows we attempted to keep vessel speed over ground below 3 km/hr (2 kt). Trawls conducted in high wind and seas were more successful because the vessel traveled more slowly. The shallowest depth fished was 21 m, the deepest, 37 m (Table 6.8). All tows were made in a north - south direction. Tows lasted from 14 to 64 min, distances trawled ranged from 0.298 to 2.722 km, and areas swept were from 0.0811 to 1.3338 ha (Table 6.8).

A total of 2,367 fish was caught, representing at least 30 species in 13 families (Table 6.9). Some fishes, such as juvenile rockfishes and osmerids, could be identified only to family. Six species occurred in at least ten of the fifteen successful tows, whereas seven species occurred in only one of the fifteen tows. The six species most frequently encountered included speckled sanddab (*Citharichthys stigmaeus*), Pacific sand lance (*Ammodytes hexapterus*), english sole (*Parophrys vetulus*), butter sole (*Isopsetta isolepis*), sand sole (*Psettichthys melanostictus*), and Pacific tomcod (*Microgadus proximus*). Juvenile osmerids (smelt) were also frequently collected; they occurred in all sampling areas, but in only nine tows. Of the most common species, english sole, butter sole, and sand sole are important commercial species (Lukas and Carter 1990). The Pacific sand lance is an important prey item of salmon (*Oncorhynchus* sp.), lingcod (*Ophiodon elongatus*), Pacific halibut (*Hippoglossus stenolepis*), other fishes (Hart 1973), and several bird species.

Table 6.7. List of invertebrate species caught with trawl gear.

| Polychaeta | Crustacea |
|---|---|
| *Axiothella rubrocincta* | *Ampelisca careyi* |
| *Glycera americana* | *Anonyx cf. lilljeborgi* |
| *Glycera capitata* | *Archeomysis grebnitzkii* |
| *Glycera robusta* | *Cancer branneri* |
| *Harmothoe* sp. Indet. | *Cancer magister* |
| *Nephtys magellanica* | *Cancer productus* |
| *Ophelia* sp. 1 | Cirripedia |
| *Phyllodoce hartmanae* | *Colurostylis occidentalis* |
| *Phyllodoce williamsi* | *Crangon alaskensis* |
| *Schizobranchia insignis* | *Crangon alba* |
| *Trypanosyllis gemmipara* | *Crangon stylirostris* |
| | Crangon - zoea |
| Mollusca | *Foxiphalus major* |
| *Glycymeris subobsoleta* | *Gnorimosphaeroma oregonensis* |
| *Lirularia lirulata* | Lironeca sp. Indet. |
| *Loligo opalescens* | *Metacaprella cf. kennerlyi* |
| *Lyonsia pugettensis* | *Monocludes spinipes* |
| *Melanochlamys diomedea* | Mysidacea sp. Indet. |
| *Mitrella gouldi* | *Neomysis kadiakensis* |
| *Nassarius fossatus* | *Pagurus setosus* |
| *Nitidiscala indianorum* | *Pagurus* sp. Indet. |
| *Olivella baetica* | *Pagurus* sp. Juv. |
| *Olivella biplicata* | *Pandalopsis ampla* |
| *Olivella pycna* | *Pandalus* cf. *platyceros* |
| *Onchidoris bilamellata* | *Peramphithoe humeralis* |
| *Polinices lewisi* | *Photis parvidons* |
| *Psephidia lordi* | *Porcellanidae zoea* |
| *Rictaxis punctocaelatus* | *Rocinela* cf. *angustata* |
| *Tellina nuculoides* | |
| | Nemertea |
| Asteroidea | Nemertinea sp. Indet. |
| *Crossasater papposus* | |
| *Leptosynapta transgressor* | |
| *Dendraster excentricus* | |
| Echinoidea | |

Table 6.8. Station data for fish tows.

| TOW NUM | USGS STN | DATE | TIME START | TIME END | POSITION START | POSITION END | DEPTH (m) START | DEPTH (m) END | Km TOWED | AREA (ha) | SUBSTRATE (S= Sand, G=Gravel) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1* | 6 | 9/25/90 | 1117 | 1137 | 42° 19.37'<br>124° 26.65' | 42° 20.46'<br>124 °26.83' | 22 | 21 | 1.89 | 0.513 | S |
| 2* | 6 | 9/25/90 | 1203 | 1233 | 42 20.65<br>124 26.84 | 42 18.94<br>124 26.91 | 20 | 29 | 1.58 | 0.429 | S |
| 3# | 6 | 9/25/90 | 1315 | 1345 | 42 19.30<br>124 26.89 | 42 20.77<br>124 26.99 | 28 | 23 | 2.72 | 1.334 | S |
| 4# | 6 | 9/25/90 | 1425 | 1440 | 42 20.05<br>124 26.74 | 42 19.02<br>124 26.61 | 22 | | 1.91 | 0.935 | S |
| 5# | 6 | 9/25/90 | 1515 | 1530 | 42 19.74<br>124 27.09 | 42 20.59<br>124 27.13 | 32 | 26 | 1.57 | 0.771 | S |
| 7* | 15 | 9/27/90 | 1609 | 1651 | 42 50.87<br>124 35.72 | 42 51.98<br>124 35.73 | 31 | 35 | 0.30 | 0.081 | S |
| 8* | 15 | 9/28/90 | 1154 | 1258 | 42 50.93<br>124 35.72 | 42 51.97<br>124 35.77 | 30 | 37 | 1.88 | 0.511 | S |
| 9* | 16 | 9/30/90 | 1041 | 1117 | 42 45.38<br>124 33.13 | 42 46.54<br>124 33.12 | 32 | 27 | 2.03 | 0.551 | S/G |
| 10* | 16 | 9/30/90 | 1150 | 1217 | 42 45.25<br>124 33.17 | 42 46.12<br>124 33.19 | 33 | @ | 1.59 | 0.433 | S |
| 11* | 16 | 9/30/90 | 1256 | 1324 | 42 45.17<br>124 33.22 | 42 46.12<br>124 33.21 | @ | 29 | 1.67 | 0.453 | S |
| 12* | 15 | 9/30/90 | 2221 | 2245 | 42 50.95<br>124 35.72 | 42 51.93<br>124 35.72 | 28 | 36 | 1.73 | 0.470 | S |
| 13* | 15 | 9/30/90 | 1502 | 1533 | 42 50.93<br>124 35.72 | 42 51.92<br>124 35.73 | 27 | 36 | 1.44 | 0.391 | S |
| 14* | 15 | 10/1/90 | 1617 | 1653 | 42 51.01<br>124 35.73 | 42 51.93<br>124 35.73 | 27 | 34 | 1.63 | 0.443 | S |
| 15* | 15 | 10/1/90 | 2129 | 2149 | 42 51.02<br>124 35.72 | 42 51.92<br>124 35.73 | 29 | 36 | 1.50 | 0.407 | S |
| 16* | 19 | 10/2/90 | 1431 | 1447 | 42 46.42<br>124 33.17 | 42 46.80<br>124 33.17 | 27 | 24 | 0.66 | 0.180 | G |
| 17* | 19 | 10/2/90 | 1517 | 1536 | 42 46.41<br>124 33.17 | 42 46.80<br>124 33.20 | 27 | 23 | 0.66 | 0.180 | G |

* Beam trawl
# Otter trawl
@ Fathometer inoperative
Tow 6 was aborted

Table 6.9. Substrate type and numbers of fish of each species caught by trawl gear.

| | | Sand | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Gravel | | | | |
| | | Gold Beach | | | | | Cape Blanco West | | | | | | Cape Blanco South | | | | | | |
| | | South | | | | | | | | | | | South | | | | | | |
| | Trawl: | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 12 | 13 | 14 | 15 | 10 | 11 | 9* | 16 | 17 | TOTAL | MEAN |
| *Citharichthys stigmaeus* | Bothidae | 2 | 12 | 302 | 7 | | 13 | 210 | 145 | 25 | 55 | 142 | 29 | 51 | 117 | 33 | 47 | 1190 | 74.4 |
| *Ammodytes hexapterus* | Ammodytidae | | | | | | 5 | 13 | 4 | 2 | 4 | 3 | 22 | 1 | 149 | 240 | 172 | 615 | 38.4 |
| *Parophrys vetulus* | Pleuronectidae | 1 | 1 | 15 | 1 | | | 7 | 12 | 15 | 13 | 9 | 14 | 20 | 28 | | | 136 | 8.5 |
| Juvenile osmeridae | Osmeridae | | 1 | | 5 | | 1 | | 3 | 2 | 3 | 1 | | 20 | 79 | | | 115 | 7.2 |
| *Isopsetta isolepis* | Pleuronectidae | | 1 | 19 | 2 | | | 3 | 16 | 1 | 2 | 11 | | 1 | 1 | 1 | | 58 | 3.6 |
| *Citharichthys sordidus* | Bothidae | | | | | | | 55 | | 1 | | | | | | | | 56 | 3.5 |
| *Psettichthys melanostictus* | Pleuronectidae | 2 | 1 | 9 | | | | 6 | 4 | | 4 | 3 | 3 | 3 | 3 | 1 | | 39 | 2.4 |
| *Leptocottus armatus* | Cottidae | | | 25 | | | | | | | 1 | | | | | | | 26 | 1.6 |
| *Microgadus proximus* | Gadidae | | | 3 | 1 | | | | 3 | 2 | | 7 | 1 | 1 | 1 | 1 | | 20 | 1.3 |
| *Artedius fenestralis* | Cottidae | | | | | | | | | | | | | | 1 | 9 | 10 | 20 | 1.3 |
| *Spirinchus starksi* | Osmeridae | | | | 16 | | | | | | | | | | | | | 16 | 1 |
| *Allosmerus elongatus* | Osmeridae | | | 3 | 6 | | | | 1 | | | 1 | | | | | | 11 | 0.7 |
| *Pallasina barbata* | Agonidae | | | 2 | | | | 3 | 1 | | | 2 | | | | | | 8 | 0.5 |
| Juvenile rockfish | Scorpaenidae | | | | 1 | | | | | | | | 1 | | 5 | | 1 | 8 | 0.5 |
| *Enophrys bison* | Cottidae | | | | | | | | | | | | | | 2 | 1 | 3 | 6 | 0.4 |
| *Raja binoculata* | Rajidae | | | | 1 | | | 1 | 1 | 1 | | 1 | | | | | | 5 | 0.3 |
| *Ophiodon elongatus* | Hexagrammidae | | | 3 | 1 | | | | | | | | | | 1 | | | 5 | 0.3 |
| *Lepidopsetta bilineata* | Pleuronectidae | | | | | | | | | | | | | | 1 | 2 | 2 | 5 | 0.3 |
| *Scorpaenichthys marmoratus* | Cottidae | | | | | | | 1 | | | 1 | | | | | 1 | 1 | 4 | 0.3 |
| Osmeridae | Osmeridae | | 3 | 1 | | | | | | | | | | | | | | 4 | 0.3 |
| *Liparis pulchellus* | Liparididae | | | | | | | | | | 1 | | | | | 1 | 2 | 4 | 0.3 |
| *Hemilepidotus spinosus* | Cottidae | | | | | | | | | | | | | | 2 | | 1 | 3 | 0.2 |
| *Gobiesox maeandricus* | Gobiesocidae | | | | | | 3 | | | | | | | | | | | 3 | 0.2 |
| *Pleuronichthys decurrens* | Pleuronectidae | | | | | | | 1 | | | | | | | | | 1 | 2 | 0.1 |
| *Liparis fucensis* | Liparididae | | | | | | | | | | 1 | 1 | | | | | | 2 | 0.1 |
| *Sebastes melanops* | Scorpaenidae | | | | 1 | | | | | | | | | | | | | 1 | 0.1 |
| *Occella verrucosa* | Agonidae | | | | | | | | | | | 1 | | | | | | 1 | 0.1 |
| *Glyptocephalus zachirus* | Pleuronectidae | | | | | | | | | | | | | 1 | | | | 1 | 0.1 |
| *Eopsetta jordani* | Pleuronectidae | | | 1 | | | | | | | | | | | | | | 1 | 0.1 |
| *Aulorhynchus flavidus* | Aulorhynchidae | | | | | | | | | | | | | | 1 | | | 1 | 0.1 |
| *Agonopsis vulsa* | Agonidae | | | | | | | | | | | | | | 1 | | | 1 | 0.1 |
| All Taxa Combined | | 5 | 19 | 383 | 42 | 0 | 22 | 300 | 190 | 49 | 85 | 182 | 70 | 98 | 392 | 290 | 240 | 2367 | 147.9 |

* Trawl 9 covered both sand and gravel.

The species composition observed in this study is similar to the species composition observed in shallow water along the entire Oregon coast. Richardson et al. (1980) describe a larval fish species assemblage occurring in shallow water from Cape Blanco to the Columbia River. Species reported in the larval assemblage include all of the dominant species we observed with the exception of speckled sanddab and Pacific tomcod. Those two species were caught in shallow water as larvae, but not in large abundances.

Richardson et al. (1980) reported that the species assemblage of larval fish in nearshore waters was quite constant over four years and suggest that concentrations of larvae are due to spawning areas of adults and coastal circulation patterns. Larvae of inner shelf spawners such as english sole, butter sole, and smelt remain close to shore because of alongshore currents. They believe that annual variations in dominance and relative abundance in specific areas may reflect timing and intensity of adult spawning and larval survival. Their results suggest that multiple sampling cruises at different times of the year and over a several year period will be necessary to describe seasonal and annual variations in relative abundance of species in the study area.

Studies of dredged material disposal sites show that similar species occur as juveniles and adults in shallow water along the length of the Oregon coast. Emmett et al. (1987), studying disposal sites off Tillamook Bay, Depoe Bay, the Siuslaw River, and the Umpqua River reported the most commonly caught fish included speckled sanddab, Pacific tomcod, english sole, sand sole, and juvenile smelt. Hancock et al. (1980) found a similar species composition off Coos Bay, with speckled sanddab, english sole, and Pacific tomcod being the most abundant species caught.

In our study, a few taxa comprised the bulk of the catch, both by numbers and by weight. For instance, by number per hectare, the top four taxa (Pacific sand lance, speckled sanddab, english sole, and juvenile smelt) comprised 89% of the total catch. By weight (g/ha), the top four species (cabezon (*Scorpaenichthys marmoratus*), Pacific sand lance, speckled sanddab, and sand sole) comprised 78% of the total catch. The most abundant species were Pacific sand lance by mean number per hectare (Table 6.10), and cabezon by mean weight per hectare (Table 6.11). These results are artifacts of sampling, however. Pacific sand lance was extremely abundant in two trawl tows in one location over a gravel substrate, and is not representative of most sample locations. Similarly, the cabezon weights represent four adult fish. The four cabezon apparently had left refuge in nearby rocky areas to forage over sand. Stomachs of the cabezon collected contained numerous speckled sanddab, sand sole, and juvenile crab.

If Pacific sand lance and cabezon are removed from consideration, speckled sanddab was the most abundant fish caught by number and by weight. It was ubiquitous, occurred in all tows

Table 6.10. Substrate type and number of fish of each species caught per hectare by trawl gear. The mean is the sum of the catch per hectare divided by 16.

| | Sand | | | | | | | | | | | | | Gravel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gold Beach South | | | | Cape Blanco West | | | | | | | Cape Blanco South | | | | | MEAN |
| Trawl: | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 12 | 13 | 14 | 15 | 10 | 11 | 9* | 16 | 17 | Catch/ha |
| *Ammodytes hexapterus* | | | | | | 61.7 | 25.4 | 8.5 | 5.1 | 9.0 | 7.4 | 50.8 | 2.2 | 270.4 | 1332.6 | 955.0 | 170.5 |
| *Citharichthys stigmaeus* | 3.9 | 28.0 | 226.4 | 7.5 | | 160.3 | 410.6 | 308.5 | 64.0 | 124.2 | 349.0 | 67.0 | 112.5 | 212.3 | 183.2 | 261.0 | 157.4 |
| *Parophrys vetulus* | 1.9 | 2.3 | 11.2 | 1.1 | | | 13.7 | 25.5 | 38.4 | 29.4 | 22.1 | 32.3 | 44.1 | 50.8 | | | 17.1 |
| Juvenile osmerids | | 2.3 | | 5.3 | | 12.3 | | 6.4 | 5.1 | 6.8 | 2.5 | | 44.1 | 143.3 | | | 14.3 |
| *Citharichthys sordidus* | | | | | | | 107.5 | | 2.6 | | | | | | | | 6.9 |
| *Artedius fenestralis* | | | | | | | | | | | | | | 1.8 | 50.0 | 55.5 | 6.7 |
| *Isopsetta isolepis* | | 2.3 | 14.2 | 2.1 | | | 5.9 | 34.0 | 2.6 | 4.5 | 27.0 | | 2.2 | 1.8 | 5.6 | | 6.4 |
| *Psettichthys melanostictus* | 3.9 | 2.3 | 6.7 | | | | 11.7 | 8.5 | | 9.0 | 7.4 | 6.9 | 6.6 | 5.4 | 5.6 | | 4.6 |
| *Microgadus proximus* | | | 2.2 | 1.1 | | | | 6.4 | 5.1 | | 17.2 | 2.3 | 2.2 | 1.8 | 5.6 | | 2.7 |
| *Gobiesox maeandricus* | | | | | | 37.0 | | | | | | | | | | | 2.3 |
| *Enophrys bison* | | | | | | | | | | | | | | 3.6 | 5.6 | 16.7 | 1.6 |
| *Lepidopsetta bilineata* | | | | | | | | | | | | | | 1.8 | 11.1 | 11.1 | 1.5 |
| *Leptocottus armatus* | | | 18.7 | | | | | | | 2.3 | | | | | | | 1.3 |
| *Liparis pulchellus* | | | | | | | | | | 2.3 | | | | | 5.6 | 11.1 | 1.2 |
| Juvenile rockfish | | | | 1.1 | | | | | | | | 2.3 | | 9.1 | | 5.6 | 1.1 |
| *Spirinchus starksi* | | | | 17.1 | | | | | | | | | | | | | 1.1 |
| *Scorpaenichthys marmoratus* | | | | | | | 2.0 | | | 2.3 | | | | | 5.6 | 5.6 | 1.0 |
| *Pallasina barbata* | | | 1.5 | | | | 5.9 | 2.1 | | | 4.9 | | | | | | 0.9 |
| *Allosmerus elongatus* | | | 2.2 | 6.4 | | | | 2.1 | | | 2.5 | | | | | | 0.8 |
| *Raja binoculata* | | | | 1.1 | | | 2.0 | 2.1 | 2.6 | | 2.5 | | | | | | 0.6 |
| *Hemilepidotus spinosus* | | | | | | | | | | | | | | 3.6 | | 5.6 | 0.6 |
| *Pleuronichthys decurrens* | | | | | | | 2.0 | | | | | | | | | 5.6 | 0.5 |
| Osmerids | | 7.0 | 0.7 | | | | | | | | | | | | | | 0.5 |
| *Ophiodon elongatus* | | | 2.2 | 1.1 | | | | | | | | | | 1.8 | | | 0.3 |
| *Liparis fucensis* | | | | | | | | | | 2.3 | 2.5 | | | | | | 0.3 |
| *Occella verrucosa* | | | | | | | | | | | 2.5 | | | | | | 0.2 |
| *Glyptocephalus zachirus* | | | | | | | | | | | | | 2.2 | | | | 0.1 |
| *Aulorhynchus flavidus* | | | | | | | | | | | | | | 1.8 | | | 0.1 |
| *Agonopsis vulsa* | | | | | | | | | | | | | | 1.8 | | | 0.1 |
| *Sebastes melanops* | | | | 1.1 | | | | | | | | | | | | | 0.1 |
| *Eopsetta jordani* | | | 0.7 | | | | | | | | | | | | | | 0.0 |
| All Taxa Combined | 9.7 | 44.2 | 286.7 | 45.0 | 0.0 | 271.3 | 586.6 | 404.1 | 125.5 | 192.1 | 447.5 | 161.6 | 216.1 | 711.1 | 1610.5 | 1332.8 | 402.8 |

* Trawl 9 covered both sand and gravel.

