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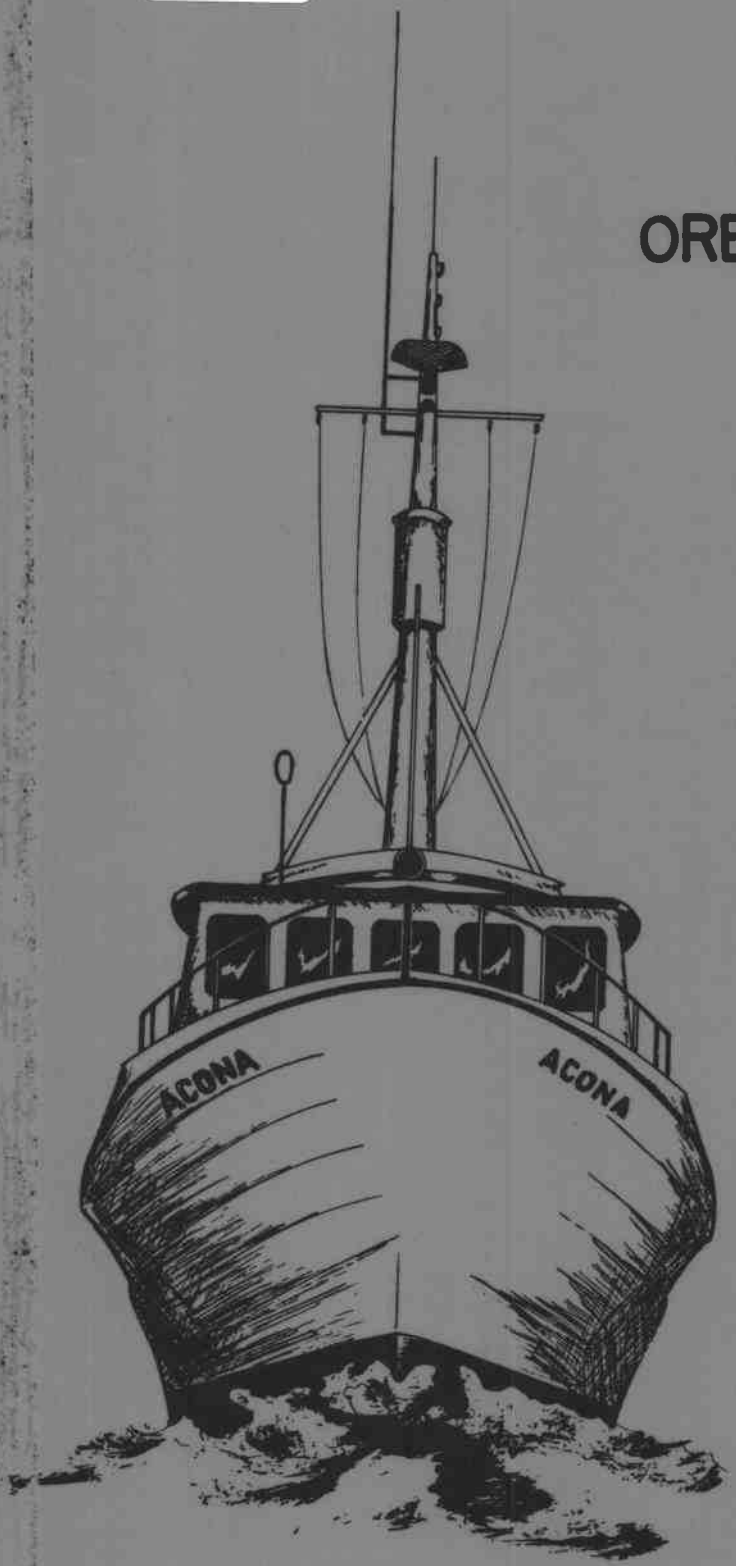
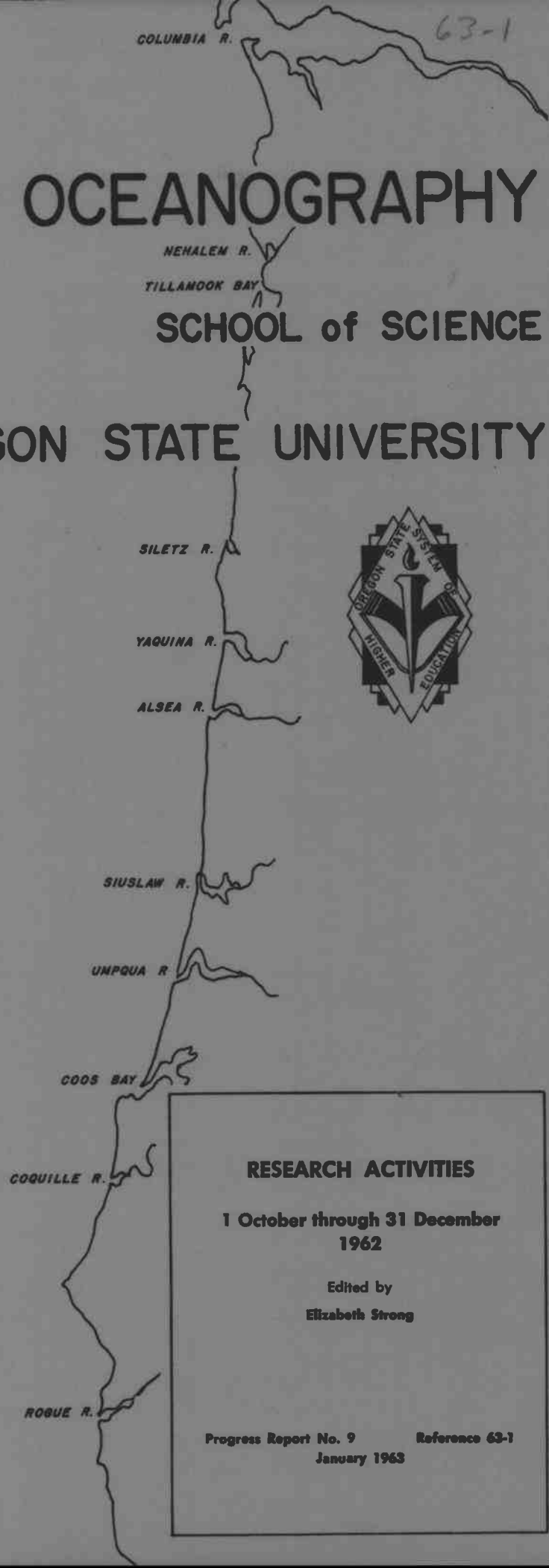
DEPARTMENT of OCEANOGRAPHY

