

GC 856

073

LIBRARY
Marine Science Laboratory
Oregon State University

DEPARTMENT of OCEANOGRAPHY

COLUMBIA R.

NEHALEM R.

TILLAMOOK BAY

SCHOOL of SCIENCE

OREGON STATE UNIVERSITY

SILETZ R.

YAQUINA R.

ALSEA R.



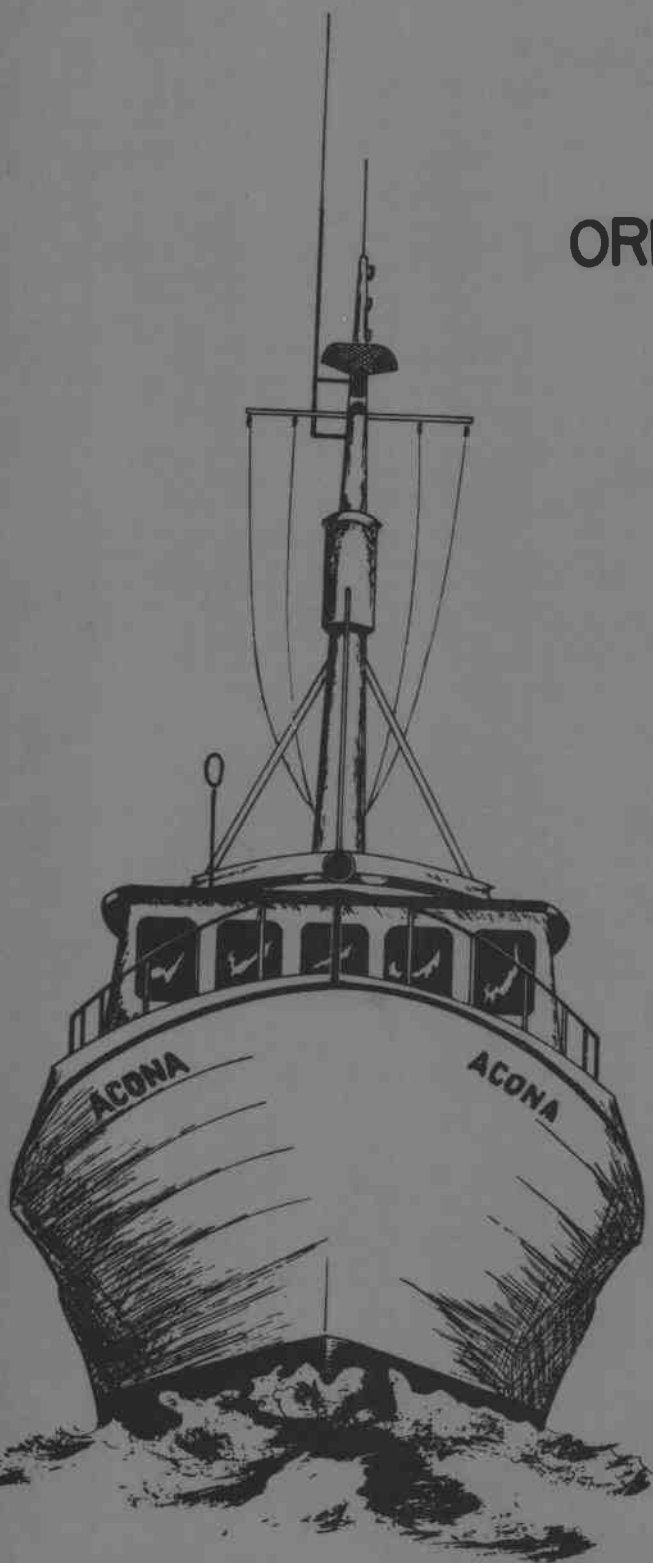
SIUSLAW R.

UNPQUA R.

COOS BAY

COQUILLE R.

ROGUE R.



RESEARCH ACTIVITIES

1 April through 30 September
1964

Edited by
Susan Borden

Progress Report No. 14 Reference 64-38
November 1964

Department of Oceanography
School of Science
Oregon State University

Wayne V. Burt
Chairman

Progress Report No. 14
RESEARCH ACTIVITIES

During the period
1 April 1964 through 30 September 1964

Edited by

Susan Borden

Office of Naval Research

Contract Nonr 1286(10)
Project NR 083-102
Contract Nonr 1286(09)
Project NR 083-600

Atomic Energy Commission

Contract AT(45-1)1750
Contract AT(45-1)1751
Contract AT(45-1)1758
Contract AT(45-1)1784

Public Health Service

Grant AI 05640-02
Grant ES 00026-01

National Science Foundation

Grant GP 2808
Grant GB-531
Grant GP-3582
Grant G -21303
Grant GP-2232
Grant GP-2186
Grant GB-1588
Grant GP-2150
Grant GP-2566
Grant GP-2876
Grant GB-2472

Air Force

Grant AF 49(638)1403
Grant 19(628)2778

Reference 64-38

November 1964

Reproduction in whole or in part is permitted for any purpose of the
United States Government.