Table 6.11. Weight (g) of fish caught per hectare by species. The mean is the sum of the weight per hectare of all trawls divided by 16.

| | Sand | | | | | | | | | | | | | | Gravel | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gold Beach | | | | Cape Blanco West | | | | | | | Cape Blanco South | | | | | MEAN |
| | South | | | | | | | | | | | | | | | | |
| Trawl: | 1 | 2 | 3 | 4 | 5 | 7 | 8 | 12 | 13 | 14 | 15 | 10 | 11 | 9* | 16 | 17 | g/ha |
| *Scorpaenichthys marmoratus* | | | | | | | 8537 | | | 10885 | | | | | 17318 | 16213 | 3309.6 |
| *Ammodytes hexapterus* | | | | | | 445 | 111 | 60 | 37 | 65 | 53 | 261 | 63 | 1233 | 6143 | 12912 | 1336.5 |
| *Citharichthys stigmaeus* | 89 | 263 | 1042 | 38 | | 818 | 1996 | 1509 | 364 | 897 | 1881 | 261 | 689 | 1081 | 788 | 1260 | 810.9 |
| *Psettichthys melanostictus* | 442 | 263 | 510 | | | | 1386 | 362 | | 960 | 558 | 1898 | 1814 | 2058 | 1732 | | 749.0 |
| *Raja binoculata* | | | | 182 | | | 2716 | 240 | 4936 | | 123 | | | | | | 512.3 |
| *Lepidopsetta bilineata* | | | | | | | | | | | | | | 154 | 3554 | 1577 | 330.3 |
| *Isopsetta isolepis* | | 529 | 382 | 2 | | | 499 | 966 | ** | 513 | 1116 | | 437 | 258 | 4 | | 294.1 |
| *Parophrys vetulus* | 89 | 2 | 234 | 1 | | | 166 | 483 | 73 | 192 | 627 | 328 | 249 | 309 | | | 172.0 |
| *Sebastes melanops* | | | | 2183 | | | | | | | | | | | | | 136.4 |
| *Citharichthys sordidus* | | | | | | | 1329 | | 73 | | | | | | | | 87.6 |
| *Leptocottus armatus* | | | 468 | | | | | | | 384 | | | | | | | 53.2 |
| *Microgadus proximus* | | | 38 | 18 | | | | 121 | 86 | | 278 | 7 | 37 | 52 | 93 | | 45.5 |
| *Glyptocephalus zachirus* | | | | | | | | | | | | | 501 | | | | 31.3 |
| Juvenile osmeridae | | 2 | | 3 | | 1 | | 11 | 9 | 12 | ** | | 62 | 164 | | | 16.5 |
| *Eopsetta jordani* | | | 255 | | | | | | | | | | | | | | 15.9 |
| *Pleuronichthys decurrens* | | | | | | | 221 | | | | | | | | | 14 | 14.7 |
| *Spirinchus starksi* | | | | 182 | | | | | | | | | | | | | 11.4 |
| *Ophiodon elongatus* | | | 64 | 30 | | | | | | | | | | 52 | | | 9.1 |
| *Pallasina barbata* | | | 14 | | | | 56 | 20 | | | 47 | | | | | | 8.5 |
| *Allosmerus elongatus* | | | 22 | 24 | | | | 4 | | | 70 | | | | | | 7.5 |
| *Artedius fenestralis* | | | | | | | | | | | | | | 7 | 43 | 54 | 6.5 |
| Juvenile rockfish | | | | 12 | | | | | | | | 13 | | 55 | | 19 | 6.2 |
| *Enophrys bison* | | | | | | | | | | | | | | 4 | 10 | 57 | 4.4 |
| *Hemilepidotus spinosus* | | | | | | | | | | | | | | 17 | | 26 | 2.7 |
| *Liparis pulchellus* | | | | | | | | | | 1 | | | | | 4 | 4 | 0.6 |
| *Agonopsis vulsa* | | | | | | | | | | | | | | 10 | | | 0.6 |
| *Gobiesox maeandricus* | | | | | | 9 | | | | | | | | | | | 0.5 |
| *Aulorhynchus flavidus* | | | | | | | | | | | | | | 6 | | | 0.4 |
| *Liparis fucensis* | | | | | | | | | | 1 | 1 | | | | | | 0.1 |
| Osmeridae | | | | | | | | | | | | | | | | | |
| *Occella verrucosab* | | | | | | | | | | | | | | | | | |
| All Taxa Combined | 620 | 1060 | 3028 | 2675 | 0 | 1272 | 17017 | 3776 | 5577 | 13910 | 4753 | 2769 | 3851 | 5458 | 29690 | 32138 | 7974.6 |

* Trawl 9 covered both sand and gravel.
** less than 0.5g

that caught fish, and was the most abundant species in 11 of the 15 tows that caught fish. English sole was the second most abundant fish caught by number and weight; it occurred in 12 of the 15 tows that caught fish. Using the coefficient of variation of the number of fish caught per hectare among tows as a measure of patchiness, speckled sanddab, sand sole, and english sole were most evenly distributed. They were also the most frequently occurring species (although sand sole was tied for third with two other species). Frequencies of occurrence were (respectively) 94, 75, and 69% of tows.

We divided the trawl catch data into four groups for comparison. This approach reduces the number of replicate trawl tows for the survey as a whole, but enables comparisons between areas and corresponds to the areas selected for analysis of invertebrates and birds. The four areas are labeled Cape Blanco West, Cape Blanco South-sand, Cape Blanco South-gravel, and Gold Beach South. The Cape Blanco West area includes invertebrate sampling Station 1; the Cape Blanco South-sand area includes invertebrate sampling Station 17; the Cape Blanco South-gravel area includes invertebrate sampling Station 18; and the Gold Beach South area includes invertebrate sampling Stations 4 and 5.

Except for the Cape Blanco South-gravel location, species composition and relative abundances were similar in all areas (Table 6.10). The non-parametric Kruskal-Wallis analysis of variance by ranks showed no significant difference when the gravel station was excluded from analysis. The same test showed a significant difference ($P < 0.05$) in weight per hectare and number of fish per hectare between all stations when the gravel station was included. The Cape Blanco South-gravel station clearly had a higher mean weight per hectare and number of fish per hectare than the other stations (Tables 6.10 and 6.11).

We calculated the Shannon-Wiener index of diversity (H'), the Simpson Diversity Value (SD), Species Richness (SR), and Evenness (J) indices (Begon et al. 1986, Krebs 1972) for each location (Table 6.12). Measures of species diversity were similar at all locations except the Cape Blanco South-gravel location. Species diversity and evenness were much lower in the gravel. Although an analysis of variance using the normally distributed H' showed no significant difference ($p > 0.05$), more replicate sampling probably would show the gravel station to have a lower index of species diversity, due to the large number of Pacific sand lance caught at that location.

Emmett et al. (1987) included crab when they calculated density and diversity indices at four dredged material disposal sites. We included crab and recalculated diversity indices for future comparisons of changes (Table 6.12), but did not try to compare density or diversity indices with those presented by Emmett et al. (1987). Gear differences between the two studies are too great to allow meaningful comparisons.

Table 6.12. Diversity indices for fish caught and for fish and crabs (*Cancer magister*) caught in trawls.

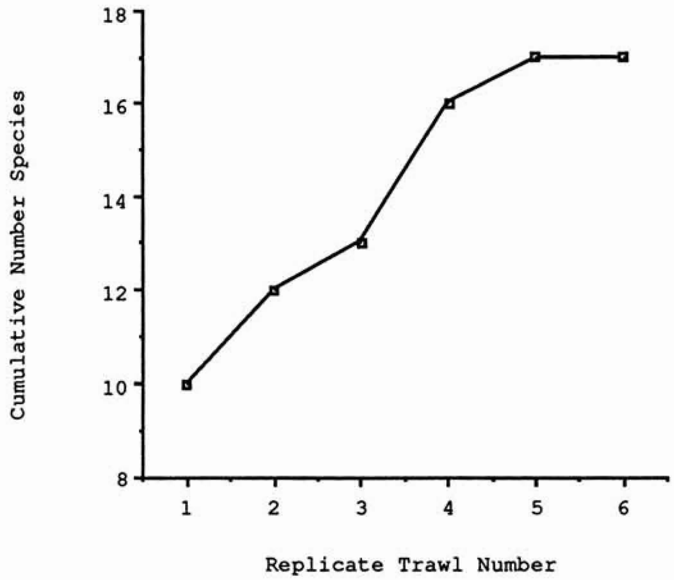
| | Mean No. Species Caught | Mean No. Individuals Caught | Mean No. fish/ha | Mean Wt. (g/ha) | Diversity H' | Diversity SD | Species Richness | Species Evenness |
|---|---|---|---|---|---|---|---|---|
| Fish | | | | | | | | |
| Cape Blanco West | 9.0 | 138.0 | 338.0 | 7717.5 | 1.59 | 0.51 | 1.74 | 0.70 |
| Cape Blanco South-Sand | 7.0 | 84.0 | 189.0 | 3310.0 | 1.87 | 0.67 | 1.36 | 0.54 |
| Cape Blanco South-Gravel | 10.0 | 265.0 | 1472.0 | 30914.0 | 1.14 | 0.38 | 1.62 | 0.68 |
| Gold Beach South | 7.8 | 89.8 | 96.0 | 1476.6 | 1.82 | 0.59 | 1.83 | 0.35 |
| All Areas Combined | 8.9 | 147.9 | 402.8 | | 1.67 | 0.55 | 1.74 | 0.57 |
| Fish and Crab | | | | | | | | |
| Cape Blanco West | 9.8 | 153.8 | | | 1.79 | 0.57 | 1.84 | 0.58 |
| Cape Blanco South-Sand | 7.0 | 84.0 | | | 1.87 | 0.67 | 1.36 | 0.68 |
| Cape Blanco South-Gravel | 10.0 | 265.0 | | | 1.14 | 0.38 | 1.62 | 0.35 |
| Gold Beach South | 8.5 | 125.0 | | | 1.92 | 0.61 | 1.98 | 0.68 |
| All Areas Combined | 9.5 | 164.9 | | | 1.77 | 0.58 | 1.82 | 0.59 |

We can compare our estimates of english sole density with those reported by Krygier and Pearcy (1986), who used a 1.52 m beam trawl with a 1.5-3.5 mm stretch liner to capture english sole in estuaries and along the shallow open coast. In October, english sole densities along the open coast between the Umpqua River and Tillamook Bay ranged from $0.001/m^2$ to $0.010/m^2$. Mean density of english sole in our study was $0.002/m^2$, near the lower end of the range observed by Krygier and Pearcy (1986). The comparable density of english sole indicates that species abundances in our study area are similar to other shallow sand habitats along the central Oregon coast, especially when seasonal variability is taken into account. Krygier and Pearcy (1986) noticed a large variation in relative abundance between months, again indicating the importance of sampling in different seasons. They observed up to a 17-fold difference in nearshore density of english sole as juvenile fish migrated in the spring and summer from nearshore areas into estuaries. Hancock et al. (1980) also reported a sizeable decrease in english sole density off Coos Bay between April and October.

At one station, we attempted to identify day-night differences in trawl sample catches. We completed four trawl tows during the day and two at night west of Cape Blanco. Speckled sanddab and butter sole abundances appeared to be higher at night than during the day by a factor of three or more. Mann-Whitney u-tests of differences in abundances/ha for all fish and for each species individually, however, were not significant ($P > 0.05$). Species composition between day and night was similar.

Since species composition was similar, we used all six transects to determine how many trawls are needed to adequately characterize the species composition at a location. We randomized the six tows conducted in the Cape Blanco West area and plotted the cumulative number of species versus replicate trawl number (Fig. 6.14). Four replicate trawl tows appear to be necessary to catch 90% of the species occurring in the Cape Blanco West area. The same type of analysis with number caught per hectare and weight per hectare was inconclusive; more than six tows are needed to stabilize the coefficient of variation around the mean (Fig. 6.14). This implies that a large number of replicate tows would be necessary to identify changes in relative abundance with a specific degree of statistical confidence.

Trawl sampling means and variances can be used to estimate the number of tows that would be needed to quantify changes in fish abundances. The same three methods used to estimate invertebrate sample sizes (Gonor and Kemp 1978) provide estimates of the number of replicate tows needed to quantify changes in fish densities (Table 6.13). The estimates were derived from mean density and standing crop from all trawl tows at Cape Blanco West excluding Trawl 7, a trawl that snagged a large clump of floating kelp half way through the tow and did not fish correctly.



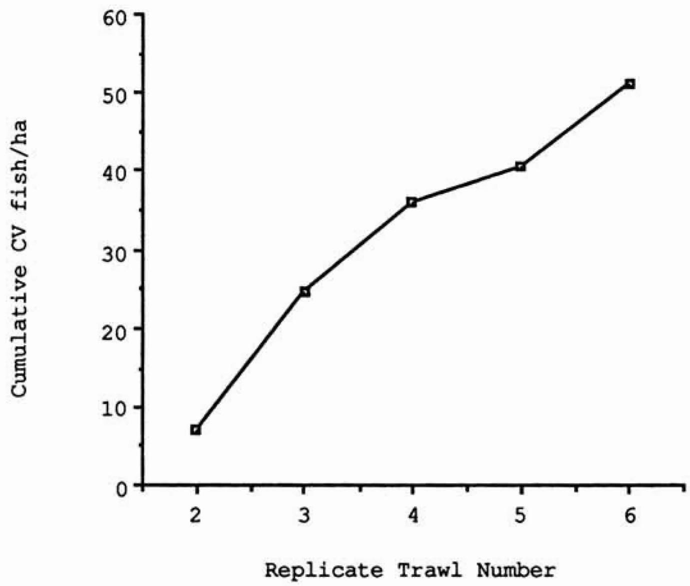




Fig. 6.14. Cumulative number of fish species captured and cumulative coefficient of variation (CV) of mean fish density per random replicate trawl tow in the Cape Blanco West area.

Table 6.13. Three methods for estimating the number of trawl tows needed to characterize differences in density (number/ha) and standing crop (g/ha) of fish in the Cape Blanco West area.

Estimated number of replicate trawl tows needed based on tolerable percent error from the mean.

| | Density (number/ha) | Standing Crop (g/ha) | Standing Crop without Cabezon |
|---|---|---|---|
| 10% error | 29 | 45 | 17 |
| 20% error | 7 | 11 | 4 |
| 40% error | 2 | 3 | 1 |

Estimated number of replicate trawl tows needed based on tolerable range of 95% confidence limits around the mean.

| | Density (number/ha) | Standing Crop (g/ha) | Standing Crop without Cabezon |
|---|---|---|---|
| 10% range | 112 | 172 | 65 |
| 20% range | 28 | 43 | 16 |
| 40% range | 7 | 11 | 4 |

Estimated number of replicate trawl tows needed based on probability of showing significantly different means with a difference of x%.

| | Density (number/ha) | Standing Crop (g/ha) | Standing Crop without Cabezon |
|---|---|---|---|
| 95% chance for 20% diff | 189 | 291 | 110 |
| 90% chance for 20% diff | 153 | 235 | 89 |
| 80% chance for 20% diff | 115 | 177 | 67 |
| 95 % chance for 40% diff | 47 | 73 | 28 |
| 90% chance for 40% diff | 38 | 59 | 22 |
| 80% chance for 40% diff | 29 | 44 | 17 |

The first method calculates the number of replicate trawl tows needed based on a tolerable error for estimating the mean density of fish at a trawl station. Replicate tow estimates for a 10%, 20%, and 40% error from the true mean indicate that seven replicate tows would provide an estimate of the mean number of fish per hectare within 20% of the actual density (Table 6.13). If the few large cabezon caught are omitted from the analysis, four tows are required to provide an estimate of the standing crop of smaller fish within 20% of the mean.