SCHOOL of SCIENCE

OREGON STATE UNIVERSITY





OREGON STATE SYSTEM OF HIGHER EDUCATION

RESEARCH ACTIVITIES

1 October through 31 December 1962

Edited by

Elizabeth Strong

Progress Report No. 9 Reference 63-1
January 1963

Department of Oceanography
School of Science
Oregon State University

Wayne V. Burt
Chairman

Progress Report No. 9

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National Science Foundation
Grant GP 622
Grant G 23103
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Office of Naval Research
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INTRODUCTION

This report summarizes the research conducted during the fourth quarter of the calendar year 1962 by the Department of Oceanography, Oregon State University, under contract Nonr 1286(02) Project NR 083-102 with the Office of Naval Research, grants GP 622, G 23103 and G 24353 with the National Science Foundation, contracts AT(45-1)-1726, AT(45-1)-1750 and AT(45-1)-1751 with the Atomic Energy Commission, and grant AF-AFOSR-62-376 with the Advanced Research Projects Agency.

PHYSICAL OCEANOGRAPHY

Hydrography of Oregon Coastal Waters - Wyatt, Kujala, Borden

Hydrographic cruises were made during October and December. In October a series of stations were made off Newport, Astoria and Brookings. The December cruise consisted of a series of stations off Astoria, Newport and Coos Bay. Data have been processed for cruises through October 1962. In addition, the hydrographic data from the five 1962 drogue cruises were processed. Error programs are being run on the hydrographic data to check the accuracy of the interpolation scheme used in the hydrographic program.