TABLE OF CONTENTS

PHYSICAL OCEANOGRAPHY

Processes Affecting Sea Water Characteristics at Oregon Coast Stations - Pattullo	1
Upwelling - Smith, Moriyasu, Pattullo, Lane	1
The Permanent Pycnocline - Collins, Pattullo.	3
Currents - Stevenson, Wyatt, Pattullo.	3
Short-Wave Solar Radiation - Minard, Pattullo	3
Air-Sea Interchange - Lane	4
Instrumentation - Mesecar, Maughan	5
Vertical Eddy Diffusion - Weyl, Ingham.	5

GEOLOGICAL OCEANOGRAPHY

Geology of the Oregon Continental Shelf and Slope - Byrne, Fowler, Maloney, Runge	9
Astoria Canyon - Byrne, Carlson	9
Foraminiferal Ecology - Fowler.	10
Deep Sea Sedimentation - Oregon - Byrne, Nelson.	10
Deep Sea Sedimentation - Atlantic - Byrne, Fowler, Ensminger.	10
Terrace Deposits - Kulm, Byrne	11
Netarts Bay Foraminifera - Fowler, Hunger.	11
Yaquina Bay Foraminifera - Fowler, Manske	11
Nearshore Carbonate Sands of Bermuda - Kulm, Byrne, Carlson.	12

GEOFYSICAL OCEANOGRAPHY

Seismic Work at Sea - Berg, Whitcomb, Erickson.	13
Land Gravity Studies - Berg, Thiruvathukal, Rinehart	13
Theoretical Studies - Berg, Bodvarsson, Maloof, Stone, Odegard, Papageorge.	13
Thermal Studies - Berg, Bodvarsson, Hutt.	14
Marine Gravity - Dehlinger, Rinehart, Couch.	14
Magnetics - Berg, Rinehart, Ropes, Bales.	14
Instrumentation - Bales.	15
Seismicity and Crustal Structure of Oregon - Dehlinger, V. Rinehart, Chiburis	15

CHEMICAL OCEANOGRAPHY

Offshore Chemistry - Park, Dobson, George, Kennedy, Matson	17
Conductometric Determination of Alkalinity - Park, George .	17
Dissolved Radionuclides as Water Mass Indicators - Park George	17
The Paleochemistry of the Oceans - Weyl.	17
Physical Chemistry of Sea Water - Weyl, Connors, Duedall .	21
Chemical Reactions in Sea Water - Pytkowicz, Kester	22
Antarctic Oceanography - Pytkowicz	22
Removal of Alkalinity from Sea Water by Clays - Deffeyes, Weyl.	23

MARINE RADIOCHEMISTRY AND RADIOECOLOGY

Instrumentation - Osterberg.	25
Nekton - Percy, Osterberg, Wyandt, Larsen, Dickson	26
Benthos - Carey, Osterberg, Larsen, Hancock, Dickson . . .	26
<u>In Situ</u> Probe Studies - Jennings, Osterberg, Fredrick.	27
Dissolved Organics - Cronin, Johnson, Cutshall, Osterberg .	27
Geochemistry - Cutshall, Johnson, Osterberg.	28
Estuarine Collections - Haertel, Heimermann, Cross, Larsen, Osterberg	28
Stable Trace Element Analysis - Cronin, Johnson, Osterberg	28

BIOLOGICAL OCEANOGRAPHY

Benthic Ecology and Systematics - Carey, McCauley, Alspach, Hancock	29
Animal-Sediment Relationships - Carey, Hancock	29
Polychaete Distribution in Yaquina Bay - Morrison, Carey	29
Plankton Inventories at Yaquina Bay - Frolander.	30
Oceanic Trematode Studies - McCauley, Eagle	30
Hydroid Ecology - McCormick, McCauley	31
Energy and Element Transfer in the Lower Marine Food Web - Small.	31
Phytoplankton Ecology - Curl, Small, Hardy.	31
Marine Microbiology - Morita	31
Distribution and Ecology of Oceanic Animals - Percy, Hebard, Hubbard, Forss, VanArsdale	32
Vertical Distribution and Migration Studies - Percy, Renshaw, Laurs, Forss.	32
Effects of Upwelling in the Biomass of Trophic Levels - Laurs, Percy.	33

EDUCATIONAL PROGRAM

Summer Program in Oceanography	34
Students Receiving Degrees	34

FACILITIES

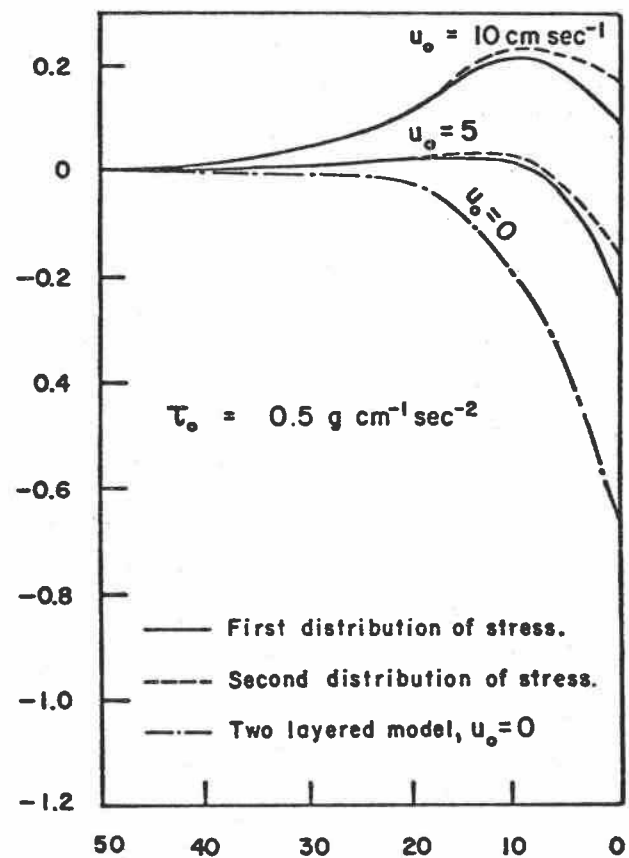
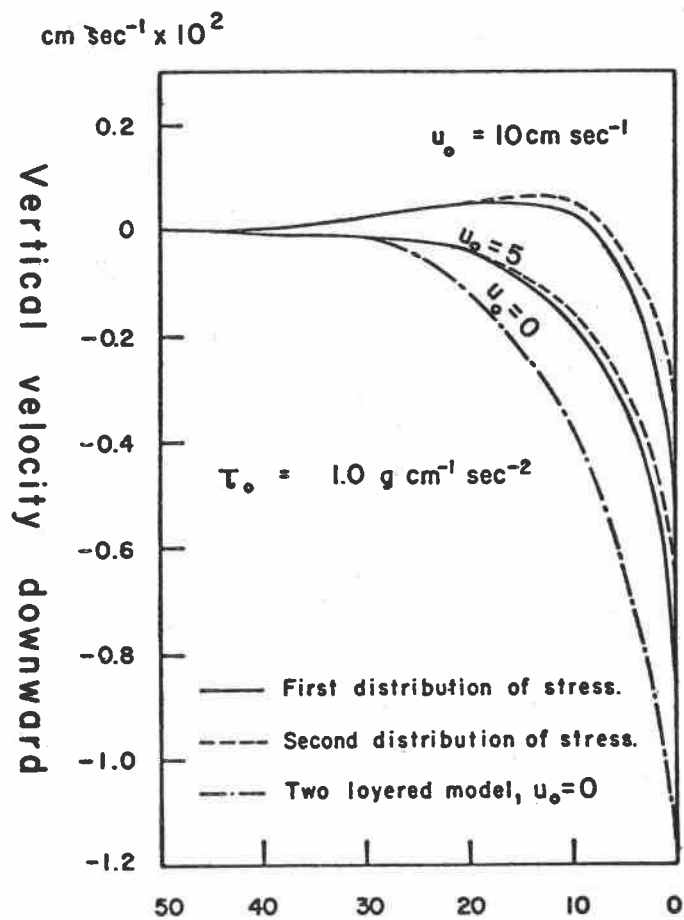
Research Vessel ACONA	37
Research Vessel YAQUINA	37
Oceanography Building	38
Coastal Marine Science Laboratory	38