The second method calculates the number of replicate tows needed based on tolerable 95% confidence limits around the mean. This method identifies the number of replicate samples needed to provide a 95% confidence interval that is within a given percentage of the true mean. Again, we present the replicate tow estimates for a 10%, 20%, and 40% range of the confidence interval. Results suggest that seven trawl tows are needed to specify that the 95% confidence interval of trawl density is within 40% of the actual mean density. Four trawl tows are required to specify that the 95% confidence interval of standing crop is within 40% of the actual mean; however, 16 trawl tows are needed to bring the 95% confidence interval of standing crop within 20% of the mean.

The third method calculates the number of replicate tows required based on a desired probability of showing a statistical difference (95% level) between sample means that differ by a given percentage. In this case we present estimates of the number of replicate tows needed to statistically ascertain a difference between a pre-disturbance mean density and a post-disturbance mean density. Presented are replicate tow number estimates for having a 95%, 90%, and 80% probability of showing a significant difference between means that vary by 20% and 40% (Table 6.13). The data show that many replicate trawl tows are needed to detect changes in density of fish or standing crop due to an environmental disturbance. These data indicate an intensive trawl sampling program may be needed to accurately characterize changes in fish density or standing crop that would be attributable to an environmental disturbance such as mining.

Laroche and Richardson (1979), Richardson et al. (1980), Day (1968), Laroche and Holton (1979), and Krygier and Pearcy (1986) all provided evidence suggesting that nearshore sand environments are important rearing grounds for juvenile fish. The gear we used targeted small fish, and many of the fish caught were juveniles. Size ranges within species varied widely (Table 6.14). Some species such as Pacific sand lance and padded sculpin (*Artedius fenestralis*) had relatively low standard deviations around mean lengths; others (most of the abundant species) had high standard deviations that resulted from multiple size modes. Maximum lengths for species with high standard deviations were up to 13 times the minimum lengths. Length frequency histograms of several species (Pacific sand lance, Pacific sanddab, speckled sanddab,

Table 6.14. Summary of length measurements for each species of fish caught.

| Species | No. | Mean Total Length (mm) | Min. Total Length (mm) | Max. Total Length (mm) | SD |
|---|---|---|---|---|---|
| *Agonopsis vulsa* | 1 | 101.0 | 101 | 101 | 0.0 |
| *Allosmerus elongatus* | 11 | 99.7 | 62 | 134 | 26.8 |
| *Ammodytes hexapterus* | 284 | 109.1 | 90 | 155 | 9.0 |
| *Artedius fenestralis* | 20 | 39.0 | 26 | 65 | 12.7 |
| *Aulorhynchus flavidus* | 1 | 136.0 | 136 | 136 | 0.0 |
| *Citharichthys sordidus* | 56 | 98.5 | 55 | 214 | 35.6 |
| *Citharichthys stigmaeus* | 659 | 76.3 | 28 | 160 | 20.5 |
| *Enophrys bison* | 6 | 48.0 | 36 | 60 | 9.9 |
| *Eopsetta jordani* | 1 | 284.0 | 284 | 284 | 0.0 |
| *Glyptocephalus zachirus* | 1 | 324.0 | 324 | 324 | 0.0 |
| *Gobiesox maeandricus* | 3 | 28.0 | 25 | 33 | 4.4 |
| *Hemilepidotus spinosus* | 3 | 70.7 | 68 | 74 | 3.1 |
| *Isopsetta isolepis* | 58 | 119.3 | 20 | 276 | 75.5 |
| Juvenile osmerids | 64 | 63.2 | 35 | 92 | 7.7 |
| Juvenile rockfish | 8 | 77.8 | 63 | 98 | 11.8 |
| *Lepidopsetta bilineata* | 5 | 219.2 | 118 | 396 | 119 |
| *Leptocottus armatus* | 26 | 132.0 | 115 | 219 | 20.1 |
| *Liparis fucensis* | 2 | 28.5 | 23 | 34 | 7.8 |
| *Liparis pulchellus* | 4 | 38.5 | 33 | 46 | 5.4 |
| *Microgadus proximus* | 20 | 105.5 | 57 | 136 | 17.4 |
| *Occella verrucosa* | 1 | 78.0 | 78 | 78 | 0.0 |
| *Ophiodon elongatus* | 5 | 155.8 | 137 | 174 | 13.2 |
| Osmerids | 1 | 101.0 | 101 | 101 | 0.0 |
| *Pallasina barbata* | 8 | 108.9 | 100 | 142 | 13.8 |
| *Parophrys vetulus* | 127 | 92.9 | 52 | 285 | 34.5 |
| *Pleuronichthys decurrens* | 2 | 122.0 | 58 | 186 | 90.5 |
| *Psettichthys melanostictus* | 39 | 220.9 | 130 | 427 | 74.4 |
| *Raja binoculata* | 5 | 370.0 | 180 | 625 | 200.0 |
| *Scorpaenichthys marmoratus* | 4 | 568.3 | 532 | 610 | 46.2 |
| *Sebastes melanops* | 1 | 520.0 | 520 | 520 | 0.0 |
| *Spirinchus starksi* | 13 | 111.3 | 87 | 131 | 13.8 |

sand sole, butter sole, english sole) seem to show clear evidence of cohorts. Pacific sanddab and sand sole show evidence of three cohorts, the remaining species show evidence of two cohorts (Fig. 6.15, 6.16).

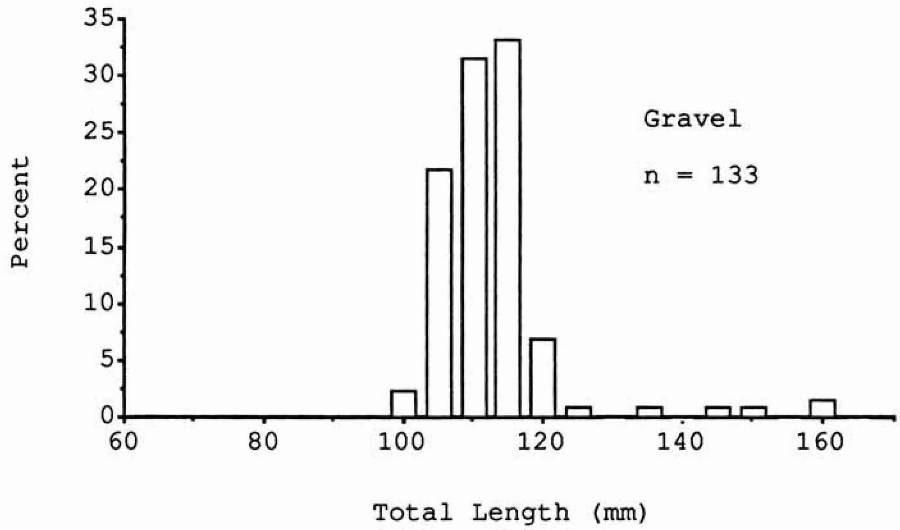
Mean lengths and length frequencies of fish caught are similar to those reported in other studies of Oregon nearshore waters. Hancock et al. (1980) reported catching english sole, sand sole, and speckled sanddab off Coos Bay in October in similar length ranges as reported here. Emmett et al. (1987), using a semi-balloon otter trawl with a larger liner than used in our study, caught speckled sanddab in several size frequencies, one of which was just slightly larger than the 60-70 mm mode we observed. Length frequencies of english sole off Tillamook, Depoe Bay, and the Siuslaw River varied, but were similar to this study.

Caution is required when comparing length frequencies between studies, because fish lengths can vary tremendously with season, year of survey, depth, and collection method. Both Laroche and Holton (1979) and Krygier and Pearcy (1986) reported that mean sizes of english sole varied greatly with small changes in depth. Hancock et al. (1980) reported the same phenomenon for english sole and sand sole. Nevertheless, it appears that fish we caught were similar in size to fish caught at the same time of year in other locations along the Oregon coast.

One of the primary cruise objectives was to describe species composition in the study area. The substrate types encountered in the study area included sand, gravel, rock, and rock with kelp. Each type of substrate harbors different types of fish, and requires different sampling techniques. Logistical constraints allowed us to sample only sand and gravel substrates. Rock, kelp, and water column habitats should also be sampled in the future to adequately characterize the biota of the study area.

Although we were not equipped to sample rock and kelp habitats, we attempted to evaluate differences in species composition between sand and gravel habitats. The Gold Beach South and Cape Blanco West areas contained fine sand, but extensive patches of gravel occurred between sand bottoms in the Cape Blanco South area. By using side-scan SONAR and the precise Del Norte navigation system, we were able to tow the trawl exclusively over gravel patches.

We completed two trawl tows in each of sand and gravel substrates in Cape Blanco South and one trawl tow over both sand and gravel. The sand bottoms contained fine sand and the gravel patches contained small gravel. Forty-two percent of the gravel brought up in the beam trawl was retained by a 6.35 mm sieve, and 52% passed through the 6.35 mm sieve but was retained by a 1.98 mm sieve. The largest gravel measured more than 30 mm, but most was much smaller. The side-scan SONAR traces along the path of the trawl that covered both sand and gravel (Trawl 9) showed clearly distinguishable sand and gravel, suggesting that sand and gravel



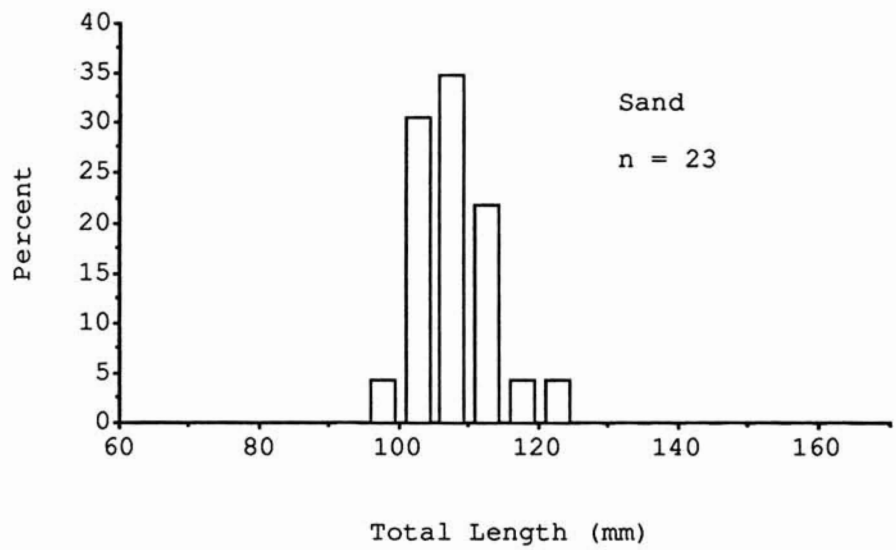




Figure 6.15. Length-frequency distributions of Pacific sand lance caught over gravel and sand bottoms.

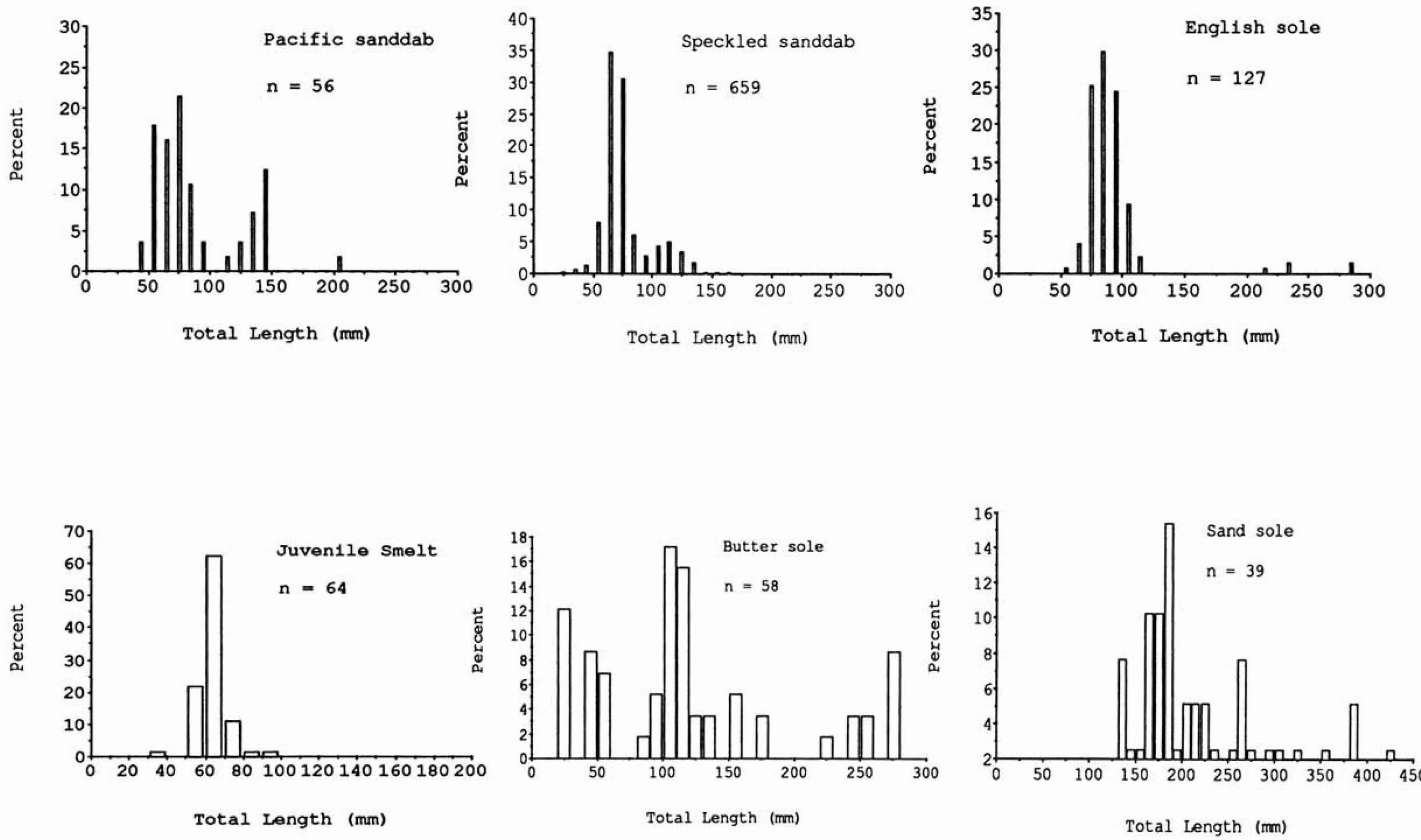



Figure 6.16. Length-frequency distributions of six commonly caught fishes.

substrates sampled were sharply divided. The sharp division in substrates created large differences in species composiiton and abundance. Qualitative observations of invertebrates caught in trawl nets indicated that the gravel habitats sampled contained an order of magnitude more crab and shrimp than sand habitats.

A number of fish species occurred only on gravel, but most of these were collected in such low numbers (three or fewer) that the significance of their occurrence cannot be assessed. However, five or more fish were captured from each of three species that occurred only on gravel (padded sculpin, buffalo sculpin (*Enophrys bison*), and rock sole (*Lepidopsetta bilineata*)). Conversely, some species occurred only on sand. English sole was notable in this respect because by number it was the third most common species. Other "sand species" were Pacific sanddab, Pacific staghorn sculpin (*Leptocottus armatus*), night smelt (*Spirinchus starksi*), and tubenose poacher (*Pallasina barbata*). Furthermore, the tow with the highest species richness was Trawl 9 (at least 15 taxa), which sampled a mix of sand and gravel. The species composition of Trawl 9 reflects an integration by the trawl of fish catches from sharply different adjoining substrates, rather than catches from an area where substrates (and associated fauna) from the two substrates gradually intergrade. Consequently species richness in Trawl 9 is greater than in either gravel or sand alone.

Pacific sand lance was most common on gravel bottoms at Cape Blanco South and absent from sands off Gold Beach South. In Trawl 9, which fished both gravel and sand at Cape Blanco South, it was intermediate in numerical abundance between tows that fished only one substrate (Table 6.10). Both by weight and by number, it was one or two orders of magnitude more abundant on gravel than it was on sand. Mean length of Pacific sand lance differed significantly between populations on gravel and on sand (Student's 't' test, $P < 0.05$). Mean lengths on gravel were about 2 mm greater than those on sand (108.9 vs 106.3 mm). This difference was due to an apparent lack of larger individuals on sand. Individuals longer than 120 mm were absent from sand; similarly sand areas contained fewer individuals between 105 and 120 mm. The size difference was also due to the larger number of individuals 100-105 mm long on sand than on gravel (Fig. 6.15). There were no significant differences in mean sizes within other species on the two different substrates.

Studies of nearshore bottom fishes have concentrated on describing the distribution and life history of the fish, rather than the factors that determine their distribution, such as substrate. For instance, Krygier and Pearcy (1986) intensively sampled english sole off the central Oregon coast and found high variability in abundances related to geographic location. The variability they described could be the result of substrate differences; our data show that this species prefers sand over gravel bottoms. Movement of sediments on the Oregon continental shelf occurs down to at least 204 m (Komar et al. 1972). Seasonal shifts in distribution and availability of gravel and sand seem likely to result in related distributional changes among the fishes. The possible effects of this relationship on distributions of the species concerned are significant, and indicate a more thorough survey of gravel and sand substrates is needed in the study area.

Most of the speckled sanddab and crangonid shrimp (Crustacea, decapoda, *Crangon* sp.) caught over gravel had a mottled color; most individuals caught on sand were unmottled. As expected, the speckled sanddab and shrimp caught from mixed sand and gravel were more evenly divided between mottled and unmottled. The fact that some unmottled individuals were caught over gravel and that some mottled individuals were caught over sand indicates that there are sand patches in gravel (and vice-versa), that there is a substantial interchange of fish between the two habitats, or that some individuals do not adjust color to match the substrate. If there are patches of sand or gravel in a predominantly gravel or sand substrate, perhaps the scale, rather than simply composition, of gravel or sand patches is significant in affecting distributions of species. Additional work is needed to more clearly describe the character and importance of the gravel habitats in the study area.