The recent expansion of computer facilities makes it possible to extend the hydrographic data program. An extended program that will make it possible to process deeper casts and to interpolate and calculate sigma-t and dynamic height in one operation is now being debugged.

Summary of Samples Taken on Hydrographic and Drogue Cruises

Hydrographic casts	66
BT casts	110
Surface temperature and salinity observation	128
Drift bottles released	720
Midwater trawl hauls	30
Plankton tows	38
Meter net tows	2
Drogue current measurements	7

Graphic sections of properties investigated at all stations occupied since 1959 are being prepared. These graphs will be used in the preparation of a manuscript on the hydrography of the waters off Oregon. Analyses of currents and salinity distribution are nearly completed.

Shore Station Observations - Wyatt, Still

Sea water temperature and salinity have been observed at least weekly at 12 shore stations for two years. Stations are visited by department personnel once each quarter. Data for the calendar year 1962 is being compiled and will be published as a Data Report.

Arrangements are being made with the Coast Guard to collect wind data from several of their lifeboat stations along the Oregon coast.

Temperature and Salinity Variability - Denner, Pattullo

This study has been broadened to include an analysis of simultaneous variations in temperature and salinity. A statistical analysis is being performed on all available data. These include data for 1959 through 1962 collected at shore stations set up by the Department of Oceanography and data for 1933 and 1934 collected at tide stations by the U. S. Coast and Geodetic Survey. Analyses are nearly completed.

Oceanic Fronts - Pattullo, Wyatt, Maughan

During November a cruise was made on the U. S. Coast Guard vessel MODOC to collect additional data for this study. High winds and rain squalls made operation difficult, but seven drogues with parachutes at various depths down to 1000 meters were released and tracked for 25 hours. A fixed reference point was established by anchoring a float in 1200 fathoms of water (10,000 feet of wire were used). Drogue positions were determined by radar range and bearings from this fixed reference buoy. Temperature and salinity data were obtained using Nansen bottles and a BT. Data from hydrographic casts and BT casts made off Newport on 11 and 12 December will also be used in this study of oceanic fronts.

One day was spent in Yaquina Bay testing the effectiveness of obtaining radar fixes on a weather balloon attached to the drogue. Balloons were inflated with helium; one to five balloons were tied together and attached to the drogues with variable lengths of line. The use of weather balloons as an aid in tracking drogues will be investigated further.

A program has been developed for processing drogue tracking data. This program is currently being tested.

Water Masses off the Oregon Coast - Rosenberg, Pattullo

Data collected by the department since Mr. Rosenberg's thesis was written have been incorporated into this study. Several characteristics of the distributions not clearly evident heretofore have now been defined. A paper is in preparation.

Heat and Water Budgets - Pattullo, Bernhardt

With the addition of Lucille Bernhardt to the staff as an Assistant in Oceanography, it has become possible to resume the extensive work begun earlier on these studies. Computation of the water budget for the Pacific Ocean during the IGY has just been completed. Insufficient data were collected during the IGY in the Indian and Atlantic Oceans for a similar calculation to be made; estimates will be made by including data for other years.

Subsurface Current Measurements - Smith

The electronic components for receiving pinger signals have been built. The system is to be tested at sea during the next drogue cruise.

GEOLOGICAL OCEANOGRAPHY

Geology of the Oregon Continental Terrace

Lithology - Byrne, Maloney, Bushnell, Kulm

Rocks were dredged from 14 different locations on the continental shelf in the vicinity of Stonewall Bank during the past quarter. To date, rocks have been collected from 68 different localities on the shelf and slope off the coast of central Oregon. Faunal analyses made by outside agencies suggest that these rocks are no older than late Miocene, and are probably Pliocene or younger.

Laboratory analyses on the sediment samples collected from the continental shelf between 43°30'N and 45°00'N have been completed; a report describing the results of these analyses is now in preparation.

Sediment cores were obtained with a Phleger corer from four locations on the continental shelf (50 to 100 fathoms along latitude 44°45'N) and four locations in a submarine valley on the continental slope (550 to 640 fathoms along a line from 44°39.2'N, 125°01.0'W to 44°37.7'N, 125°02.0'W). The cores have not as yet been examined.