NEW STAFF	39
---------------------	----

VISITING LECTURERS	40
------------------------------	----

PUBLICATIONS AND PAPERS	41
-----------------------------------	----

Figure 1. Vertical velocity of the pycnocline as a function of wind stress, river outflow, and internal distribution of stress. (adapted from Moriyasu. in press)



u_0 = River outflow
 τ_0 = Wind stress from north

PHYSICAL OCEANOGRAPHY

Processes Affecting Sea Water Characteristics at Oregon Coast Stations - Pattullo (with Warren Denner, now at the U. S. Naval Postgraduate School)

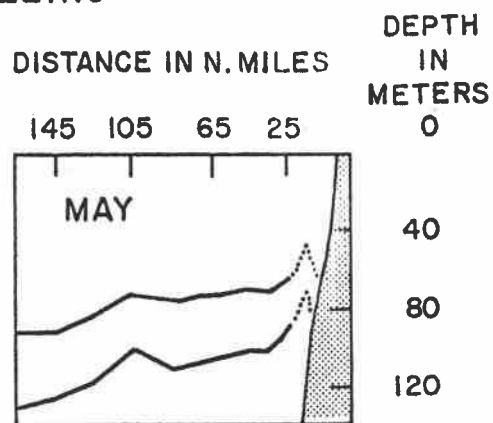
The data used in Mr. Denner's M. S. thesis have been combined with more recent data, and additional statistical analyses have been made. It was found useful to group the data into sets, each set representing the prevalence of a particular physical process or event: heating, rainfall, upwelling, admixture of Columbia River water, or combinations of these. The resulting tabulations show the relative frequency of occurrence of each process, the variation in frequency with season, and the change in effectiveness of each process with position along the coast.

Upwelling - Smith, Moriyasu, Pattullo, Lane

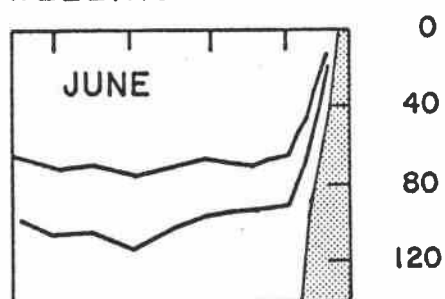
In May 1963 two series of observations were made during early-stage upwelling off Brookings, Oregon. The data have been analyzed for onshore-offshore flow in four ways: 1) conservation of concentration of salt and heat is assumed, and transport offshore between isograms is computed from change of volume; 2) Ekman transport is computed using weather maps, geostrophic winds, and usual methods of deducing wind stress; 3) Ekman transport is computed from heat budget considerations and estimations of the meteorological terms, with the change in heat storage determined from the temperature observations. All methods yielded values differing by not more than a factor of two. This is surprising, since method 1 and method 4 are contradictory in premise. Apparently the offshore flow during the period was so marked that local heating, internal mixing and longitudinal gradients all played roles secondary to that of the offshore transport.

Dr. Moriyasu sought and found a theoretical solution to the problem of coastal upwelling, under the influence of wind stress, when river outflow is also present. He adapted assumptions, previously used by Yoshida, to a three-layered case. He was able to find an analytical solution, and his paper on this subject contains illustrations of upwelling or downwelling that could be expected with wind stresses and river outflow typical of the Columbia River outflow area (Figure 1). No quantitative evaluation has yet been made, but his solution offers an explanation of the marked subsurface (30 m) changes in temperature and salinity that are observed off Astoria during summer.