The distribution of rock habitats and kelp beds is also an important factor influencing the distribution of fish. Low power, high resolution seismic profiling devices showed rock outcrops near several of the geologic target sites. Kelp grew nearby as well. The seismic and side-scan equipment, with observations of kelp beds, indicate a diversity of soft and hard bottom habitats in the general vicinity of the geologic target sites.

The Oregon Department of Fish and Wildlife used aerial surveys to map the distribution of kelp while the *M/V Aloha* cruise was in progress (Fig. 6.1, 6.2). In the future, biological surveys should include the kelp habitats since they occur so close to potential mineral target locations. The presence of adult cabezon with stomachs full of flatfish and crabs indicates that some fish may take refuge in rocky areas and forage on the sand substrates. Food habit studies would be appropriate to evaluate interactions between species in the complex array of habitats present in the study area.

6.3.3 Seabird and Marine Mammal Observations

We observed 3,915 birds representing 48 species (Table 6.15), and report bird densities as birds/km along a 300 m wide transect. These densities can all be converted to birds/km$^2$ by multiplying by 0.3. Bird density averaged 11.2 birds/km. None of the birds observed was close to a rookery; all birds were observed over open water. Cassin's auklets were by far the most numerous bird species observed. Cassin's auklets represented 57% of the birds observed, and were 7.8 times more numerous than the next most abundant species. Faxon (1990) reported that in 1990, Cassin's

Table 6.15. List of bird species observed.

| | |
|---|---|
| Arctic tern | *Sterna paradisaea* |
| Barn swallow | *Hirundo rustica* |
| Black-footed albatross | *Diomedea nigripes* |
| Black-legged kittiwake | *Rissa tridactyla* |
| Black scoter | *Melanitta nigra* |
| Bonaparte's gull | *Larus philadelphia* |
| Brandt's cormorant | *Phalacrocorax penicillatus* |
| Brown pelican | *Pelecanus occidentalis* |
| Cassin's auklet | *Ptychoramphus aleuticus* |
| California gull | *Larus californicus* |
| Common loon | *Gavia immer* |
| Common murre | *Uria aalge* |
| Double-crested cormorant | *Phalacrocorax auritus* |
| Elegant tern | *Sterna elegans* |
| Great blue heron | *Ardea herodias* |
| Glaucous-winged gull | *Larus glaucescens* |
| Herring gull | *Larus argentatus* |
| Heermann's gull | *Larus heermanni* |
| Mallard | *Anas platyrhynchos* |
| Marbled murrelet | *Brachyramphus marmoratus* |
| Mew gull | *Larus canus* |
| Northern fulmar | *Fulmaris glacialis* |
| Northern harrier | *Circus cyaneus* |
| Parasitic jaeger | *Stercorarius parasiticus* |
| Pacific loon | *Gavia pacifica* |
| Pelagic cormorant | *Phalacrocorax pelagicus* |
| Pigeon guillemot | *Cepphus columba* |
| Pink-footed shearwater | *Puffinus creatopus* |
| Pomarine jaeger | *Stercorarius pomarinus* |
| Ring-billed gull | *Larus delawarensis* |
| Red phalarope | *Phalaropus fulicarius* |
| Rhinoceros auklet | *Cerorhinca monocerata* |
| Red-necked phalarope | *Phalaropus lobatus* |
| Red-throated loon | *Gavia stellata* |
| Sabine's gull | *Xema sabini* |
| Sanderling | *Calidris alba* |
| Sooty shearwater | *Puffinus griseus* |
| Song sparrow | *Melospiza melodia* |
| Surf scoter | *Melanitta perspicillata* |
| Thick-billed murre | *Uria lomvia* |
| Thayer's gull | *Larus thayeri* |
| Tufted puffin | *Lunda cirrhata* |
| Unidentified gull | *Larus sp.* |
| Unidentified tern | *Sterna sp.* |
| Western grebe | *Aechmophorus occidentalis* |
| Western gull | *Larus occidentalis* |
| White-throated sparrow | *Zonotrichia albicollis* |
| White-winged scoter | *Melanitta fusca* |

auklets and rhinoceros auklets were seen in unusually large numbers close to the coast. Briggs et al. (1991) also reported high densities of Cassin's auklets in both 1990 and 1991. In September 1989, the highest densities of Cassin's auklets along the Washington and Oregon coast were recorded off Cape Blanco, just before the birds moved into Calfornia in September and October (Briggs et al. 1987).

We divided the 68 bird transects into five groups that correspond to the fish and invertebrate sampling locations (Fig. 6.17). The mean abundance of birds observed in each group ranged from 7.5 to 20.6 birds/km (Table 6.16). The Cape Blanco West group and the offshore area between Cape Blanco and the Rogue Reef contained the lowest bird densities, whereas the area inside of Orford Reef (Cape Blanco South) contained the highest mean density. The area inside of Orford Reef also contained the most species in a group and the highest Shannon-Wiener index of diversity (H'). The Gold Beach West group contained as many species as Cape Blanco South but had a lower diversity index because of the abundance of Cassin's auklets in that area. Although the Cape Blanco West group contained the lowest number of birds/km, it had the second highest index of diversity and evenness. This was due to the relative lack of Cassin's auklets in that region.

Three species were most abundant in the Cape Blanco West group (Table 6.17). Cassin's auklets averaged 4.6 birds/km over the 40.5 km of transect covered, and California and herring gulls were also commonly observed. The common murre and western gulls were not as abundant as the first three species, but were present in densities greater than 1.0 bird/km. The endangered brown pelican occurred in this group, as it did in the other nearshore groups. The only mew gull we saw was in this region. All other birds observed at Cape Blanco West occurred in at least three of the five groups.

The Cape Blanco South group contained the most species and the greatest densities of birds observed (Table 6.17). Six species were most abundant in the 30.8 km of transect covered in the area: Cassin's auklets, common murres, surf scoters, Pacific loons, and California gulls. Ring billed gulls, northern harriers, red-throated loons, Heermann's gulls, and double crested cormorants were also observed in densities greater than 1.0 birds/km. This region contained the transect with the study's highest density; the 41.7 birds/km reflects one flock of over 100 gulls flying south high over one transect. We saw two brown pelicans and two marbled murrelets in this region. The black scoter and sanderling occurred only in the Cape Blanco South group.

Three species were most abundant in the Offshore group (Table 6.17). In 74.1 km of transect, Cassin's auklets averaged 5.9 birds/km. Arctic terns and sooty shearwaters were also commonly observed. Mean bird density was lowest here, as was the number of

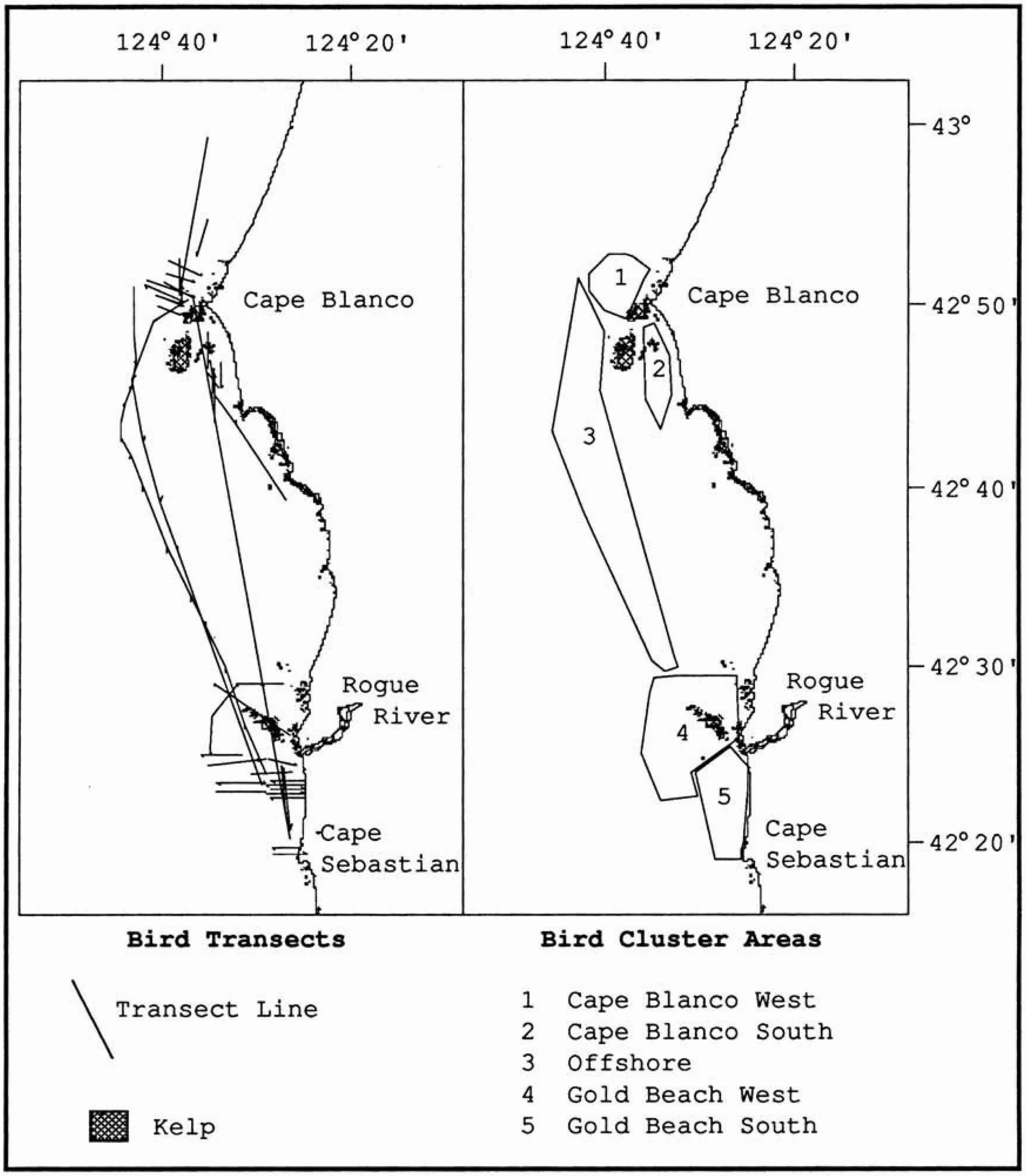



Figure 6.17. Bird transects and cluster groupings.

Table 6.16: Bird densities and diversity indices by area.

| All Birds<br>Area | Birds/Km | Km Run | No. Species | No. Birds | No. Transects | Species Diversity (H') | (SD) | Species Richness (SR) | Species Evenness (J) |
|---|---|---|---|---|---|---|---|---|---|
| Cape Blanco West | 10.0 | 40.5 | 20 | 404 | 12 | 2.67 | 0.74 | 3.17 | 0.62 |
| Cape Blanco South | 20.6 | 30.8 | 26 | 635 | 12 | 3.05 | 0.82 | 3.86 | 0.65 |
| Offshore | 7.5 | 74.1 | 16 | 552 | 17 | 1.96 | 0.58 | 2.38 | 0.49 |
| Gold Beach West | 15.4 | 71.2 | 26 | 1098 | 12 | 1.76 | 0.43 | 3.57 | 0.37 |
| Gold Beach South | 18.8 | 48.8 | 23 | 919 | 11 | 2.35 | 0.63 | 3.22 | 0.52 |

| All Birds Excluding Cassin's auklets<br>Area | Birds/Km | Km Run | No. Species | No. Birds | No. Transects | Species Diversity (H') | (SD) | Species Richness (SR) | Species Evenness (J) |
|---|---|---|---|---|---|---|---|---|---|
| Cape Blanco West | 5.38 | 40.5 | 19 | 218 | 12 | 2.15 | 0.95 | 3.35 | 0.51 |
| Cape Blanco South | 13.05 | 30.8 | 25 | 402 | 12 | 2.52 | 0.95 | 4.00 | 0.54 |
| Offshore | 2.81 | 74.1 | 15 | 208 | 17 | 1.89 | 0.97 | 3.90 | 0.48 |
| Gold Beach West | 3.89 | 71.2 | 25 | 277 | 12 | 1.44 | 0.94 | 4.27 | 0.31 |
| Gold Beach South | 7.73 | 48.8 | 22 | 377 | 11 | 1.90 | 0.98 | 3.54 | 0.43 |

Table 6.17. Abundant bird species by area.

| Area | Species | Birds/Km |
|---|---|---|
| Cape Blanco West | Cassin's auklet | 4.6 |
| | California gull | 2.3 |
| | Herring gull | 1.6 |
| | Common murre | 1.2 |
| | Western gull | 1.1 |
| Cape Blanco South | Unidentified gull | 41.7 |
| | Cassin's auklet | 7.6 |
| | Common murre | 3.0 |
| | Surf scoter | 2.7 |
| | Pacific loon | 2.1 |
| | California gull | 1.9 |
| | Ring-billed gull | 1.4 |
| | Northern harrier | 1.1 |
| | Red-throated loon | 1.1 |
| | Heermann's gull | 1.1 |
| | Double-crested cormorant | 1.0 |
| Gold Beach West | Cassin's auklet | 15.3 |
| | Brandt's cormorant | 2.1 |
| | Pelagic cormorant | 1.8 |
| | Surf scoter | 1.8 |
| | Unidentified tern | 1.8 |
| | Sooty shearwater | 1.2 |
| | White-winged scoter | 1.1 |
| Gold Beach South | Cassin's auklet | 11.1 |
| | Red-necked phalarope | 3.0 |
| | Surf scoter | 2.4 |
| | Brandt's cormorant | 1.9 |
| | Barn swallow | 1.6 |
| | Rhinoceros auklet | 1.3 |
| | Common murre | 1.2 |
| Offshore | Cassin's auklet | 5.9 |
| | Arctic tern | 2.5 |
| | Sooty shearwater | 1.9 |

species observed. This was the only group that contained arctic terns, red phalaropes, Sabine's gulls, and Thayer's gulls, probably due to the area's greater distance offshore. We also had a surprising sighting of a white throated sparrow.

The Gold Beach West group contained predominantly five species. Cassin's auklets, Brandt's cormorants, pelagic cormorants, surf scoters, and unidentified terns all occurred in densities greater than 1.8 birds/km (Table 6.17). We also counted sooty shearwaters and white winged scoters in densities greater than 1.0 birds/km on the 71.2 km of transects. The 15.3 birds/km of Cassin's auklets was the highest bird density observed during the cruise, excluding the one flock of gulls observed in the Cape Blanco South area. Birds occurring only in the Gold Beach West group included a Bonaparte's gull, a great blue heron, a song sparrow, and a thick-billed murre south of its normal range.

The Gold Beach South group also contained a diverse species assemblage. Cassin's auklets, red-necked phalaropes, surf scoters, Brandt's cormorants, rhinoceros auklets, and common murres dominated the region. We also saw numerous barn swallows, reflecting this region's proximity to shore. Most of the 48.8 km of transect covered in the Gold Beach South group was within 5 km of shore off Cape Sebastian. This region contained the only tufted puffins we saw; they had left a nesting site on a nearshore island and flew out to sea.

When the Cassin's auklet is removed from the analysis, the mean density of birds in all transects in the study area drops to 4.9 birds/km. The relative differences between the groups did not change except that the Cape Blanco West area showed less of a drop in mean density because Cassin's auklets represented a lower total percentage of birds observed in the area. The mean density of birds exclusive of Cassin's auklets observed in each group ranged from 2.8 to 13.1 birds/km (Table 6.16). The offshore area between Cape Blanco and the Rogue Reef contained the lowest bird density, whereas the Cape Blanco South area inside of Orford Reef contained the highest mean density. The Cape Blanco South area also contained the most species in a group and the highest Shannon-Wiener index of diversity (H').

Transect lengths in this study averaged 4.1 km. We plotted the number of species observed in a transect versus the length of the transect for each group to determine if there is an optimum length of transect to maximize the species/km ratio. We found no apparent correlation between transect length and number of species observed in any of the groups.

The study design did enable us to determine how many transects are necessary to encounter all the species in an area. We randomized the transects within each group and plotted the cumulative number of new species observed versus replicate transect number. The results indicate that nine transects averaging over 4 km in length are sufficient to describe more than 90% of the species observed in each region (Fig. 6.18).

Wind and sea conditions proved not to greatly influence the number of species observed during the transects, perhaps because bird and mammal observations were conducted from a relatively high deck of the ship. Regression analysis suggests a slight negative correlation between wind speed and the number of species observed on a transect (Fig. 6.19). Although the regression is significant, the slope of the line is slight and the fit is poor.

We did, however, observe a much stronger negative correlation between wind speed and the number of individuals observed (Fig. 6.20). Any future attempts to document changes in bird populations in the study area should account for variations in the number of birds observed due to wind conditions.

The time of day had little effect on the number of birds observed. The data show no significant ($P > 0.05$) relationship between time of day and the number of birds observed. We did find a significant ($P < 0.05$) relationship between the number of species observed and the time of day (Fig. 6.21). We observed slightly fewer species later in the day than we did in the early part of the day. Care should be taken when evaluating this relationship, however. Since wind speed and time of day are autocorrelated, we may have seen fewer species later in the day because of increased wind speed rather than the time of day.

We observed 17 individuals representing six species of marine mammals. The harbor porpoise (*Phocoena phocoena*), gray whale (*Eschrichtius robustus*), and the northern sea lion (*Eumetopias jubatus*) were the most numerous species observed. We also saw a few California sea lions (*Zalophus californianus*), harbor seals (*Phoca vitulina*), and one unidentified porpoise. The number of northern sea lions observed may be low because we attempted to stay over 1.6 km away from all bird and mammal rookeries. Rookeries and haul-out areas for the northern sea lion are located within 10 km of several of the stations. A survey of rookeries is needed to estimate the number of pinnipeds in the study region. Brown (1990) has conducted aerial surveys of pinnipeds since 1975. Future studies should incorporate the results his surveys of pinnipeds in Southern Oregon.