Surface sediments from 25 cores taken in and around Astoria Submarine Canyon have been analyzed for gamma-ray emitters. All gamma-ray spectra were made with the Hanford low-background anti-coincidence spectrometer at Hanford, Washington; an IBM 1620 computer was used to analyze the spectra. The radio-isotopes present in the sediments were chromium-51 and zinc-65 (products of the atomic reactor at Hanford); zirconium-95, niobium-95, ruthenium-103 and cerium-141 (products of nuclear fallout); and potassium-40 (naturally occurring). All radioactive isotopes decreased in abundance with distance from the mouth of the Columbia. A report on the radioactivity of these sediments has been submitted to Science (Osterberg, et al).

Topography - Byrne, Maloney

Bathymetric surveys of Daisy Bank (44°39'N, 124°44'W) and Stonewall Bank (44°30'N, 124°22'W) were made using the EDO (AN/UQN) echo-sounder with the Precision Depth Recorder. Six traverses with 30° of rotation between traverses were made of Daisy Bank; three east-west traverses were made across Stonewall Bank. The depth records suggest that Stonewall Bank is an anticlinal fold, possibly complicated by faulting at the northern end, and that Daisy Bank is either a fold or fault structure. Bathymetric charts of the continental shelf and upper slope between 42°00'N and 43°30'N, and 45°00'N and 46°30'N made from unpublished soundings of the United States Coast and Geodetic Survey are in final stages of preparation and will be submitted for publication during the first quarter of 1963.

CHEMICAL OCEANOGRAPHY

Radionuclides in Phytoplankton - Osterberg, Curl

Filterable particles from large volumes of sea water are being assayed for radionuclides. Water samples for this work are being collected in conjunction with other projects primarily from stations off Astoria using plant pigments from the same water samples. A study is being made of the proportion of radionuclides in phytoplankton as compared to seston.

Inorganic Nutrient Survey of Yaquina Bay - Park, Matson

In conjunction with the plankton inventories by Frolander, a biweekly nutrient survey of Yaquina Bay is underway. During November and December, PO_4 in the bay water ranged from 0.5 to 1.6 μg-atom/liter. Inorganic phosphate concentrations were generally richer in bottom waters than in surface waters. Work on determination of soluble silicate will begin next quarter.

Calcium Carbonate Solubility - Park

A paper on pure aragonite synthesis, coauthored with Kitano and Hood, was published in the Journal of Geophysical Research. An additional report on the rate and mode of aragonite synthesis is being prepared.

Conductometric Analysis of Alkalinity of Sea Water - Park, Freund, Oliphant

By the use of the salinometer, alkalinity of sea water has been measured. Shipboard applicability of this new method will be reported in the future.

Dissolved Oxygen Calibration - Park

Dr. D. E. Carritt of M.I.T. and Woods Hole has attempted to standardize the calibration of dissolved oxygen analyses among various institutions. Using the results of his study, we are planning to build a micro-nonburet oxygen titration setup that Dr. J. H. Carpenter of Johns Hopkins University has developed.

Chemical Conditions off the Oregon Coast - Park, Oliphant

During October upwelling was still observable off Brookings but not off Astoria or Newport. Off Brookings, inorganic phosphate concentration in the surface water was greater than 1.5 μg-atom/liter near the coast, while offshore it fell to nearly 0.5 μg-atom/liter. Both dissolved oxygen and salinity profiles indicated the presence of upwelling.

Surface Chemistry of Marine Sediments - Stump

A study is being made of (1) dispersion effects of glauconite as a function of the ionic strength of the medium and (2) effects of temperature on change in porosity of glauconite. Mathematical analysis of the Frenkel-Halsey-Hill adsorption isotherm and capillary condensation (as given by Conway Pierce, Jour. Phys. Chem., 64:9, 1184-87, 1960) is being undertaken. The purpose of this study is to distinguish between multilayer adsorption and capillary condensation, an important factor in calculation of the distribution of micropore size.