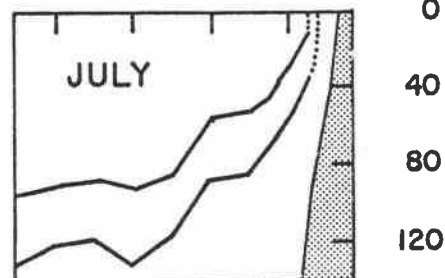
PREUPWELLING



EARLY UPWELLING



WELL DEVELOPED UPWELLING



POST UPWELLING

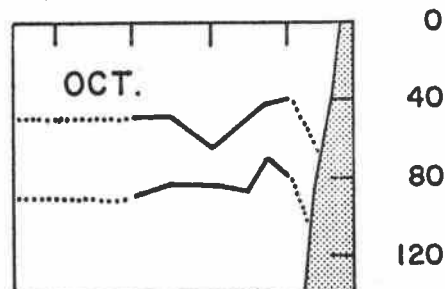


Figure 2. Pycnocline structure and its relationship to upwelling. (Collins, 1964)

The Permanent Pycnocline - Collins, Pattullo

Work on a paper describing the results of this investigation is continuing. A graphical summary of the seasonal changes in pycnocline features is shown in Figure 2. Note the deep, nearly horizontal pycnocline present before upwelling, and the shallow, nearly horizontal pycnocline after upwelling. In the paper these changes are considered as the result of onshore-offshore transport and cross-pycnocline mixing.

Currents - Stevenson, Wyatt, Pattullo

One drogue cruise was made in May. Fortunately, fixes were closely spaced in time due to good operation of the radar and new design of the anchored reference buoy. The stability and excellent radars of the YAQUINA offer promise of good success in this work at higher wind speeds than previously. (Force four winds were encountered on this cruise.) Analyses of the records from this and all previous drogue cruises are continuing.

During the cruise fluorescent dye was injected at a pre-determined subsurface depth, and tracked for several hours by shipboard fluorometric analysis. The feasibility of such work off the Oregon coast, with the oceanic and meteorological conditions we may expect to meet is clearly demonstrated. A fluorometer will be purchased, and work will be continued on the computer prediction of patterns and the definitive design of experiments.

Short-Wave Solar Radiation - Minard, Pattullo

A summary of short-wave radiation received by the Eppley pyrheliometer aboard the ACONA during the summer of 1963 has been compiled by Mr. David R. Minard and has been accepted by the university for his Master of Science thesis. The instrument has since been overhauled and will shortly be installed on the R/V YAQUINA.

Primary results of the work are the following: 1) Distribution of the frequency of radiation of various intensities during summer was determined. 2) The usual (Kimball) equations for estimating incident radiation under clear skies were examined and found to coincide with observed amounts. 3) The hypothesis that solar radiation varies with distance from shore was found not true for this period of observation.

Air-Sea Interchange - Lane

An examination of the heat budget at the ocean surface adjacent to Oregon for the period 1952 to 1962 has been completed. It has been found that the processes of evaporation and conduction are much smaller in the upwelling region than farther offshore. Upwelling in summer appears to cause an increase in the relative humidity and a decrease in the temperature of air moving into Oregon from the Pacific Ocean. These effects are not substantial, however, because of the relatively small area of the upwelling zone. Total annual heat exchange near the coast of Oregon varies considerably from year to year. This variation appears to be influenced mainly by sea surface temperature and cloud cover.

It was also found that the net monthly heat exchange at the air-sea interface, Q_t , can be related to the difference between Q_e' and Q_e , where Q_e is the heat lost from evaporation. Q_e' is found by the formula:

$$Q_e' = (\text{solar radiation}) \times (2.67 \times \text{air temperature} - 51.46)$$

The relationship between Q_t and $(Q_e' - Q_e)$ for the region adjacent to Oregon during the ten-year period is shown in Figure 3.

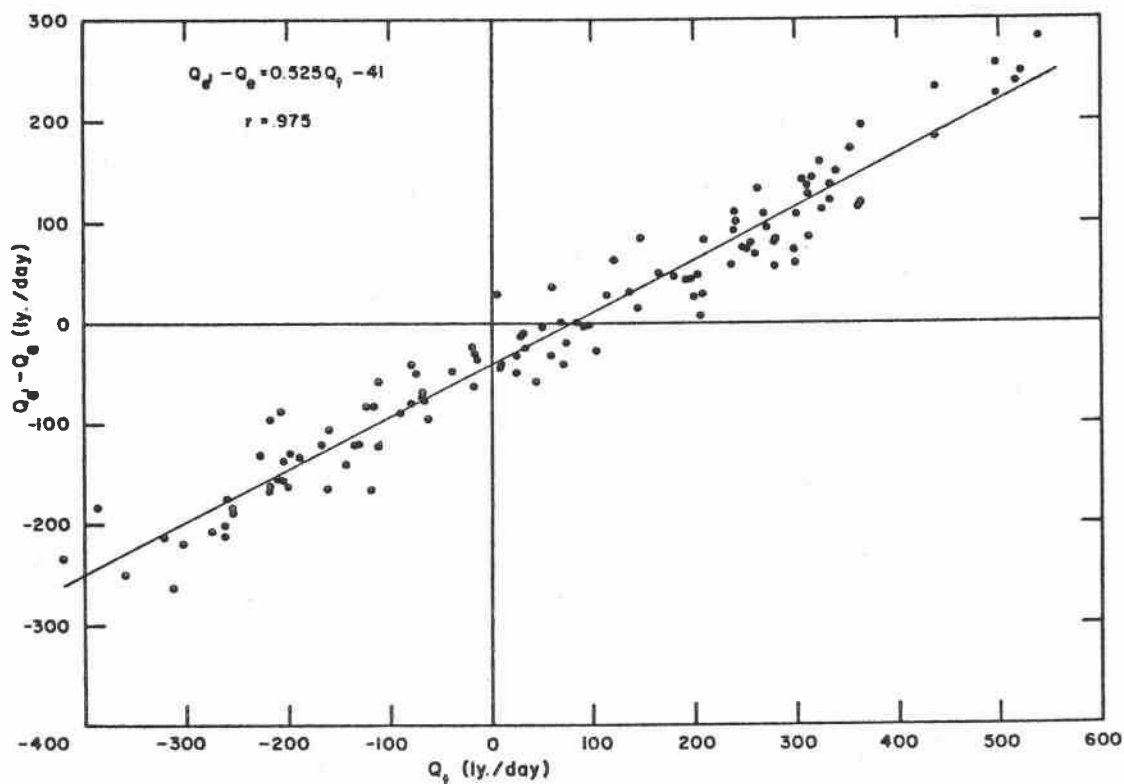


Figure 3. Correlation of Q_t and $Q_e' - Q_e$ for the ocean region adjacent to Oregon, 1952-1962.