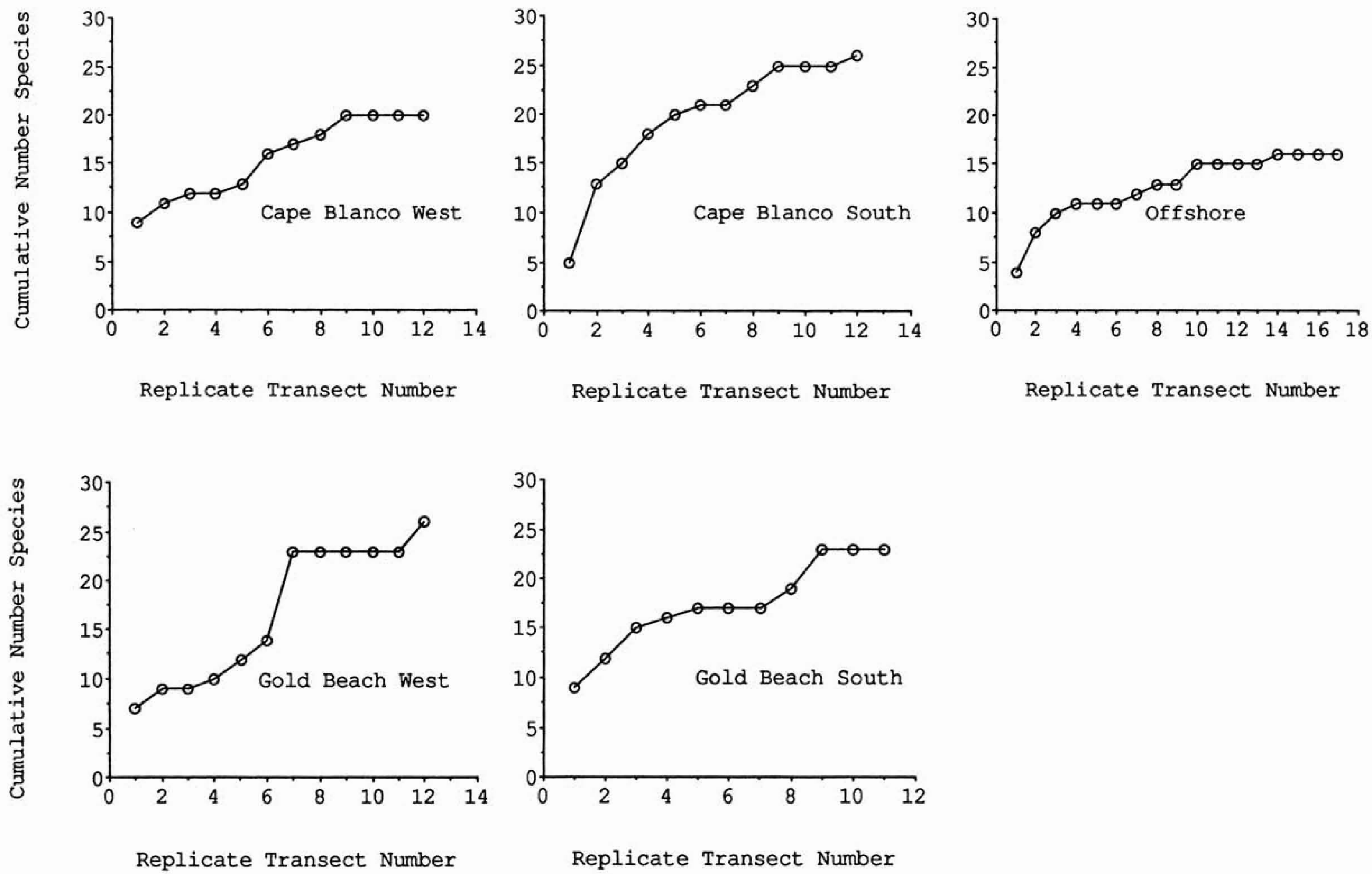



Figure 6.18. Cumulative number of bird species sighted per replicate transect.

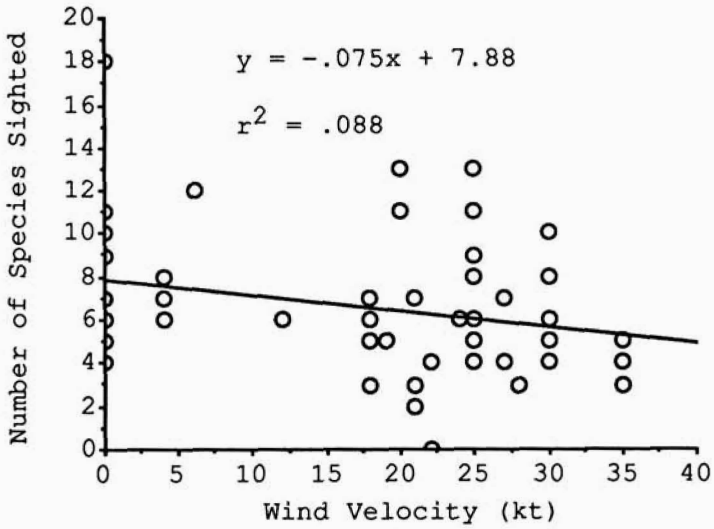



Figure 6.19. The relationship between wind velocity and the number of bird species observed on a transect.

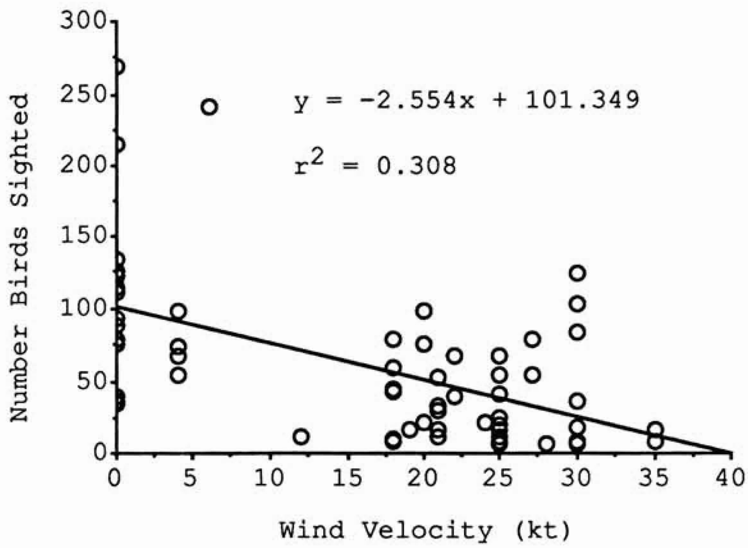



Figure 6.20. The relationship between wind velocity (kt) and the number of individual birds observed on a transect.

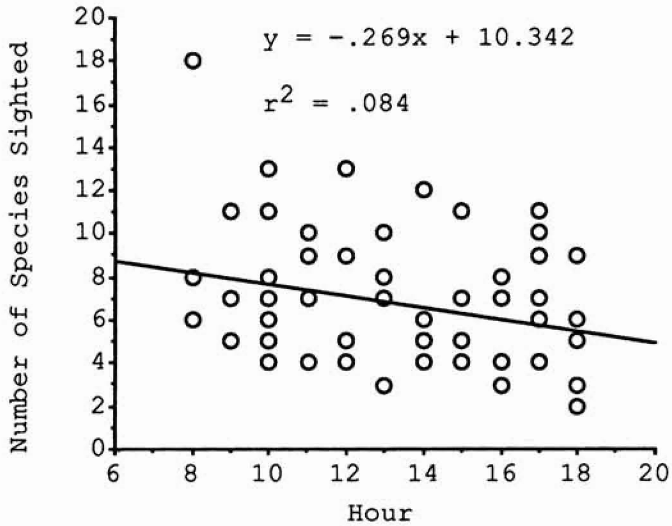



Figure 6.21. The relationship between the number of species observed and the time of day of the transect.

# SECTION 7.0

# CONCLUSIONS

## SECTION 7.0

## CONCLUSIONS

### 7.1. Geophysical/Geological Investigations

Data collected during the cruise provide new insight into the potential for placer minerals on the southern Oregon shelf. Conclusions are presented here as they refer to the two general target areas, one off the Rogue River, and the other off Cape Blanco.

#### 7.1.1. Rogue River Area

Nine different target sites were identified in the Rogue River area on the basis of anomalous concentrations of heavy minerals in the surficial sediment and/or magnetic anomalies (Table 1.1 and Figure 1.2). Of these, five (Target Sites Rogue 3 through Rogue 7) were thought to represent possible paleo-shoreline deposits (and in the case of Rogue 3, a possible paleo-river channel as well). Two others (Rogue 8 and 9) were thought to possibly result from concentration on the south side of a paleo-headland, and the remaining two were thought to owe any economic potential to their proximity to the Rogue River mouth.

Vibralift samples were taken on or near Target Sites 1 (VIBL 02A, Fig. 2.35), 2 (VIBL 03A, Fig. 2.35), 4 (VIBL 05 A, Fig. 2.38), and 5 (VIBL 04A, Fig. 2.37). The vertical distribution of subsamples at each vibralift site is shown in Figure 2.55. In every case, the sand beneath the sea floor texturally and mineralogically resembles that at the present surface. All of this sediment was very likely deposited under conditions similar to those of the present time on the modern-day Oregon shelf. Magnetic anomalies in the Rogue River shelf area that were previously attributed to concentrations of heavy minerals in the surficial sediments are assigned on the basis of the current study to near-surface masses of bedrock. There is no geological or geophysical evidence for fossil beach deposits in the Holocene section on this part of the shelf. The contact with underlying Pleistocene sediment was likely encountered 20 feet (6 m) below the sea floor in Vibralift 03 A, and lies at least 16-20 feet (5-6 m) below the sea floor at the locations of the other vibralift samples. The character and heavy mineral content of the Pleistocene sediment remains unknown.

Heavy mineral concentrations potentially lie at the floor of the paleo-channels of the Rogue River that were identified on the shelf west of the present river mouth. The amount of overburden (25-50 m or 80 - 160 feet) that covers any such deposits would make any recovery difficult and costly.

7.1.2. Cape Blanco Area

Target sites in this area were identified on the basis of prior studies and were thought to include paleo-shoreline deposits, paleo-headland deposits, and deposits that formed at river-mouths when sea level stood at a lower position. The inability to collect samples at depth in the Cape Blanco area limits the geological interpretation of the nature and mineralogy of substrate on this part of the shelf. The magnetometer data, and such sample information as is available, suggests that the surficial concentrations of heavy minerals that have been observed off Cape Blanco do not overlie fossil buried beaches. Such beaches, if enriched in heavy minerals such as magnetite, would be expected to produce linear magnetic anomalies trending more or less parallel to the present shoreline. The magnetic survey (Fig. 2.12) shows no linear trends in this area, and most of the anomalies appear to be the small, sharply delineated type that reflects the magnetic susceptibility of the near-surface bedrock below the sea floor.

The small box cores taken from the Smith-McIntyre grab samples contain concentrations of heavy minerals in the upper 7 cm. The concentrations are somewhat mixed by subsequent faunal burrowing and winnowing by fairly recent storms. The samples that show these concentrations are distributed over a broad area west of Cape Blanco, in water depths that range from 17 to 48 m. The samples taken from stations on a line from SMAC 10 through SMAC 14 , (Fig. 2.24) span a distance of 2.5 km (about 1.4 mi). Another sample with mineral concentrations, at station SMAC-08A, lies nearly 2 km north of this line. These data suggest that modern-day storms concentrate heavy minerals over a broad area west of Cape Blanco. It is likely that the concentrations of heavy minerals previously detected in the surface sediment in this area result from storm winnowing of modern shelf sediment, rather than from reworking of underlying fossil beach material.

If the heavy mineral concentrations on this part of the shelf are produced by present-day storms, it is questionable whether the grade will increase with depth. The most realistic geological model for these deposits, based on our limited data, probably is of an areally-extensive concentration of heavy minerals at a grade similar to that at the sea floor. The thickness of the concentration is unknown. Elsewhere on the southern Oregon shelf, the thickness of the modern shelf sand depends on the neotectonic setting. In areas of downwarp, such as near Cape Sebastian, the Holocene sediment may be more than 20 feet (6 m) thick. Cape Blanco, however, lies along a line of apparent uplift, near the axis of an anticline in the onshore Pleistocene deposits. The Holocene sediment in this setting may be little more than a veneer over underlying Pleistocene material (as it seems to be in the Cape Blanco south area). Accordingly, the heavy-mineral-rich sand may be very thin in this area. On the other hand, much of this part of the shelf is covered by more than 10 m of unconsolidated sediment above the bedrock surface (Figs 2.34 and 2.49); it is possible that a significant amount of this material formed on Pleistocene shelves under conditions similar to those of the present day. If so, the placer-bearing section could be 20 to 30 feet (6 to 9 m) or more thick. Detailed magnetic modelling or a successful deep coring program would seem the only ways to resolve the question.

## 7.2. Environmental Investigations

The highest concentration of Ti (~9%) was found in the Cape Blanco 0-1 m vibralift sample. This concentration is equivalent to that found in only marginally attractive land-based sources. The highest concentration of chromite (~2%) found, also at Cape Blanco, is subeconomic. Traces of gold, platinum group metals, and zirconium were also found in the Cape Blanco 0-1 m sample. Gravity concentration produced a 31.2% $TiO_2$ concentrate, but low intensity magnetic separation did not improve the product. Correct commercial concentrates from land-based sources range from 45-65% $TiO_2$.

Biological surveys of nearshore sand areas off southern Oregon were designed to provide three primary types of information. Biologists attempted to (1) estimate species composition, diversity, and relative abundance of animals in the study area; (2) compare species diversity and relative abundance of fish and invertebrates living in areas containing deposits of heavy minerals with similar areas containing no deposits of heavy minerals; and (3) collect and analyze samples in a manner that will help determine appropriate statistical sampling designs, should further studies be conducted.

(1) Species composition, diversity, and relative abundance in nearshore sand areas off Southern Oregon were similar to comparable sand habitats in other parts of Oregon. Data from the cruise reflect only one season, however; biological sampling should occur over several years in all seasons to more accurately reflect species composition and relative abundance in the study area.

The substrate types encountered in the study area included sand, gravel, rock, and rock with kelp. Each type of substrate harbors different types of fish and invertebrates, and requires different sampling techniques. Logistical constraints allowed us to sample only sand and gravel substrates. Rock, kelp, and water column habitats should also be sampled in the future to adequately characterize the biota of the study area. Side-scanning sonar should be used to map the distribution of sand, gravel, and rock habitats.

Additional work is needed to more clearly describe the character and importance of the gravel and kelp habitats in the study area, and their relationship with sand habitats. The catch of adult cabezon with stomachs full of flatfish and crabs over sand substrates indicates that some fish may take refuge in rocky areas and forage on the sand substrates. Food habit studies would be appropriate to evaluate interactions between species in the complex array of habitats present in the study area. The water column habitat should also be studied, as particulate matter from a mining operation wold impact animals in the water column.

(2) Since large concentrations of heavy minerals were not positively identified, we could not compare target and control stations. The species observed, along with evidence of a dynamic physical environment, suggests that it may be difficult to identify differences in biota between areas containing heavy minerals and nearby sand areas without minerals. Future work should be designed to examine relationships between species distribution and metal concentrations. We also recommend studies of suspended metal uptake by organisms. If a target location is selected in future work, a more direct comparison between targets and controls should be made. If mining were to occur, an area within the concentration of heavy minerals should be set aside as a control site to compare biological changes within a control to biological changes in the mined area.

(3) Data are presented in the report to help design future studies that are statistically valid. Based on our results and those of past studies, we recommend future benthic infauna sampling be stratified by both depth and geographic separation. Suggested depth strata would be 0-15 m, 15-35 m, and 35-50 m. The Blanco area should be a separate stratum from the Rogue Reef/Cape Sebastian area. An additional stratum should be located off the mouth of the Rogue River to adequately describe this river mouth area. Station locations should be chosen at random within the strata. Control stations should be in a similar stratum as the target stations but distant enough to ensure they are not disturbed.

We recommend that a 0.5 mm sieve be used in the study area for impact analysis. Future projects should also weigh the biota so that biomass can be estimated. To describe the recovery of an impacted area, it would also be desirable to obtain life history information pertaining to recruitment, growth, and reproduction for the most abundant species.

Crab pots should be used if the purpose of a sampling project is to estimate the carapace width of commercial sized crab in an area. Conversely, trawls should be used if the purpose is to estimate the numbers of all size classes of crab in the study area. Trawling for crab should occur at night to adequately sample young of the year.

Fish data collected from trawls indicate an intensive trawl sampling program may be needed to accurately characterize changes in fish density or standing crop that would be attributable to an environmental disturbance such as mining. Future researchers may need to accept a large probable error or conclude that both number per hectare and weight per hectar would be poor indicators of environmental disturbance in the study area. Ctenophores, crangonid shrimp, mysid shrimp, and amphipods were caught in large numbers in trawls. Future studies should attempt to quantify these populations as they are important prey species. This study concentrated on juvenile fish. Future work to evaluate environmental impacts should also include studies of adult fish.

The results of the bird surveys indicate that nine transects averaging over 4 km in length are sufficient to describe more than 90% of the species observed in each region. Any future attempts to document changes in bird populations in the study area should account for variations in the number of birds observed due to wind conditions. A survey of mammal rookeries is needed to estimate the number of pinnipeds in the study region.