Radioanalysis of Marine Organisms - Osterberg, Larsen, Cutshall

Both the 3" x 3" and 5" x 5" detectors have been received and placed in lead shields. A number of qualitative analyses have been made with the new equipment. When we receive our dual-channel amplifier, we will be able to use both detectors simultaneously, and quantitative work can be initiated in our laboratory.

In the meantime, radioanalyses of about 20 samples have been completed at Hanford. These analyses continue to show the presence of the neutron-induced and fallout radionuclides in marine plankton previously reported. With the assistance of Dr. Jensen, Department of Statistics, the statistical analysis of the gamma-ray spectrometry data has been reworked and refinements incorporated into a new IBM program. Also, the raw data are now being printed out along with the results. This means that numerical errors in the spectrum analysis can be checked rapidly.

Radioanalyses of Inland Sands and Waters - Larsen, Cutshall, Osterberg

Radioanalyses of various sands and aggregates from local supplies were begun to find a source of building material low in natural radioactivity for use in the new oceanography building. This study has been expanded to include gravel, etc. from other areas of the valley.

A filtration and ion exchange program is being carried out to assay the fallout radioactivity in river water and rain water. Preliminary results indicate trace amounts of fission products in the Willamette River.

Zinc-65 in Sea Water - Osterberg, Park, Curl

Equipment and supplies to search for zinc-65 in sea water have been obtained. A cruise to obtain sea water was scheduled for mid-October, but postponed because of bad weather. It has been rescheduled for February. The sea water will be filtered and the filtrate treated with Dowex 1-A Chelating resin, and cation and anion resins. Radioanalysis of the filters and the resins will be carried out to determine the fraction of particulate and ionic zinc-65 in sea water near the mouth of the Columbia River.

BIOLOGICAL OCEANOGRAPHY

Plankton Inventories at Yaquina Bay - Frolander

A regular program is being maintained at Yaquina Bay to study variations in the plankton population and related physical and chemical properties of the water. Weekly sampling is made at four stations in the bay. Physical measurements are made of temperature, salinity, and dissolved oxygen. Quantitative and qualitative studies are being made of the biological data collected in net tows.

All biological samples are being accessioned in a ledger and referenced in a permanent card file. Specimens are preserved and catalogued so that they are available to staff or students for research projects.

Physical, chemical and biological parameters have been plotted for bottom and surface samples at Buoy 15 and Buoy 21. Locations were selected to compare an area representing bay conditions with an area influenced by the ocean.

Oceanic Nekton Studies - Pearcy, Hubbard, Laurs

The sampling program for small nekton over the continental slope is being continued. Collections are being made with the Isaacs-Kidd midwater trawl. In addition, experimental tows, which sampled three depths down to 1000 m, were made with an opening-closing bucket on the midwater trawl.

The results of the first year's collections of midwater fishes are currently being prepared for publication.

Macroplankton Studies - Hebard, Renshaw, Pearcy

Opening-closing meter nets for serial sampling within the upper 1000 m were tested on two cruises. It was found necessary to redesign the nets, and this has been done. We are now looking for a better way to attach the nets to the towing cable so that the cable can rotate while the nets are being lowered or retrieved.

Identification and enumeration of euphausiids and other macroplankters from the midwater trawl samples is continuing.

Epibenthic Fishes - Day, Pearcy

Collections of epibenthic fishes from the continental shelf and slope have been completed. Identifications and tabulation of species distributions are being made and will be incorporated in a master's thesis. Mr. Day has accepted a temporary position with the U. S. Fish and Wildlife Service in Seattle.

Enzyme Respiration Studies of Oceanic Animals - Curl, Pearcy, Karinen

Data on the succinoxidase activity of many species of fish and larger zooplankton are being analyzed. Major modifications in the method have been made to correct for absorption at 490 mu by carotenoids and to give accurate weight-based data. Work has begun on an examination of alternative pathways to the succinoxidase system, since low activity may be a result of shunts rather than inherent low respiration. Instrumentation is being designed to measure gaseous (O_2) metabolism before the enzymatic method is applied to a specimen.