The effluent from the Columbia River, by providing a strong vertical density structure in the waters seaward from the upwelling zone, may conserve sufficient heat near the surface of the ocean to affect the evaporation process. That is, a stronger effluent may promote a higher rate of evaporation.

Instrumentation - Mesecar, Maughan

A transistorized data acquisition system has been received for check-out. The unit has capacity for scanning up to 999 signal inputs from resistive bridge networks or voltaic transducers. Each analog input is converted to a digital format and recorded on punched paper tape. The analog-to-digital signal conversion is accurate to 0.1% and is accomplished in ten milliseconds per transducer. The digital format on the punched paper tape can be converted to alphanumeric characters on a special typewriter for review by the researcher. The tape can also be used directly for digital computer processing. The system will be used for oceanographic data logging on board ship.

A relatively inexpensive (\$350) system has been developed to integrate signals from solar radiation detectors. The unit converts the detector signal to a proportionally weighted series of pulses. A counter unit sums the pulses at a rate of 80 pulses per second. By a programmed command signal, the counter total is printed out in alphanumeric format on a reel of paper tape. The unit can be battery supplied for use in remote stations.

Vertical Eddy Diffusion - Weyl, Ingham

In parts of the ocean where the temperature and salinity both decrease downwards, there may be an amplification of vertical eddy diffusion due to the more rapid molecular diffusion of heat than salt. A simple model of spherical turbulent globs has been investigated. It is found that there is a range of size for which amplification takes place. Larger spheres will return to the equilibrium position before significant diffusion of heat while smaller spheres will rapidly lose both heat and salt. The range of sizes depends primarily on the ratio of the slope of the T-S curve to the slope of the isopycnal. Using typical values of the other parameters and a slope ratio of two, amplification will take place for radii from 0.7 to 4.7 cm. At a slope ratio of 5, the range of sizes is 1 to 3 cm.