# SECTION 8.0

# REFERENCES

## SECTION 8.0

## REFERENCES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## SECTION 9.0

## APPENDIX

**APPENDIX A.**

Radio carbon Ages of Shelf Sediment Samples

## APPENDIX

## RADIOCARBON AGES* OF SHELF SEDIMENT SAMPLES

Sample: USBM ME 2343 (Shell)
Location: N. Cape Sebastian, 3 ft subsurface depth
Beta Number-45569
C-14 Age Years BP ± one Sigma: 2,090 ±80
C13/C12: +1.0 0/00
C13 Adjusted 2,520 ±80 BP
Calibrated: two Sigma Maximum Range 1,510-1,900 BP

Sample: USBM ME 2345-46 (Shell)
Location: N. Cape Sebastian, 9-12 ft subsurface depth
Beta Number-45570
C-14 Age Years BP ± one Sigma: 3,790 ±70
C13/C12: +1.2 0/00
C13 Adjusted 4,220 ±70 BP
Calibrated: two Sigma Maximum Range 3,589-3,969 BP

Sample: USBM ME 2348-49 (Shell)
Location: N. Cape Sebastian, 17-20 ft subsurface depth
Beta Number-45571
C-14 Age Years BP ± one Sigma: 5,540 ± 90
C13/C12: +1.2 0/00
C13 Adjusted 5,970 ± 90 BP
Calibrated: two Sigma Maximum Range 5,749-6,189 BP

* Radiocarbon Age Analyses Performed (1991) by Beta Analytic Inc., Coral Gables, Florida

## APPENDIX B.

Isopach Data

Cape Blanco West 7/29/91

| Time | Long | Lat | Water Depth | 1st R Thick | 1st R Depth |
|---|---|---|---|---|---|
| 150 | 124.5880 | 42.9170 | 63 | 12 | 75 |
| 155 | 124.5775 | 42.9172 | 60 | 11 | 71 |
| 200 | 124.5697 | 42.9152 | 56 | 7 | 63 |
| 205 | 124.5640 | 42.9140 | 50 | 6 | 56 |
| 210 | 124.5606 | 42.9125 | 45 | 5 | 50 |
| 215 | 124.5500 | 42.9100 | 38 | 7 | 45 |
| 220 | 124.5375 | 42.9061 | 33 | 4 | 37 |
| 225 | 124.5340 | 42.9050 | 26 | 4 | 30 |
| 230 | 124.5320 | 42.9000 | 22 | 0 | 22 |
| 235 | 124.5350 | 42.8970 | 23 | 0 | 23 |
| 240 | 124.5381 | 42.8952 | 22 | 0 | 22 |
| 245 | 124.5441 | 42.8968 | 26 | 4 | 30 |
| 250 | 124.5519 | 42.8992 | 30 | 5 | 35 |
| 255 | 124.5582 | 42.9011 | 36 | 5 | 41 |
| 300 | 124.5660 | 42.9031 | 41 | 5 | 46 |
| 305 | 124.5728 | 42.9047 | 46 | 8 | 54 |
| 310 | 124.5801 | 42.9075 | 51 | 12 | 63 |
| 315 | 124.5864 | 42.9085 | 56 | 14 | 70 |
| 320 | 124.5945 | 42.9105 | 62 | 12 | 74 |
| 325 | 124.5997 | 42.9097 | 66 | 6 | 72 |
| 330 | 124.6063 | 42.9048 | 66 | 12 | 78 |
| 335 | 124.6061 | 42.9012 | 63 | 12 | 75 |
| 340 | 124.5958 | 42.8994 | 60 | 5 | 65 |
| 345 | 124.5883 | 42.8974 | 52 | 10 | 62 |
| 350 | 124.5808 | 42.8954 | 47 | 11 | 58 |
| 355 | 124.5735 | 42.8933 | 40 | 12 | 52 |
| 400 | 124.5660 | 42.8913 | 35 | 10 | 45 |
| 405 | 124.5591 | 42.8887 | 30 | 5 | 35 |
| 410 | 124.5619 | 42.8838 | 25 | 13 | 38 |
| 415 | 124.5668 | 42.8803 | 28 | 7 | 35 |
| 420 | 124.5727 | 42.8818 | 30 | 9 | 39 |
| 425 | 124.5792 | 42.8835 | 37 | 10 | 47 |
| 430 | 124.5856 | 42.8854 | 42 | 11 | 53 |
| 435 | 124.5922 | 42.8872 | 46 | 5 | 51 |
| 440 | 124.5991 | 42.8889 | 51 | 10 | 61 |
| 445 | 124.6063 | 42.8908 | 51 | 20 | 71 |
| 450 | 124.6130 | 42.8926 | 63 | 16 | 79 |
| 455 | 124.6189 | 42.8930 | 68 | 15 | 83 |
| 500 | 124.6233 | 42.8889 | 70 | 17 | 87 |
| 505 | 124.6238 | 42.8840 | 69 | 6 | 75 |
| 510 | 124.6166 | 42.8820 | 64 | 11 | 75 |
| 515 | 124.6090 | 42.8800 | 52 | 26 | 78 |
| 520 | 124.6050 | 42.8780 | 52 | 18 | 70 |
| 525 | 124.5950 | 42.8760 | 45 | 16 | 61 |
| 530 | 124.5890 | 42.8740 | 40 | 8 | 48 |
| 535 | 124.5780 | 42.8720 | 35 | 5 | 40 |
| 540 | 124.5740 | 42.8700 | 30 | 5 | 35 |

Cape Blanco West 7/29/91

| | | | | | |
|---|---|---|---|---|---|
| 545 | 124.5710 | 42.8696 | 25 | 0 | 25 |
| 550 | 124.5696 | 42.8648 | 25 | 0 | 25 |
| 555 | 124.5728 | 42.8582 | 20 | 0 | 20 |
| 600 | 124.5779 | 42.8599 | 26 | 4 | 30 |
| 605 | 124.5848 | 42.8616 | 30 | 5 | 35 |
| 610 | 124.5917 | 86.8636 | 35 | 7 | 42 |
| 615 | 124.5988 | 42.8656 | 40 | 13 | 53 |
| 620 | 124.6065 | 42.8676 | 45 | 19 | 64 |
| 625 | 124.6131 | 42.8693 | 45 | 17 | 62 |
| 630 | 124.6197 | 42.8711 | 56 | 11 | 67 |
| 635 | 124.6277 | 42.8734 | 63 | 4 | 67 |
| 640 | 124.6300 | 42.8730 | 65 | 5 | 70 |
| 645 | 124.6340 | 42.8650 | 70 | 5 | 75 |
| 650 | 124.6350 | 42.8640 | 71 | 4 | 75 |
| 655 | 124.6260 | 42.8630 | 66 | 14 | 80 |
| 700 | 124.6230 | 42.8600 | 57 | 26 | 83 |
| 705 | 124.6160 | 42.8580 | 50 | 35 | 85 |
| 710 | 124.6080 | 42.8560 | 45 | 37 | 82 |
| 715 | 124.6000 | 42.8540 | 40 | 10 | 50 |
| 720 | 124.5950 | 42.8510 | 31 | 9 | 40 |
| 725 | 124.5940 | 42.8460 | 28 | 7 | 35 |
| 730 | 124.5980 | 42.8420 | 27 | 8 | 35 |
| 735 | 124.6060 | 42.8420 | 33 | 7 | 40 |
| 740 | 124.6096 | 42.8437 | 40 | 10 | 50 |
| 745 | 124.6194 | 42.8481 | 47 | 0 | 47 |
| 750 | 124.6287 | 42.8509 | 52 | 8 | 60 |
| 755 | 124.6398 | 42.8540 | 65 | 10 | 75 |
| 800 | 124.6512 | 42.8553 | 75 | 5 | 80 |
| 805 | 124.6534 | 42.8485 | 74 | 13 | 87 |
| 810 | 124.6485 | 42.8433 | 75 | 13 | 88 |
| 815 | 124.6397 | 42.8422 | 65 | 15 | 80 |
| 820 | 124.6305 | 42.8399 | 52 | 20 | 72 |
| 825 | 124.6231 | 42.8376 | 50 | 6 | 56 |
| 830 | 124.6156 | 42.8354 | 45 | 8 | 53 |
| 835 | 124.6087 | 42.8335 | 37 | 5 | 42 |
| 840 | 124.6279 | 42.8271 | 37 | 6 | 43 |
| 845 | 124.6501 | 42.8214 | 40 | 5 | 45 |
| 850 | 124.6501 | 42.8214 | 42 | 5 | 47 |
| 940 | 124.6279 | 42.8271 | 51 | 19 | 70 |
| 1010 | 124.6501 | 42.8214 | 65 | 18 | 83 |
| 1015 | 124.6446 | 42.8205 | 59 | 23 | 82 |
| 1020 | 124.6381 | 42.8190 | 55 | 20 | 75 |
| 1025 | 124.6318 | 42.8174 | 50 | 17 | 67 |
| 1030 | 124.6249 | 42.8155 | 47 | 16 | 63 |
| 1035 | 124.6180 | 42.8137 | 44 | 11 | 55 |
| 1040 | 124.6106 | 42.8120 | 40 | 0 | 40 |
| 1045 | 124.6030 | 42.8100 | 37 | 0 | 37 |
| 1050 | 124.6027 | 42.8082 | 35 | 0 | 35 |

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| | | | | | |
|---|---|---|---|---|---|
| 1055 | 124.6068 | 42.8074 | 32 | 0 | 32 |
| 1100 | 124.6119 | 42.8071 | 43 | 0 | 43 |
| 1105 | 124.6184 | 42.8077 | 45 | 12 | 57 |
| 1110 | 124.6252 | 42.8085 | 47 | 14 | 61 |
| 1115 | 124.6334 | 42.8099 | 50 | 15 | 65 |
| 1120 | 124.6391 | 42.8122 | 54 | 21 | 75 |
| 1125 | 124.6447 | 42.8150 | 58 | 18 | 76 |
| 1130 | 124.6512 | 42.8172 | 65 | 19 | 84 |
| 1135 | 124.6584 | 42.8191 | 71 | 14 | 85 |
| 1140 | 124.6616 | 42.8153 | 76 | 20 | 96 |
| 1145 | 124.6582 | 42.8129 | 78 | 18 | 96 |
| 1150 | 124.6523 | 42.8111 | 72 | 22 | 94 |
| 1155 | 124.6460 | 42.8094 | 64 | 20 | 84 |
| 1200 | 124.6399 | 42.8077 | 58 | 23 | 81 |
| 1205 | 124.6329 | 42.8060 | 52 | 21 | 73 |
| 1210 | 124.6253 | 42.8036 | 50 | 13 | 63 |
| 1215 | 124.6230 | 42.8000 | 45 | 10 | 55 |
| 1220 | 124.6230 | 42.7970 | 47 | 8 | 55 |
| 1225 | 124.6270 | 42.7960 | 51 | 4 | 55 |
| 1230 | 124.6280 | 42.7990 | 53 | 7 | 60 |
| 1235 | 124.6270 | 42.8030 | 50 | 13 | 63 |
| 1240 | 124.6240 | 42.8080 | 48 | 11 | 59 |
| 1245 | 124.6200 | 42.8120 | 45 | 15 | 60 |
| 1250 | 124.6170 | 42.8160 | 45 | 13 | 58 |
| 1255 | 124.6120 | 42.8200 | 43 | 7 | 50 |
| 1300 | 124.6070 | 42.8240 | 40 | 0 | 40 |
| 1305 | 124.6020 | 42.8280 | 36 | 0 | 36 |
| 1310 | 124.6000 | 42.8316 | 34 | 0 | 34 |
| 1315 | 124.5994 | 42.8381 | 33 | 2 | 35 |
| 1320 | 124.5988 | 42.8438 | 37 | 5 | 42 |
| 1325 | 124.5985 | 42.8495 | 34 | 9 | 43 |
| 1330 | 124.5965 | 42.8548 | 36 | 3 | 39 |
| 1335 | 124.5932 | 42.8601 | 35 | 5 | 40 |
| 1340 | 124.5900 | 42.8655 | 35 | 5 | 40 |
| 1345 | 124.5866 | 42.8711 | 37 | 7 | 44 |
| 1350 | 124.5834 | 42.8766 | 37 | 8 | 45 |
| 1355 | 124.5795 | 42.8830 | 38 | 5 | 43 |
| 1400 | 124.5762 | 42.8884 | 38 | 10 | 48 |
| 1405 | 124.5729 | 42.8939 | 40 | 10 | 50 |
| 1410 | 124.5691 | 42.9002 | 41 | 9 | 50 |
| 1415 | 124.5659 | 42.9055 | 42 | 8 | 50 |
| 1420 | 124.5627 | 42.9109 | 45 | 0 | 45 |
| 1425 | 124.5592 | 42.9168 | 47 | 6 | 53 |

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| Time | Long | Lat | Water Depth | 1st R Thick | 1st R Depth |
|---|---|---|---|---|---|
| 200 | 124.5804 | 42.7770 | 34 | 0 | 34 |
| 205 | 124.5810 | 42.7713 | 41 | 4 | 45 |
| 210 | 124.5812 | 42.7649 | 45 | 8 | 53 |
| 215 | 124.5813 | 42.7585 | 51 | 8 | 59 |
| 220 | 124.5811 | 42.7521 | 58 | 8 | 66 |
| 225 | 124.5808 | 42.7444 | 64 | 8 | 72 |
| 230 | 124.5719 | 42.7427 | 65 | 10 | 75 |
| 235 | 124.5668 | 42.7456 | 53 | 15 | 68 |
| 240 | 124.5667 | 42.7515 | 48 | 17 | 65 |
| 245 | 124.5666 | 42.7541 | 46 | 15 | 61 |
| 250 | 124.5667 | 42.7600 | 42 | 15 | 57 |
| 255 | 124.5667 | 42.7660 | 37 | 12 | 49 |
| 300 | 124.5667 | 42.7710 | 36 | 12 | 48 |
| 305 | 124.5665 | 42.7770 | 33 | 10 | 43 |
| 310 | 124.5666 | 42.7820 | 31 | 5 | 36 |
| 314 | 124.5650 | 42.7860 | 28 | 0 | 28 |
| 323 | 124.5525 | 42.7871 | 28 | 12 | 40 |
| 330 | 124.5520 | 42.7770 | 31 | 12 | 43 |
| 337 | 124.5129 | 42.8539 | 33 | 5 | 38 |
| 340 | 124.5300 | 42.8000 | 34 | 10 | 44 |
| 345 | 124.5522 | 42.7550 | 36 | 19 | 55 |
| 350 | 124.5510 | 42.7480 | 39 | 21 | 60 |
| 400 | 124.5398 | 42.7460 | 31 | 22 | 53 |
| 405 | 124.5375 | 42.7517 | 28 | 15 | 43 |
| 410 | 124.5376 | 42.7580 | 26 | 10 | 36 |
| 415 | 124.5376 | 42.7645 | 26 | 8 | 34 |
| 420 | 124.5377 | 42.7710 | 24 | 8 | 32 |
| 425 | 124.5377 | 42.7777 | 23 | 8 | 31 |
| 430 | 124.5375 | 42.7845 | 23 | 8 | 31 |
| 431 | 124.5360 | 42.7860 | 23 | 0 | 23 |
| 435 | 124.5305 | 42.7903 | 21 | 3 | 24 |
| 440 | 124.5311 | 42.7816 | 20 | 5 | 25 |
| 445 | 124.5334 | 42.7746 | 21 | 5 | 26 |
| 447 | 124.5391 | 42.7743 | 22 | 5 | 27 |
| 455 | 124.5457 | 42.7746 | 23 | 11 | 34 |
| 500 | 124.5545 | 42.7745 | 32 | 5 | 37 |
| 505 | 124.5638 | 42.7745 | 34 | 8 | 42 |
| 507 | 124.5680 | 42.7745 | 34 | 8 | 42 |
| 510 | 124.5756 | 42.7689 | 35 | 5 | 40 |
| 520 | 124.5713 | 42.7635 | 42 | 7 | 49 |
| 525 | 124.5630 | 42.7634 | 39 | 11 | 50 |
| 530 | 124.5542 | 42.7633 | 35 | 10 | 45 |
| 535 | 124.5455 | 42.7630 | 31 | 10 | 41 |
| 542 | 124.5344 | 42.7632 | 24 | 4 | 28 |
| 550 | 124.5340 | 42.7540 | 23 | 0 | 23 |
| 555 | 124.5459 | 42.7527 | 29 | 15 | 44 |
| 600 | 124.5510 | 42.7526 | 35 | 20 | 55 |

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| | | | | | |
|---|---|---|---|---|---|
| 605 | 124.5570 | 42.7526 | 40 | 19 | 59 |
| 610 | 124.5653 | 42.7526 | 46 | 16 | 62 |
| 615 | 124.5742 | 42.7527 | 52 | 10 | 62 |
| 620 | 124.5828 | 42.7526 | 58 | 8 | 66 |
| 622 | 124.5893 | 42.7517 | 62 | 5 | 67 |