Phytoplankton Ecology - Curl, Small, Verity, Trione

Two daylight in-situ experiments were conducted at a station 30 miles off Newport. Thirty-four samples from this station were analyzed for productivity by the C^{14} method. Twenty samples were collected for photosynthetic pigments and ten samples for species composition. Ambient illumination and depth attenuation measurements were made on both cruises. A recording light meter is being installed aboard the ACONA.

Pigment samples, species composition samples and light measurements are now being made at all hydrographic stations; such measurements have been made on two cruises.

Identification of phytoplankton species has begun. Species composition analyses of fixed samples will be started as soon as we become sufficiently familiar with the local flora.

Phytoplankton Physiology - Curl, Small, Trione, Davey

Eight species of phytoplankton diatoms, including Skeletonema costatum, Thalassiosira sp., Fragillaria oceanica, and Chaetoceros sp. have been isolated from nutrient-enrichment cultures of coastal waters and are now in persistent culture. They are currently being made bacteria-free. Enrichment cultures are being made on all hydrographic cruises for the purpose of isolating additional species.

Illumination in the culture room was found to be at a level where some species were being grown close to the compensation point. Higher intensity fluorescent lights have been added.

Energy and Nutrient Transfer at Lower Trophic Levels - Small, Curl, Cross

Pelagic copepods and Artemia salina are being used to determine direct radioisotope uptake by second trophic level organisms. As soon as possible, the cultures for the uptake experiments will be moved from the culture room to the "aquastat" which is under construction. A literature survey on the maintenance of cultures of marine copepods is underway. Earlier quantitative zooplankton samples are being analyzed to aid in more meaningful extrapolation of laboratory data to natural populations.

Benthic Ecology - Carey

The benthic-sampling program is being continued. At a series of stations off Newport, five depths were sampled in October, and six replicate dredge hauls at 800 meters were made in December. Twenty-five quantitative anchor dredge samples have been collected to date.

Radioanalysis studies of the benthos are underway to determine the extent of radioisotopes introduced into the environment from the Columbia River. Preliminary results from analysis of bulked samples from 1000-2800 m indicate that zinc-65 and possibly other radioisotopes are present in the organisms. Detailed radioanalysis of the benthos will be made on the six anchor dredge samples collected in December.

Sediment samples were obtained on both benthic cruises and these will be analyzed.

Psychrophilic Nature of Malic Dehydrogenase of a Marine Bacterium - Morita

An enzyme preparation was obtained by growing the cells of a marine vibrio for 24 hours at 21° C and harvesting them in a Servall SS-3 centrifuge. The cell paste was treated in a Raytheon 10 kc sonic oscillator for five minutes to disintegrate the cells. The cell suspension was then centrifuged in a Spinco Model L preparative ultracentrifuge for 120 minutes at 144,000 x g. The clear, straw-colored supernatant liquid was decanted and frozen.

Malic dehydrogenase catalyzes the reaction of malate to oxaloacetate in the presence of DPN and vice versa. Therefore, a Beckman DU spectrophotometer was used to measure the enzyme reaction at pH 7.5 for the amount of DPNH·H oxidized when oxaloacetate was added to the system. When the enzyme preparation was kept at temperatures above 45° C for five minutes, no enzyme reaction remained. The following table illustrates the effect of various temperatures on the denaturation of malic dehydrogenase from the marine psychrophilic vibrio.

Treatment of Enzyme before Assay	Activity Remaining*
40° C -- 10 min.	17%
35° C -- 20 min.	16%
30° C -- 40 min.	16%
30° C -- 8 min.	50%

*The amount of activity with untreated enzyme represents 100% activity.

Benthic Fauna of the Chukchi Sea - McCauley

During the month of October, Dr. James McCauley joined the scientific party on a postseason cruise of the Coast Guard Cutter NORTHWIND. He had an opportunity to observe the arctic environment and to collect marine life from the area.

Collections were made from depths of 20 to 45 meters at 15 stations by towing an otter trawl (22-foot gulf-type shrimp trawl) at slow speeds. Specimens were preserved and brought back to the laboratory for identification and further study. The fishes have been turned over to Dr. Pearcy. Of the more than 300 species of animals collected, over 60 invertebrates and 20 fishes have been tentatively identified. Arctic birds and mammals were observed. Ice conditions ranged from ice that was just forming to thick ice that the ship had to break through. A preliminary report has been submitted to the Coast Guard for inclusion in the scientific reports of the NORTHWIND cruise.