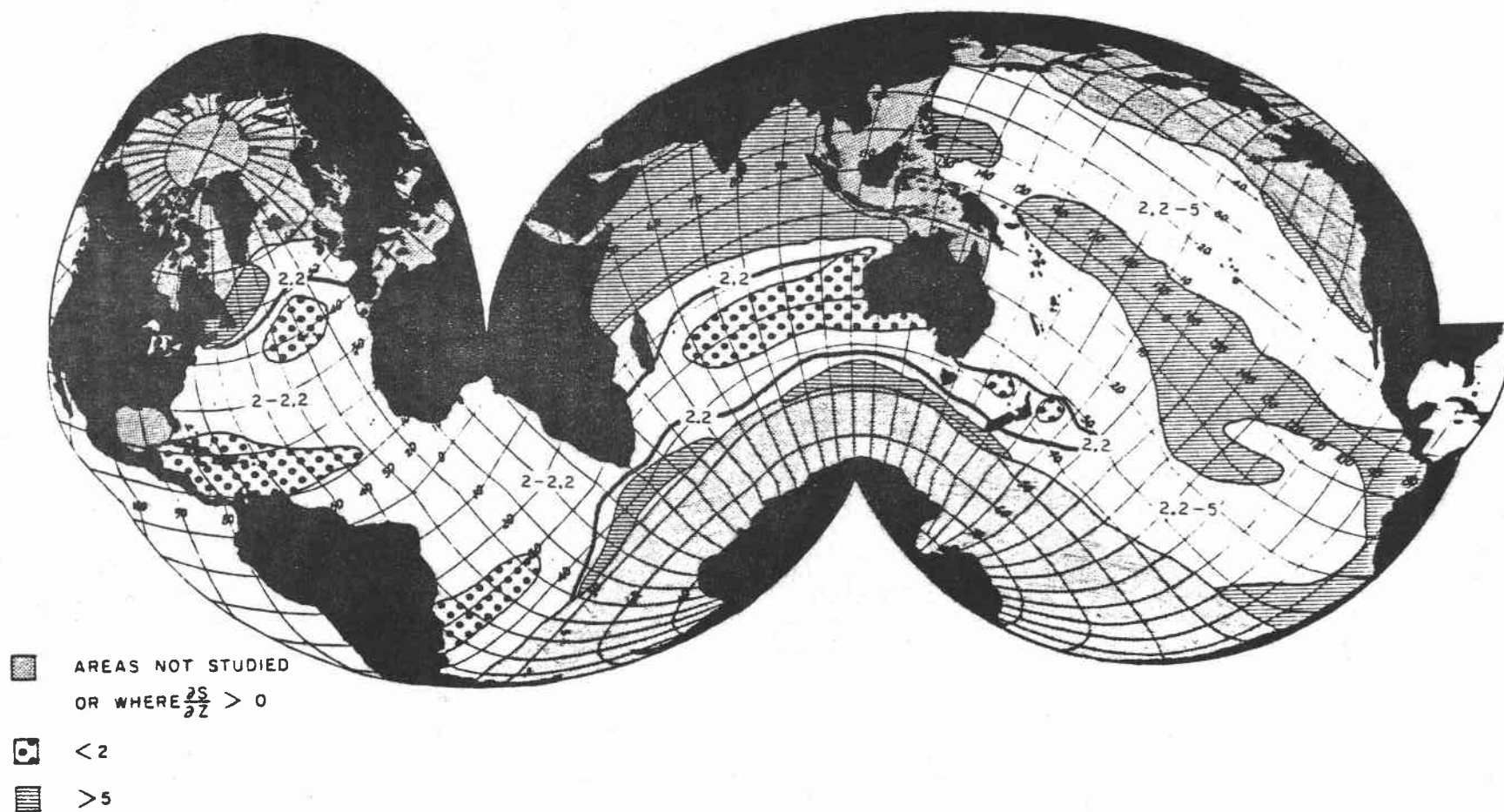


Figure 4. Ratio of the slope of the T-S curve to the slope of the isopycnals.

The T-S data for the world ocean between the near-surface salinity maximum and the underlying salinity minimum have been examined. Curves whose slope is proportional to the slope of the isopycnals fit the data very much better than the straight line approximation sometimes used, in spite of the fact that these curves, like the straight lines, involve only two parameters. The values of the slope ratio obtained are mapped in Figure 4. The slope ratio is close to two for most of the Atlantic and the southern part of the Indian Ocean, but is significantly higher for most of the Pacific and the northern Indian Ocean. Lower values of the ratio correlate with high salinities at maximum, indicating that amplified downward diffusion of heat and salt may be taking place in these areas. If this is so, salt would be diffused to greater depth than heat and the usual mixing relations employed by oceanographers would be inadequate for these portions of the T-S curve. The examination of the T-S data is continuing.

GEOLOGICAL OCEANOGRAPHY

Continental Margin

Geology of the Oregon Continental Shelf and Slope - Byrne, Fowler, Maloney, Runge

Preliminary sampling of the continental shelf on a three mile grid has been completed from the latitude of Port Orford ($42^{\circ}44'N$) to Cape Disappointment ($46^{\circ}20'N$). South of $43^{\circ}15'N$ samples were collected at two mile intervals across the shelf in order to obtain better sampling control where the shelf is relatively narrow. To date samples have been taken at approximately 650 different locations; textural analyses have been completed on about 500 of these. Mineralogical studies will be made of representative samples in order to determine the net movement of sediment on the continental shelf.

The investigation of the continental margin (shelf and slope) off the central coast of Oregon has been completed, and a final report is in preparation. Stratigraphic structural, and geophysical data suggest that during the Tertiary as much as 20,000 feet of sediment accumulated off the central coast of Oregon in the area of the present continental shelf. Recent sediments in this region consist of well-sorted, fine to very fine, detrital sands on the inner shelf grading to poorly-sorted glauconite-rich clayey silts on the outer shelf. Continental slope sediments are primarily clayey silts containing small percentages of foraminifera, radiolarians, diatoms and sponge spicules. Lithologic and faunal similarities of the Recent sediments with sedimentary rocks exposed along the coast and on the shelf and slope indicate that deposition during late Tertiary time occurred in shelf and slope environments. The fossil faunas also indicate that portions of the continental margin may have been uplifted as much as 4000 feet since the late Tertiary, and that there has been a general westward shifting of the sites of sediment accumulation.

Astoria Canyon - Byrne, Carlson

The survey of Astoria Submarine Canyon begun in 1962 has been reinstituted. Approximately 440 miles of sounding lines were obtained during the summer, bringing the total to 1040 miles of soundings using the Precision Depth Recorder. In addition, about 90 miles of sub-bottom profiles were obtained between the head of the canyon and the mouth of the Columbia River using the "sparker" in cooperation with the geophysics group. Numerous filled channel-type structures were observed in this area. Bathymetric charts of the canyon are now in preparation.

Foraminiferal Ecology - Fowler

Information is being collected to enable more precise paleo-environmental determinations to be made on faunas from rocks collected from the sea floor off Oregon, thus clarifying its geologic evolution. During May, initial collections of foraminifera were made along a series of projected traverse lines across the shelf and slope. Seventeen stations between 20 and 2800 meters off Yaquina Head ($44^{\circ}40'N$); 22 stations between 15 and 2600 meters off Nestucca Bay ($45^{\circ}10'N$); and 9 stations between 150 and 1200 meters off Nehalem Bay ($45^{\circ}40'N$) have been occupied to date. Samples were taken with a Phleger corer, Dietz-LaFond grab sampler and multiple corer. Additional coverage of inshore areas between Nestucca Bay and Siletz Bay was obtained in August. Thirty-four grab samples were taken between 18 and 126 meters along five lines spaced 1.5 to 5 nautical miles apart. Eight tide pool and beach samples were collected during September between Cape Blanco and Humbug Mountain. Analyses of these samples are now underway.

Deep-Sea Sedimentation

Oregon - Byrne, Nelson

A study of the abyssal sediment of Astoria Fan and Cascadia Abyssal Plain was instituted. Six cores twenty feet in length obtained with the Ewing piston corer together with as many Phleger cores have been collected from the Astoria Fan in the general vicinity of Astoria Canyon. The cores have not yet been analyzed, but appear to consist of greenish gray mud with interbedded thin sand layers.