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| Time | Long | Lat | Water Depth | 1st R Thick | 1st R Depth |
|---|---|---|---|---|---|
| 336 | 124.4903 | 42.3999 | 51 | 5 | 56 |
| 347 | 124.5050 | 42.4034 | 57 | 0 | 57 |
| 400 | 124.5206 | 42.4044 | 71 | 5 | 76 |
| 402 | 124.5282 | 42.4052 | 73 | 7 | 80 |
| 407 | 124.5366 | 42.4051 | 74 | 11 | 85 |
| 412 | 124.5448 | 42.4059 | 75 | 14 | 89 |
| 417 | 124.5530 | 42.4065 | 78 | 31 | 109 |
| 421 | 124.5812 | 42.4071 | 78 | 25 | 103 |
| 425 | 124.5630 | 42.4140 | 80 | 15 | 95 |
| 430 | 124.5635 | 42.4140 | 77 | 15 | 92 |
| 434 | 124.5615 | 42.4165 | 75 | 15 | 90 |
| 438 | 124.5537 | 42.4169 | 75 | 18 | 93 |
| 440 | 124.5432 | 42.4176 | 72 | 15 | 87 |
| 445 | 124.5432 | 42.4176 | 72 | 15 | 87 |
| 450 | 124.5331 | 42.4174 | 65 | 10 | 75 |
| 455 | 124.5233 | 42.4173 | 65 | 7 | 72 |
| 500 | 124.5124 | 42.4174 | 61 | 4 | 65 |
| 505 | 124.5067 | 42.4208 | 53 | 0 | 53 |
| 511 | 124.5059 | 42.4267 | 51 | 0 | 51 |
| 515 | 124.5103 | 42.4283 | 50 | 0 | 50 |
| 520 | 124.5179 | 42.4284 | 60 | 0 | 60 |
| 525 | 124.5262 | 42.4281 | 63 | 15 | 78 |
| 526 | 124.5270 | 42.4281 | 64 | 30 | 94 |
| 530 | 124.5359 | 42.4285 | 65 | 15 | 80 |
| 535 | 124.5451 | 42.4288 | 67 | 15 | 82 |
| 537 | 124.5451 | 42.4288 | 68 | 16 | 84 |
| 542 | 124.5529 | 42.4285 | 71 | 19 | 90 |
| 545 | 124.5577 | 42.4285 | 72 | 20 | 92 |
| 548 | 124.5630 | 42.4285 | 73 | 18 | 91 |
| 558 | 124.5605 | 42.4384 | 72 | 17 | 89 |
| 603 | 124.5526 | 42.4392 | 70 | 15 | 85 |
| 608 | 124.5429 | 42.4393 | 64 | 14 | 78 |
| 613 | 124.5329 | 42.4392 | 60 | 22 | 82 |
| 616 | 124.5233 | 42.4391 | 60 | 10 | 70 |
| 623 | 124.5139 | 42.4391 | 54 | 0 | 54 |
| 628 | 124.5063 | 42.4409 | 50 | 0 | 50 |
| 635 | 124.5056 | 42.4478 | 43 | 0 | 43 |
| 640 | 124.5103 | 42.4503 | 51 | 4 | 55 |
| 645 | 124.5202 | 42.4503 | 53 | 11 | 64 |
| 650 | 124.5294 | 42.4506 | 56 | 15 | 71 |
| 655 | 124.5385 | 42.4505 | 59 | 15 | 74 |
| 700 | 124.5464 | 42.4504 | 62 | 14 | 76 |
| 705 | 124.5548 | 42.4503 | 65 | 14 | 79 |
| 710 | 124.5631 | 42.4499 | 75 | 5 | 80 |
| 717 | 124.5677 | 42.4539 | 79 | 8 | 87 |
| 725 | 124.5544 | 42.4608 | 74 | 5 | 79 |
| 733 | 124.5430 | 42.4605 | 63 | 10 | 73 |

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| | | | | | |
|---|---|---|---|---|---|
| 736 | 124.5350 | 42.4586 | 58 | 12 | 60 |
| 745 | 124.5351 | 42.4559 | 57 | 12 | 69 |
| 750 | 124.5359 | 42.4515 | 57 | 13 | 70 |
| 755 | 124.5359 | 42.4453 | 59 | 15 | 74 |
| 800 | 124.5358 | 42.4370 | 61 | 15 | 76 |
| 806 | 124.5357 | 42.4299 | 64 | 13 | 77 |
| 812 | 124.5359 | 42.4214 | 67 | 17 | 84 |
| 817 | 124.5359 | 42.4143 | 75 | 10 | 85 |
| 828 | 124.5359 | 42.4002 | 75 | 10 | 85 |

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| Time | Long | Lat | Water Depth | 1st R Thick | 1st R Depth |
|---|---|---|---|---|---|
| 755 | 124.4705 | 42.3373 | 50 | 33 | 83 |
| 80 | 124.4783 | 42.3380 | 56 | 26 | 82 |
| 805 | 124.4847 | 42.3383 | 63 | 16 | 79 |
| 810 | 124.4916 | 42.3386 | 71 | 14 | 85 |
| 847 | 124.4517 | 42.3387 | 65 | 18 | 83 |
| 850 | 124.4580 | 42.3350 | 60 | 20 | 80 |
| 852 | 124.4662 | 42.3223 | 52 | 24 | 76 |
| 857 | 124.4585 | 42.3232 | 47 | 28 | 75 |
| 902 | 124.4506 | 42.3245 | 35 | 32 | 67 |
| 910 | 124.4482 | 42.3306 | 29 | 26 | 55 |
| 915 | 124.4535 | 42.3367 | 32 | 33 | 65 |
| 920 | 124.4612 | 42.3374 | 40 | 32 | 72 |
| 925 | 124.4711 | 42.3373 | 50 | 35 | 85 |
| 930 | 124.4795 | 42.3372 | 59 | 21 | 80 |
| 935 | 124.4879 | 42.3372 | 68 | 16 | 84 |
| 940 | 124.4963 | 42.3372 | 73 | 17 | 90 |
| 947 | 124.5056 | 42.3380 | 91 | 13 | 104 |
| 952 | 124.5045 | 42.3450 | 88 | 7 | 95 |
| 1000 | 124.4967 | 42.3472 | 72 | 8 | 80 |
| 1005 | 124.4889 | 42.3484 | 64 | 18 | 82 |
| 1010 | 124.4814 | 42.3454 | 56 | 21 | 77 |
| 1015 | 124.4739 | 42.3480 | 49 | 31 | 80 |
| 1020 | 124.4664 | 42.3479 | 42 | 26 | 68 |
| 1025 | 124.4587 | 42.3479 | 35 | 28 | 63 |
| 1030 | 124.4508 | 42.3479 | 28 | 15 | 43 |
| 1035 | 124.4415 | 42.3479 | 19 | 14 | 33 |
| 1050 | 124.4506 | 42.3585 | 26 | 17 | 43 |
| 1055 | 124.4590 | 42.3583 | 34 | 19 | 53 |
| 1100 | 124.4674 | 42.3583 | 41 | 24 | 65 |
| 1105 | 124.4775 | 42.3583 | 48 | 30 | 78 |
| 1110 | 124.4858 | 42.3583 | 55 | 20 | 75 |
| 1115 | 124.4940 | 42.3583 | 60 | 12 | 72 |
| 1220 | 124.4372 | 42.3807 | 19 | 8 | 27 |
| 1232 | 124.4425 | 42.3907 | 20 | 5 | 25 |
| 1240 | 124.4510 | 42.3913 | 25 | 0 | 25 |
| 1242 | 124.4594 | 42.3915 | 33 | 2 | 35 |
| 1247 | 124.4679 | 42.3917 | 35 | 9 | 44 |
| 1255 | 124.4783 | 42.3917 | 43 | 0 | 43 |
| 1300 | 124.4868 | 42.3918 | 35 | 0 | 35 |
| 1325 | 124.4952 | 42.3917 | 42 | 0 | 42 |
| 1315 | 124.5020 | 42.3980 | 57 | 6 | 63 |
| 1320 | 124.4952 | 42.3998 | 55 | 5 | 60 |
| 1325 | 124.4882 | 42.4018 | 50 | 5 | 55 |
| 1330 | 124.4825 | 42.3985 | 44 | 9 | 53 |
| 1335 | 124.4781 | 42.3932 | 43 | 4 | 47 |
| 1340 | 124.4755 | 42.3894 | 39 | 4 | 43 |
| 1345 | 124.4751 | 42.3839 | 40 | 9 | 49 |

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| | | | | | |
|---|---|---|---|---|---|
| 1350 | 124.4750 | 42.3772 | 43 | 7 | 50 |
| 1355 | 124.4749 | 42.3716 | 44 | 11 | 55 |
| 1400 | 124.4752 | 42.3659 | 45 | 19 | 64 |
| 1407.5 | 124.4745 | 42.3595 | 46 | 22 | 68 |
| 1412.5 | 124.4745 | 42.3529 | 49 | 23 | 72 |
| 1417.5 | 124.4747 | 42.3450 | 52 | 23 | 75 |
| 1422.5 | 124.4748 | 42.3385 | 55 | 23 | 78 |
| 1422.5 | 124.4715 | 42.3343 | 52 | 25 | 77 |
| 1432.5 | 124.4643 | 42.3364 | 45 | 30 | 75 |
| 1437.5 | 124.4628 | 42.3404 | 40 | 30 | 70 |
| 1442.5 | 124.4614 | 42.3445 | 38 | 28 | 66 |
| 1447.5 | 124.4615 | 42.3492 | 37 | 28 | 65 |
| 1500 | 124.4619 | 42.3646 | 35 | 19 | 54 |
| 1505 | 124.4618 | 42.3707 | 34 | 16 | 50 |
| 1510 | 124.4616 | 42.3754 | 33 | 14 | 47 |
| 1515 | 124.4618 | 42.3822 | 31 | 13 | 44 |
| 1520 | 124.4618 | 42.3884 | 30 | 7 | 37 |
| 1525 | 124.4619 | 42.3946 | 32 | 0 | 32 |
| 1530 | 124.4618 | 42.4006 | 30 | 7 | 37 |
| 1535 | 124.4627 | 42.4063 | 29 | 9 | 38 |
| 1540 | 124.4673 | 42.4114 | 30 | 5 | 35 |
| 1545 | 124.4728 | 42.4164 | 33 | 9 | 42 |
| 1552.5 | 124.4787 | 42.4157 | 38 | 4 | 42 |
| 1557.5 | 124.4844 | 42.4116 | 25 | 0 | 25 |
| 1600 | 124.4898 | 42.4071 | 50 | 0 | 50 |
| 1607.5 | 124.4943 | 42.4024 | 52 | 0 | 52 |
| 1612.5 | 124.4955 | 42.3966 | 56 | 4 | 60 |
| 1617.5 | 124.4988 | 42.3915 | 50 | 0 | 50 |
| 1622.5 | 124.5058 | 42.3901 | 47 | 0 | 47 |
| 1627.5 | 124.5051 | 42.3930 | 64 | 0 | 64 |
| 1632.5 | 124.5025 | 42.3985 | 57 | 0 | 57 |
| 1637.5 | 124.4967 | 42.4002 | 56 | 4 | 60 |
| 1642.5 | 124.4901 | 42.4014 | 50 | 0 | 50 |
| 1647.5 | 124.4829 | 42.4025 | 45 | 8 | 53 |
| 1652.5 | 124.4751 | 42.4031 | 33 | 0 | 33 |
| 1657.5 | 124.4674 | 42.4030 | 32 | 3 | 35 |
| 1702.5 | 124.4584 | 42.4029 | 27 | 3 | 30 |
| 1707.5 | 124.4510 | 42.4029 | 23 | 2 | 25 |
| 1712.5 | 124.4433 | 42.4026 | 19 | 4 | 23 |

## APPENDIX C.

Invertebrate species encountered in the study area

Platyhelminthes
- Nemertinea
  - *Nemertinea* sp. Indeterminate

Annelida
- Polychaeta
  - Orbiniidae
    - *Leitoscoloplos pugettensis* (Johnson, 1901)
    - *Orbinia (Phylo) felix* (Kingberg, 1866)
    - *Scoloplos acmeceps* (Chamberlin, 1919)
    - *Scoloplos armiger* (Muller, 1776)
  - Paraonidae
    - *Aricidea suecica* (Eliason, 1920)
    - *Paraonella platybranchia* (Hartman, 1961)
  - Spionidae
    - *Laonice cirrata* (Sars, 1851)
    - *Polydora cardalia* (Berkeley, 1927)
    - *Polydora socialis* (Schmarda, 1861)
    - *Scolelepis squamatus* (Muller, 1806)
    - *Spiophanes berkeleyorum* (Pettibone, 1962)
    - *Spiophanes bombyx* (Claparede, 1870)
  - Magelonidae
    - *Magelona longicornis* (Johnson, 1901)
    - *Magelona sacculata* (Hartman, 1961)
  - Chaetopteridae
    - *Mesochaetopterus taylori* (Potts, 1914)
    - *Spiochaetopterus costarum* (Claparede, 1870)
  - Cirratulidae
    - *Caulleriella alata* (Southern, 1914)
    - *Chaetozone spinosa* (Moore, 1903)
    - *Tharyx* sp. Indeterminate
  - Capitellidae
    - *Capitellidae* sp. Indeterminate
    - *Decamastus gracilis* (Hartman, 1967)
    - *Mediomastus californiensis* (Hartman, 1944)
    - *Notomastus(Clistomastus)lineatus*(Claparede, 1870
  - Maldanidae
    - *Axiothella rubrocincta* (Johnson, 1901)
    - *Maldanidae* sp. Indeterminate
  - Opheliidae
    - *Ophelia* sp. 1
    - *Travisia japonica* (Fujiwara, 1933)
  - Phyllodocidae
    - *Eteone longa* (Fabricius, 1780)
    - *Eteone* sp. Juvenile
    - *Phyllodoce (Aponaitides) hartmanae* (Blake and Walton, 1977)
    - *Phyllodoce (Anaitides) williamsi* (Hartman, 1936)
    - *Phyllodoce (Paranaitis) polynoides* (Moore, 1909)
    - *Phyllodoce* sp. Juvenile

Polynoidae

*Harmothoe* sp. Indeterminate
*Polynoidae* sp. Indeterminate
*Polynoidae* sp. Juvenile
*Tenonia priops* (Hartman, 1939)

Sigalionidae

*Thalenessa spinosa* (Hartman, 1939)
*Sthenalais tertiaglabra* (Moore, 1910)

Hesionidae

*Gyptis brevipalpa* (Hartman-Schroeder, 1959)
*Microphthalmus aberrans* (Webster & Benedict, 1887)

Syllidae

*Autolytus cornutus* (Agassiz, 1862)
*Pionosyllis uraga* (Imajima, 1966)
Syllidae sp. Indeterminate
*Syllis (Typosyllis) heterochaeta* (Moore, 1909)
*Trypanosyllis gemmipara* (Johnson, 1901)

Nereidae

Nereidae sp. Juvenile
*Nereis procera* (Ehlers, 1868)

Glyceridae

*Glycera americana* (Leidy, 1855)
*Glycera capitata* (Oersted, 1843)
*Glycera convoluta* (Keferstein, 1862)
*Glycera robusta* (Ehlers, 1868)

Goniadidae

*Glycinde armigera* (Moore, 1911)

Nephtyidae

*Nephtys caeca* (Fabricius, 1780)
*Nephtys caecoides* (Hartman, 1938)
*Nephtys* sp. Indeterminate
*Nephtys* sp. 1

Onuphidae

*Diopatra ornata* (Moore, 1911)
Onuphidae sp. Juvenile
*Onuphis (Nothria) elegans* (Johnson, 1901)
*Onuphis (Nothria) iridescens* (Johnson, 1901)
*Onuphis* sp. Juvenile

Lumbrineridae

*Lumbrineris bicirrata* (Treadwell, 1929)
*Lumbrineris* sp. Indeterminate

Oweniidae

*Owenia fusiformis* (delle Chiaje, 1841)

Ampharetidae

*Ampharete acutifrons* (Grube, 1860)
*Ampharete* sp. Juvenile

Terebellidae

*Lanassa venusta venusta* (Malm, 1874)
*Polycirrus* sp. complex
Terebellidae sp. Juvenile

Sabellidae

*Chone duneri* (Malmgren, 1867)
*Schizobranchia insignis* (Bush, 1904)

Mollusca
- Archaeogastropoda
  - Trochidae
    - *Lirularia lirulatus* (Carpenter, 1864)
- Mesogastropoda
  - Rissoidae
    - *Alvania compacta* (Carpenter, 1864)
    - *Alvania* sp. Juvenile
  - Vitrinellidae
    - *Vitrinella* sp. Indeterminate
  - Naticidae
    - *Polinices lewisi* (Gould, 1847)
  - Epitoniidae
    - *Epitonium* sp. Indeterminate
    - *Nitidiscala indianorum* (Carpenter, 1864)
  - Eulimidae
    - *Eulimidea* sp. Indeterminate
- Neogastropoda
  - Nucellidae
    - *Nucella* sp. Juvenile
  - Buccinidae
    - Buccinidae sp. Juvenile
    - *Searlesia dira* (Reeve, 1846)
  - Columbellidae
    - *Mitrella gouldi* (Carpenter, 1856)
    - *Mitrella tuberosa* (Carpenter, 1864)
  - Nassaridae
    - *Nassarius fossatus* (Gould, 1849)
    - *Nassarius* sp. Juvenile
  - Olividae
    - *Olivella baetica* (Marrat, 1871)
    - *Olivella biplicata* (Sowerby, 1825)
    - *Olivella pycna* (Berry, 1935)
    - *Olivella* sp. Indeterminate
    - *Olivella* sp. Juvenile
  - Turridae
    - *Kurtziella plumbea* (Hinds, 1843)
- Opistobranchia
  - Pyramidellidae
    - *Odostomia* sp. Indeterminate
    - *Turbonilla* sp. Indeterminate
- Cephalaspidea
  - Acteonidae
    - *Rictaxis punctocaelatus* (Carpenter, 1864)
  - Atyidae
    - *Haminoea vesicula* (Gould, 1855)
  - Retusidae
    - *Retusa* sp. Indeterminate
  - Aglajidae
    - *Melanochlamys diomedia* (Bergh, 1894)
  - Cylichnidae
    - *Cylichna alba* (Brown, 1827)
    - *Cylichnella harpa* (Dall, 1871)