Scientists from other universities and government institutions made observations of the ice, the weather, and the earth's magnetic field. Hydrographic stations were taken and phytoplankton collections made.

GEOPHYSICS

Seismic Work at Sea - Berg, Whitcomb

The Sparker gas-exploder unit was tested in Yaquina Bay. More tests are planned in the bay before starting any work on the continental shelf.

Methods of velocity control are being studied. A jig has been made to hold core samples for measuring seismic velocities.

Seismic Station - Dehlinger, Chiburis, Trembly, Mecham, Berg

The seismic station has been operated continuously as a standard seismological station. The instruments have been kept properly calibrated and in good recording condition. Long-period noise is being observed on the vertical long-period seismograph; we are working to eliminate these oscillations. Since 1 November we have been sending data to the U.S. Coast and Geodetic Survey in Washington, D.C., as a regular contributor to the network of stations for locating epicenters and origin times of earthquakes.

Portland Earthquakes - Dehlinger, Berg, Chiburis, Trembly, Mecham

The Portland earthquake of 5 November 1962 was investigated in the field and from seismograms. The shock origin time and epicenter were determined from seismograms from more than ten seismic stations in Oregon, Washington, northern California, Nevada and Idaho. The magnitude was estimated from seismograms recorded at Corvallis. Aftershocks of this quake have been recorded at Corvallis. A semitechnical article on this shock was written at OSU and published in the November issue of The Ore Bin.

The 17 December Portland shock was also recorded at Corvallis.

Gravity Studies: Ocean and Continent - Berg, Dehlinger, Rinehart, Bales

The method of analysis of gravity data for sea-continent transition zone profiles is currently being reconsidered because of increased computer capability.

Gravity stations are being set up at selected locations in Oregon to augment Woollard's data. A study is being made of the use of the aneroid altimeter for field measurements of altitudes.

Geologic profiles are being compiled which will give typical geologic cross sections of basalt flow areas in Oregon.

Surface-Ship Measurements - Berg, Dehlinger

A program to make gravity measurements at sea off the coast of Oregon and Washington and off the Aleutian Islands is being planned for the spring and summer of 1963. A proposal is being submitted to the Office of Naval Research requesting funds for support of this research.

In addition to the gravity study, magnetic and electrical studies will be carried out at the same time.

This program is being conducted with the cooperation of the U.S. Coast Guard, through the 13th C.G. District, Seattle. Tentative plans are to start gravity work off the northwest coast in May, using the C.G. Cutter YOCONA and to obtain space aboard one of the larger vessels to do gravity work in the Aleutians during the summer of 1963.

Seismicity of Oregon - Dehlinger, Berg

Portions of a proposal to AFCRL on seismicity studies of Oregon have been revised and the proposal has been resubmitted. It is anticipated that the proposed research will be initiated in February or March 1963.

Theoretical and Model Seismology - Berg, Dehlinger, Redo, Trembly, Laun, Papageorge, Chiburis

Calculations of energy have been made for the Gnome nuclear explosion for distances of 298 meters and to 6 kilometers from the source. The energy in the first half-cycle of ground motion between 0.6 and 6 kilometers appears to be representative of the total energy of the source as computed at 298 meters. Energy content of other phases of motion are under consideration. Third zone energy computations are currently in progress.

The instrumentation for the two-dimensional seismic model is complete, and plans for experimentation are being made.

A report which considers displacements from explosive sources and their relationship to charge size is in the final stages of preparation.

Thermal Studies - Berg

A thermal probe is being ordered. This instrument will be used to initiate heat flow measurements of the ocean bottom.

Instrumentation - Bales

Consideration has been given to the improvement or adjustment of instruments being used for geophysical researc. Work has been done on the gravimeter and the sparker power supply for the seismic profiler.

FACILITIES

Research Vessel ACONA

The ACONA was limited to 39 days at sea because of bad weather during the quarter. Cruises included four hydrographic studies, a drogue study of ocean fronts, a geology cruise and biological studies of benthos, nekton and phytoplankton.