Atlantic - Byrne, Fowler, Ensminger

In cooperation with the United States Naval Oceanographic Office an investigation of the sedimentary and faunal characteristics of sediment samples collected from the tropical North Atlantic has been undertaken. The study has been based on 52 samples taken from seven cores up to 2.4 meters in length. Of particular note is a 15 cm thick turbidite layer found 30 cm below the sea floor at a depth of 4762 m, 250 nautical miles southeast of the Cape Verde Islands. Identification was based upon textural characteristics of the sediment, planktonic/benthic foraminiferal ratios and percentage of displaced benthic foraminifers. Twenty-seven planktonic species have been identified

and their distributions determined. Preliminary analyses of coiling direction ratios for Globorotalia truncatulinoides, the presence or absence of G. menardii, and other indications of paleoclimate reveal trends apparently consistent with the findings of other investigators for nearby areas. A new species of Globorotalia is being described.

Coastal and Estuarine Sedimentation

Terrace Deposits - Kulm, Byrne

Ninety samples were collected from the Pleistocene coastal terrace deposits between Waldport and Brookings, Oregon. The most recent and lowest terrace levels, the Elk River beds, were sampled wherever good exposures could be obtained. A few higher and older terrace deposits were also sampled. These samples will be used in conjunction with the river, beach, and dune samples collected from southern Washington, Oregon and northern California, to study the origin and distribution of the Recent sediments in the coastal and nearshore regions of these states.

Netarts Bay Foraminifera - Fowler, Hunger

Collections have been made at 61 stations in Netarts Bay and along neighboring ocean beaches, tidal creeks, and salt marshes to determine the species composition and distribution of foraminifers. Eight stations will be used for seasonal control. Plans call for six collecting periods to be spaced approximately two months apart. To date 52 samples have been processed. Preliminary findings demonstrate the presence of more than forty species of foraminifers. Thirty-three of these have been tentatively identified. Twenty-eight species were found living at the time of collection. Population density studies indicate a maximum of 76 living foraminifers per square centimeter. Elphidium incertum characterizes the main portion of the bay, whereas Miliammina fusca and Ammonia beccarii are characteristic of areas of wide salinity and temperature fluctuation and where exposure is great at low tide.

Yaquina Bay Foraminifera - Fowler, Manske

Sampling is underway to determine seasonal variations in the species composition, population density, and areal distribution of benthic foraminifers in Yaquina Bay, Oregon. Sediment and water

samples are collected weekly from the channel of the estuary at eight stations extending inland approximately eleven miles from the coast. Salinity, dissolved oxygen, and temperature measurements are made from the water samples. Less frequent collections are planned for a greater number of stations covering all environments in the bay.

Nearshore Carbonate Sands, of Bermuda - Kulm, Byrne, Carlson

The sediment analyses of the nearshore carbonate sands of the Island of Bermuda have been completed. Textural analyses have been completed for 73 Recent carbonate sand samples collected from beach profiles during March 1964. These data are being compared with those for August 1963 to evaluate the seasonal effects of hydrography on the Bermuda beaches. A general study of the fauna and the gross physical characteristics of the carbonate sediments for both August and March will complete the compositional phase of the investigation. A wave refraction study is currently underway for the nearshore areas along the southern coast of Bermuda. Bathymetric data will be reduced by means of a computer program.

GEOPHYSICAL OCEANOGRAPHY

Seismic Work at Sea - Berg, Whitcomb, Erickson

A shallow reflection survey off Newport, Oregon, has been completed. A manuscript is being prepared for publication.

A reversed and an unreversed seismic profile were instituted off Newport, Oregon, during July 1964. These data are currently being analyzed, and a report is in preparation.

Land Gravity Studies - Berg, Thiruvathukal, Rinehart

A free-air gravity anomaly map of Oregon, based on gravity measurements made by the Department of Oceanography (Oregon State University), G. P. Wollard, Standard Oil Company of California, and the Humble Oil and Refining Company, is being constructed. Terrain corrections are being calculated for these gravity stations, and a Bouguer gravity anomaly map will be constructed. These data, combined with measurements taken at sea off the Oregon coast, are being analyzed in terms of earth structure with emphasis on the transition between deep ocean and continent.

Gravity base station ties were made using a LaCoste-Romberg geodetic land gravity meter. The data were tied to the primary gravity base in Washington, D. C.

Theoretical Studies - Berg, Bodvarsson, Maloof, Stone, Odegard Papageorge

Theoretical work is being conducted on analytical continuation of potential fields and the filtering of potential field data. One 300-mile magnetic profile has been analyzed, and a comparison is being made between depth analysis of the filtered data and other methods of interpretation.

Studies are being made of seismic wave generation and transmission in the earth. Reports extending the continuity of the waves to several hundred kilometers from the source are being completed.

Thermal Studies - Berg, Bodvarsson, Hutt

A thermal probe purchased from Alpine Geophysical Associates, Inc. has been received, and a test lowering in 400 meters of water at approximately 44°30'N, 124°45'W has been made. An instrument to measure the thermal conductivity of sediment samples from the thermo-probe has been constructed and is being tested and calibrated.

Marine Gravity - Dehlinger, Rinehart, Couch

A free-air gravity anomaly map of the region from the coast of Oregon westward about 300 miles has been completed. The gravity data was obtained on the U.S. Coast Guard Cutter YOCONA in the summer of 1963. This map is being prepared for publication, in conjunction with the free-air map of Oregon described above. As part of the marine study, 14 gravity lines were run across the seaward extension of the San Andreas fault zone to determine whether the fault trend is indicated by gravity. The fault is obscured by the effects of bottom topography on the free-air anomaly map. However, it appears as a gravity minimum of 10 to 30 mgal on a map in which the effect of bottom topography above the ocean floor has been removed. Gravity measurements along the San Andreas fault zone were continued during the summer of 1964, with several lines across the fault off northern California and the state of Washington. These recent measurements are being evaluated and will be included in a publication on the gravity survey over the San Andreas fault.