Nudibranchia

Onchidoriidae
*Onchidoris bilamellata* (Linnaeus, 1767)
Pelecypoda
Nuculidae
*Nucula tenuis* (Montagu, 1808)
Glycymeriidae
*Glycymeris subobsoleta* (Carpenter, 1864)
Mytilidae
Mytilidae sp. Juvenile
Montacutidae
*Mysella tumida* (Carpenter, 1864)
Cultellidae
*Siliqua patula* (Dixon, 1789)
Solenidae
*Solen sicarius* (Gould, 1850)
Tellinidae
*Macoma balthica* (Linnaeus, 1758)
*Macoma calcarea* (Gmelin, 1792)
*Macoma indentata* (Carpenter, 1864)
*Macoma* sp. Juvenile
*Tellina bodegensis* (Hinds, 1845)
*Tellina carpenteri* (Dall, 1900)
*Tellina nuculoides* (Reeve, 1854)
Psammobiidae
*Gari californica* (Conrad, 1849)
Veneridae
*Psephidia lordi* (Baird, 1863)
*Psephidia ovalis* (Dall, 1902)
Cooperellidae
*Cooperella subdiaphana* (Carpenter, 1864)
Hiatellidae
*Hiatella arctica* (Linnaeus, 1767)
Pandoridae
*Pandora bilirata* (Conrad, 1855)
*Pandora* sp. Juvenile
Lyonsidae
*Lyonsia californica* (Conrad, 1837)
*Lyonsia pugettensis* (Dall, 1913)
*Lyonsia* sp. Juvenile
Schaphopoda
Dentaliidae
*Dentalium* sp. Indeterminate
Cephalopoda
Loliginiidae
*Loligo opalescens* (Berry, 1911)
Arthropoda
Crustacea
Cirripedia
Cirripedia sp. Indeterminate
Ostracoda
Cylindroleberididae
*Cylindroleberis* sp. Indeterminate
Cypiridinidae
*Euphilomedes carcharodonta* (Smith, 1952)

*Philomedes* sp. Indeterminate

Mysidacea
- Mysidacea sp. Indeterminate
- Mysidae
  - *Archeomysis grebnitzkii* (Czerniavsky, 1882)
  - *Neomysis kadiakensis* (Ortmann, 1908)
  - *Neomysis* sp. Indeterminate
  - *Neomysis* sp. Juvenile
  - *Pacificanthomysis nephrophthalma* (Banner, 1948)

Cumacea
- Diastylidae
  - *Colurostylis occidentalis* (Calman, 1912)
  - *Diastylis alaskensis* (Calman, 1912)
  - *Diastylopsis dawsoni* (Smith, 1880)
  - *Diastylopsis* sp. Indeterminate
  - *Diastylopsis* sp. Juvenile
  - *Diastylopsis tenuis* (Zimmer, 1936)
- Lampropidae
  - *Lamprops quadriplicata* (Smith, 1879)
  - *Mesolamprops* sp. Indeterminate
  - *Mesolamprops* sp. Juvenile
- Nannastacidae
  - *Cumella* sp. Indeterminate
  - *Cumella* sp. Juvenile

Tanaidacea

Isopoda
- Aegidae
  - *Rocinela angustata* (Richardson, 1904)
- Cymothoidae
  - *Lironeca* sp. Indeterminate
- Idoteidae
  - *Edotea sublittoralis* (Menzies and Barnard, 1959)
  - *Synidotea* sp. Indeterminate
- Munnidae
  - *Munna* sp. Indeterminate
- Sphaeromatidae
  - *Bathycopea daltonae* (Menzies & Barnard, 1959) = *Ancinus daltonae*
  - *Gnorimasphaeroma oregoniensis* (Dana, 1854-55)

Amphipoda
- Aoroidae
  - *Aoroides exilis* (Conlan and Bousfield, 1982)
- Ampeliscidae
  - *Ampelisca agassizi* (Judd, 1896)
  - *Ampelisca careyi* (Dickinson, 1982)
  - *Ampelisca* sp. Indeterminate
  - *Ampelisca* sp. Juvenile
- Gammaridae
  - Gammaridae sp. Indeterminate
  - *Megaluropus* sp. Indeterminate
  - *Melita desdichada* (Barnard, 1962)
- Haustoriidae
  - *Eohaustorius estuarius* (Bosworth, 1973)

*Eohaustorius cf. sawyeri* (Bosworth, 1973)
*Eohaustorius sencillus* (Barnard, 1962)
*Eohaustorius* sp. Indeterminate
*Eohaustorius* sp. Juvenile

Ampithoidae

*Peramphithoe humeralis* (Stimpson, 1864)

Isaeidae

*Cheirimedeia zotea* (Barnard, 1962)
*Gammaropsis thompsoni* (Walker, 1898)
*Photis macinerneyi* (Conlan, 1983)
*Photis parvidons* (Conlan, 1983)
*Photis* sp. Indeterminate
*Photis* sp. Juvenile
*Protomedeia* sp. Indeterminate
*Protomedeia* sp. Juvenile
*Protomedeia zotea* (Barnard, 1962)

Ischyroceridae

*Ischyrocerus pegalops* (Barnard, 1962)
*Ischyrocerus* sp. Juvenile
*Jassa* sp. Indeterminate

Lysianassidae

*Anonyx* cf.*lilljeborgi* (Boeck, 1871)
*Anonyx* sp. Indeterminate
*Anonyx* sp. Juvenile
*Hippomedon denticulatus* (Bate, 1857)
*Orchomene pacifica* (Gurjanova, 1938)
*Orchomene* sp. Indeterminate

Oedicerotidae

*Monoculodes spinipes* (Mills, 1962)
*Monoculodes zernovi* (Gurjanova, 1938)
*Synchelidium shoemakeri* (Mills, 1962)
*Synchelidium* sp. Indeterminate
*Synchelidium* sp. Juvenile
*Westwoodilla caecula* (Bate, 1857

Phoxocephalidae

*Foxiphalus major* (Barnard, 1960)
*Grandiphoxus* cf. sp. R
*Mandibulophoxus gilesi* (Barnard, 1957)
*Rhepoxynius abronius* (Barnard, 1960)
*Rhepoxynius dabouis* (Barnard, 1960)
*Rhepoxynius* sp. Indeterminate
*Rhepoxynius cf. stenodes* (Barnard, 1960)
*Rhepoxynius vigitegus* (Barnard, 1971)

Tironidae

*Tiron biocellata* (Barnard, 1962)

Caprellidea

Caprellidae

*Caprella californica* (Stimpson, 1857)
*Caprella* sp. Indeterminate
*Caprella* sp. Juvenile
*Metacaprella kennerlyi* (Stimpson, 1864)

Decapoda
- Decapoda - megalopa
- Natantia
  - Pandalidae
    - *Pandalopsis ampla* (Bate, 1888)
    - *Pandalus platyceros* (Brandt, 1851)
  - Crangonidae
    - *Crangon alaskensis* (Lockington, 1887)
    - *Crangon alba* (Holmes, 1900)
    - *Crangon* sp. - megalopa
    - *Crangon* sp. Indeterminate
    - *Crangon* - zoea
- Reptantia
  - Paguridae
    - *Pagurus* sp. Indeterminate
    - *Pagurus* sp. Juvenile
  - Pinnotheridae
    - *Pinnixa* sp. Indeterminate
  - Majidae
    - *Oregonia* sp. Juvenile
  - Porcellanidae
    - Porcellanidae - megalopa
    - Porcellanidae - zoea
  - Cancridae
    - *Cancer branneri* (Rathbun, 1926)
    - *Cancer magister* (Dana, 1852)
    - *Cancer oregonensis* (Dana, 1852)
    - *Cancer productus* (Randall, 1839)

Phoronida
- *Phoronida* sp. Indeterminate

Echinodermata
- Asteroidea
  - *Crossaster papposus* (Linnaeus, 1767)
- Ophiuroidea
  - *Ophiura sarsi* (Lutken, 1855)
  - Ophiuroidea sp. Juvenile
- Echinoidea
  - Echinoidea sp. Indeterminate
  - *Dendraster excentricus* (Eschscholtz, 1831)
- Holothuroidea
  - Holothuroidea sp. Juvenile
  - *Molpadia intermedia* (Ludwig, 1894)
- Synaptidae
  - *Leptosynapta transgressor* (Heding, 1928)

**APPENDIX D.**

Bird species encountered in the study area.

Bird species encountered in the "Blanco West" area.

| Species | Number | Transect Distance (km) | Birds/km | Frequency of occurrence (No.transects) |
|---|---|---|---|---|
| Brandt's cormorant | 9 | 14.4 | 0.63 | 4 |
| Brown pelican | 1 | 3.3 | 0.30 | 1 |
| Cassin's auklet | 186 | 40.5 | 4.59 | 12 |
| California gull | 65 | 27.8 | 2.34 | 8 |
| Common Murre | 48 | 40.5 | 1.19 | 12 |
| Glaucous-winged gull | 4 | 10.1 | 0.40 | 3 |
| Herring gull | 11 | 6.9 | 1.59 | 3 |
| Heermann's gull | 5 | 14.8 | 0.34 | 4 |
| Mew gull | 1 | 1.4 | 0.71 | 1 |
| Northern fulmar | 1 | 2.8 | 0.36 | 1 |
| Pacific loon | 2 | 2.8 | 0.71 | 1 |
| Pelagic cormorant | 1 | 2.8 | 0.36 | 1 |
| Ring-billed gull | 2 | 3.3 | 0.61 | 1 |
| Rhinoceros auklet | 24 | 28.4 | 0.85 | 8 |
| Red-necked phalarope | 2 | 3.6 | 0.56 | 1 |
| Sooty shearwater | 20 | 23.4 | 0.85 | 7 |
| Surf scoter | 5 | 8.4 | 0.60 | 2 |
| Thayer's gull | 1 | 1.4 | 0.71 | 1 |
| Western gull | 15 | 13.3 | 1.13 | 4 |
| White-winged scoter | 1 | 4.3 | 0.23 | 1 |

Bird species encountered in the "Blanco South" area.

| Species | Number | Transect Distance (km) | Birds/km | Frequency of occurrence (No.transects) |
|---|---|---|---|---|
| Black-legged kittiwake | 1 | 4.0 | 0.25 | 1 |
| Black scoter | 1 | 2.4 | 0.42 | 1 |
| Brandt's cormorant | 15 | 23.7 | 0.63 | 9 |
| Brown pelican | 2 | 4.9 | 0.41 | 2 |
| Cassin's auklet | 233 | 30.8 | 7.56 | 12 |
| California gull | 45 | 23.6 | 1.91 | 8 |
| Common loon | 3 | 8.4 | 0.36 | 2 |
| Common Murre | 91 | 29.9 | 3.04 | 11 |
| Double-crested cormorant | 5 | 4.8 | 1.04 | 2 |
| Glaucous-winged gull | 10 | 11.9 | 0.84 | 4 |
| Herring gull | 11 | 16.8 | 0.65 | 6 |
| Heermann's gull | 13 | 11.9 | 1.09 | 4 |
| Marbled murrelet | 2 | 4.0 | 0.50 | 1 |
| Northern harrier | 1 | 0.9 | 1.11 | 1 |
| Pacific loon | 14 | 6.8 | 2.06 | 3 |
| Pelagic cormorant | 10 | 15.4 | 0.65 | 4 |
| Pigeon guillemott | 1 | 3.3 | 0.30 | 1 |
| Ring-billed gull | 3 | 2.2 | 1.36 | 1 |
| Rhinoceros auklet | 5 | 15.5 | 0.32 | 5 |
| Red-throated loon | 1 | 0.9 | 1.11 | 1 |
| Sanderling | 2 | 4.0 | 0.5 | 1 |
| Sooty shearwater | 1 | 2.2 | 0.45 | 1 |
| Surf scoter | 40 | 14.6 | 2.74 | 4 |
| Unidentified gull | 100 | 2.4 | 41.67 | 1 |
| Western gull | 17 | 21.2 | 0.80 | 7 |
| White-winged scoter | 8 | 9.4 | 0.85 | 3 |

Bird species encountered in the "Offshore" area.

| Species | Number | Transect Distance (km) | Birds/km | Frequency of occurrence (No.transects) |
|---|---|---|---|---|
| Arctic tern | 4 | 1.6 | 2.5 | 1 |
| Cassin's auklet | 344 | 58.5 | 5.88 | 15 |
| California gull | 36 | 51.5 | .7 | 13 |
| Common Murre | 6 | 11.4 | .53 | 3 |
| Glaucous-winged gull | 4 | 21.2 | .19 | 3 |
| Herring gull | 11 | 27.1 | .41 | 6 |
| Heermann's gull | 2 | 9 | .22 | 1 |
| Northern fulmar | 5 | 17.5 | .29 | 4 |
| Red phalorope | 2 | 7.7 | .26 | 2 |
| Pink-footed shearwater | 4 | 11.3 | .35 | 3 |
| Sabine's gull | 1 | 1.6 | .63 | 1 |
| Sooty shearwater | 89 | 47.9 | 1.86 | 13 |
| Thayer's gull | 4 | 21.1 | .19 | 3 |
| Western gull | 33 | 50.5 | .65 | 12 |
| White-throated sparrow | 1 | 6.6 | .15 | 1 |

Bird species encountered in the "Gold Beach West" area.

| Species | Number | Transect Distance (km) | Birds/km | Frequency of occurrence (No.transects) |
|---|---|---|---|---|
| Black-legged kittiwake | 1 | 5.6 | 0.18 | 1 |
| Bonaparte's gull | 1 | 2.7 | 0.37 | 1 |
| Brandt's cormorant | 51 | 23.8 | 2.14 | 5 |
| Cassin's auklet | 821 | 53.6 | 15.32 | 11 |
| California gull | 21 | 56.1 | 0.37 | 8 |
| Common Murre | 21 | 43.6 | 0.48 | 7 |
| Great blue heron | 1 | 2.7 | 0.37 | 1 |
| Glaucous-winged gull | 4 | 8.4 | 0.48 | 2 |
| Herring gull | 2 | 5.7 | 0.35 | 1 |
| Heermann's gull | 10 | 13.9 | 0.72 | 3 |
| Pacific loon | 2 | 5.6 | 0.36 | 1 |
| Pelagic cormorant | 15 | 8.2 | 1.83 | 2 |
| Pigeon guillemott | 4 | 5.6 | 0.71 | 1 |
| Pink-footed shearwater | 11 | 25.8 | 0.43 | 5 |
| Ring-billed gull | 1 | 5.6 | 0.18 | 1 |
| Rhinoceros auklet | 12 | 16.6 | 0.72 | 4 |
| Red-necked phalarope | 12 | 12.1 | 0.99 | 2 |
| Red-throated loon | 1 | 5.6 | 0.18 | 1 |
| Sooty shearwater | 46 | 38.8 | 1.19 | 8 |
| Song sparrow | 1 | 6.5 | 0.15 | 1 |
| Surf scoter | 10 | 5.6 | 1.79 | 1 |
| Thick-billed murre | 1 | 2.6 | 0.38 | 1 |
| Unidentified tern | 10 | 5.6 | 1.79 | 1 |
| Western grebe | 1 | 5.6 | 0.18 | 1 |
| Western gull | 35 | 65.6 | 0.53 | 11 |
| White-winged scoter | 3 | 2.7 | 1.11 | 1 |

Bird species encountered in the "Gold Beach South" area.

| Species | Number | Transect Distance (km) | Birds/km | Frequency of occurrence (No.transects) |
|---|---|---|---|---|
| Barn swallow | 6 | 3.7 | 1.62 | 1 |
| Brandt's cormorant | 55 | 29.1 | 1.89 | 6 |
| Brown pelican | 3 | 4.4 | 0.68 | 1 |
| Cassin's auklet | 542 | 48.8 | 11.11 | 11 |
| California gull | 12 | 20.7 | 0.58 | 5 |
| Common loon | 1 | 3.6 | 0.28 | 1 |
| Common Murre | 59 | 48.8 | 1.21 | 11 |
| Glaucous-winged gull | 1 | 3.7 | 0.27 | 1 |
| Herring gull | 4 | 8.1 | 0.49 | 2 |
| Double-crested cormorant | 1 | 4.4 | 0.23 | 1 |
| Marbled murrelet | 16 | 19.7 | 0.81 | 5 |
| Pacific loon | 2 | 10.3 | 0.19 | 2 |
| Pelagic cormorant | 3 | 10.3 | 0.29 | 2 |
| Pigeon guillemott | 1 | 4.4 | 0.23 | 1 |
| Rhinoceros auklet | 56 | 44.4 | 1.26 | 10 |
| Red-necked phalarope | 81 | 27.5 | 2.95 | 6 |
| Sooty shearwater | 7 | 9.7 | 0.72 | 2 |
| Surf scoter | 35 | 14.7 | 2.38 | 3 |
| Tufted puffin | 2 | 4.4 | 0.45 | 1 |
| Western grebe | 2 | 4.4 | 0.45 | 1 |
| Western gull | 8 | 22.4 | 0.36 | 5 |
| White-winged scoter | 21 | 21.6 | 0.97 | 5 |

**APPENDIX E.**

Disposition of samples and data.

Disposition of samples and data from the 1990 Placer Minerals Cruise

| Sample/Data Type | Institution and Place | Contact |
|---|---|---|
| Magnetics data | Portland State University<br>Portland, Oregon | Curt Peterson |
| | Dept of Geology and Mineral Ind<br>Portland, Oregon | Dennis Olmstead |
| High-resolution<br>Seismic data | Portland State University<br>Portland, Oregon | Curt Peterson |
| | Minerals Management Service<br>Camarillo, California | Ken Piper |
| Side-scanning<br>sonar data | Department of Fish & Wildlife<br>Newport, Oregon | Rick Starr |
| Vibralift<br>sediment samples | U.S. Bureau of Mines<br>Salt Lake City, Utah | John Judd |
| Benthic infauna<br>samples | Department of Fish & Wildlife<br>Newport, Oregon | Rick Starr |
| Trawl samples<br>(voucher specimens) | Oregon State University<br>Corvallis, Oregon | Joe Fisher |
| Benthic infauna<br>data | Department of Fish & Wildlife<br>Newport, Oregon | Rick Starr |
| Trawl data | Department of Fish & Wildlife<br>Newport, Oregon | Rick Starr |
| Crab pot data | Department of Fish & Wildlife<br>Newport, Oregon | Rick Starr |
| Bird observation<br>data | Department of Fish & Wildlife<br>Newport, Oregon | Rick Starr |
| Benthic grab<br>sediment samples | Dept of Environmental Quality<br>Portland, Oregon | Andy Schaedel |