William Bales has worked on servicing and adjusting electronic instruments aboard ship. Work has also been done on the hydraulic system, electrolysis problems and improvement of ventilation on the ACONA.

Oceanography Building

The contract has been awarded for the new oceanography building to be constructed on campus. Construction will begin early in 1963.

Coastal Marine Sciences Laboratory

A grant of almost a million dollars has been received by the University from the Area Redevelopment Administration to establish a Marine Sciences Laboratory on the coast at Yaquina Bay, Newport, Oregon. The facility will be developed in the harbor on 47 acres of waterfront land made available by the Port of Newport. Offices and laboratories will be provided for marine and coastal studies; docks will be provided to accommodate research vessels; an aquarium and museum for the public are being planned. The laboratory will be used jointly by personnel from a number of departments of the University.

STAFF

Dr. Peter Dehlinger has joined the staff as a professor. Dr. Dehlinger received his B.S. degree in mineralogy and geology from the University of Michigan, and holds M.S. and Ph.D. degrees in geophysics from the California Institute of Technology. He has a background rich in both commercial and academic experience. He has served as seismologist and geophysicist with two oil companies, was a research and consulting geophysicist for Batelle Memorial Institute in Ohio, and is currently also a part-time exploration geophysicist with the U.S. Geological Survey. He comes to us from the A. and M. College of Texas, where he was associate professor and professor of geophysics for eight years.

At A. and M. College Dr Dehlinger organized both undergraduate and graduate degree programs in geophysics, and also supervised two federally

sponsored research projects. Several of his students are now active in the field. His numerous publications and reports reveal his broad interests. They range over subjects such as shear wave vibration directions, ultrasonic model investigations, hydraulic treatments of oil wells, seismology in the U.S.S.R., crustal refraction studies, and investigations with shipborne gravity meters. He is a member of numerous professional societies, and of Phi Beta Kappa and Sigma Xi.

Dr. Dehlinger will be active in most of the vigorous research and instruction programs in geophysics now underway in the department. He is particularly interested in surface-ship gravity measurements in the Pacific Ocean, ultrasonic model investigations, and the seismicity of Oregon; he has been placed in charge of the OSU standard seismological station.

Degrees Completed during 1962

Andrew G. Carey was awarded a Ph.D. degree in June 1962 by Yale University with a major in marine ecology. Dr. Carey is an Assistant Professor in the Department.

W. Bruce McAlister received a Ph.D. degree with a major in Physical Oceanography from Oregon State University in June 1962. Dr. McAlister was appointed Assistant Professor on the oceanography staff.

Charles L. Osterberg completed the requirements for the Ph.D. degree at Oregon State University in October 1962. His thesis was on the "Radioactivity of Marine Organisms." Dr. Osterberg received an appointment as Assistant Professor.

VISITING SCIENTISTS

During 1962 the Department of Oceanography sponsored visits to Corvallis from outstanding scientists. The following lectures were presented:

24 July	Robert S. Arthur, Scripps Institution of Oceanography, University of California. "Ocean Jets."
8-9 October	Michitaka Uda, Tokyo University of Fisheries. "Fishery Oceanography," and "Synoptic Pacific Oceanography."
19 October	Karl Banse, Department of Oceanography, University of Washington. "On the Vertical Distribution of Zooplankton in Stratified Water."
9 November	Richard W. Castenholz, Department of Biology, University of Oregon. "Ecology of Littoral Marine Diatoms."

PUBLICATIONS AND PAPERS

Publications

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Dehlinger, P. (with D. K. Chowdhury). Investigations of elastic wave propagation along layers in two-dimensional models, Bull. Seis. Soc. Am.

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Morita, R. Y., and P. W. Stave. Electron micrograph of an ultrathin section of Beggiatoa, J. Bacteriol.

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Pattullo, J. G., and J. E. McCauley. Department of Oceanography, Oregon State University, Am. Zoologist.

Small, L. F., Research and teaching in biological oceanography. Am. Biol. Teacher.

Papers Delivered at Scientific Meetings

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