In 1964, 15 gravity profiles were run over the Mendocino escarpment between Cape Mendocino and 132°W longitude. These data are being analyzed and will be used in further investigating the nature of the escarpment. Gravity measurements were also made off the coasts of Washington and Vancouver Island. This survey will be continued in 1965 in the region from the coast to 400 miles offshore.

Magnetics - Berg, Rinehart, Ropes, Bales

The nuclear precession magnetometer built at OSU has been used to measure the earth's magnetic field off the coasts of Oregon and northern California. Approximately 2200 miles of magnetic measurements were made during this report period. These measurements are providing magnetic field data between the coast and the measurements previously made off Oregon by the Scripps Institution of Oceanography. The magnetic data are currently being analyzed.

A spinner magnetometer is being constructed for measurement of paleomagnetism in cores to be taken in the Pacific Northwest area. Construction of the magnetometer is nearing completion. It is now being checked for accuracy and reliability.

Instrumentation - Bales

During the report period, a precision radar ranging device was installed aboard the YAQUINA. Preparations are currently being made to test this equipment.

Seismicity and Crustal Structure of Oregon - Dehlinger, V. Rinehart, Chiburis

The development of local travel-time curves for the Pacific Northwest states has been completed. The curves and their geologic implications are being prepared for publication. The travel-time curves include the waves p , P^* , \bar{P} , s , S_n , L_g , and R , as based on arrivals from 14 local earthquakes at more than 40 seismic stations in the Pacific Northwest. The velocity of propagation beneath the Mohorovicic discontinuity in the region east of the Cascade Mountains is distinctly different from that in the region to the west. Both P_n and S_n waves have essentially normal velocities east of the Cascades, while velocities of both waves are approximately 3.5% lower west of the Cascades. The corresponding Poisson's ratio is 0.26 in both provinces.

A study has been completed on the nature of fault displacement along the seaward extension of the San Andreas fault zone from earthquakes that occurred between October 1962 and August 1963. Directions of the first motions of P waves indicated that nearly all of the earthquakes were consistent with the San Andreas type of motion, that is a right-lateral displacement, although three of the earthquakes in the vicinity of the Mendocino escarpment were not consistent with this direction of motion. The study also indicated that the velocity of the P_n wave is 8.0 km/sec, about the same as that in eastern Oregon.

A study has been undertaken to determine the nature of a wave, the "post- P_n " or "delayed" P_n , which arrives from most local earthquakes at epicentral distances between 200 and 1000 km. This wave is observed to have the same velocity as P_n , and has a direction of motion which is either the same or opposite to that of the P_n . The

purpose of the investigation is to determine whether this wave, in conjunction with P_n , is indicative of depth of focus. Preliminary investigations lead to the suggestion that this wave may have traveled as an sP_n (i. e. , leaving the source as a SV wave and being reflected as a P to travel as a P_n wave). This study is being continued.

The Corvallis Standard Seismograph Station and that at Klamath Falls have been operated on a routine basis. Seismograms are analyzed and wave arrivals tabulated. Quarterly Seismological Bulletins, giving arrival times for the different phases identified from earthquakes recorded are being prepared and submitted to interested seismological laboratories.

CHEMICAL OCEANOGRAPHY

Offshore Chemistry - Park, Dobson, George, Kennedy, Matson

The regular seasonal and spatial studies of salinity, dissolved oxygen, pH, and alkalinity for all the hydrographic stations were continued. In addition, gas chromatographic determination of the dissolved gases in sea water was carried out at sea during the July hydrographic cruise. Each sample was analyzed for dissolved oxygen, nitrogen, and total carbon dioxide.

Mr. Matson has completed his work on the distribution of dissolved silicates in sea water off the Oregon coast and in some estuaries, including the Columbia River. His M. S. thesis is on file in the OSU Library.

Conductometric Determination of Alkalinity - Park, George

A continuous titration cell with recorder for the determination of alkalinity is being assembled. Actual measurements will begin this winter.

Dissolved Radionuclides as Water Mass Indicators - Park, George

Eight one-hundred liter samples were obtained from the Columbia River and the sea off Oregon. These samples are currently being analyzed for their dissolved Sr^{90} and Cs^{137} activities. The results will be used in the study of the effect of Columbia River runoff on the offshore chemistry. They will also contribute to ocean-wide distribution studies of radionuclides in the Pacific.

The Paleochemistry of the Oceans - Weyl

A theoretical study of the chemical history of the oceans with special emphasis on the stability of the pH of sea water is continuing. The alkalinity-total CO_2 diagram developed by Deffeyes is particularly useful in this study. Table 1 presents rough estimates of the fluxes of these quantities into the ocean and the rates of exchange between the surface and the deep ocean.

TABLE 1

	Note	Alkali flux 10 ¹⁶ g equiv/yr	Total CO ₂ 10 ¹⁶ g mole/yr
Exchange with ocean			
River influx dissolved	1	.003	.003
Deep sea carbonate sedimentation	2	.003	.0015
Shallow-deep ocean exchange			
Net mixing rate	3	.01	.02
Transfer of organic C to deep	4		.01
Fossil fuel burning	5		.03
Juvenile CO ₂ addition	6		.0002

-
- Notes: 1. D. A. Livingston 1963 Geol. Surv. Prof. Pub. 440 G, p 40. 10 kg water/sec containing 1 millimole/kg HCO₃⁻.
2. Assume average CaCO₃ sedimentation rate of 5×10^{-4} gm/cm² yr.
3. Assume 2000 year residence time in deep ocean $\Delta\text{CO}_2 = 0.3$ millimoles/kg, $\Delta\text{alk} = .12$ meg/kg.
4. Fifty g C/m² year are fixed by photosynthesis, 7% gets below 100 m, or 1.5 mg C/kg are lost during 2000 year transit in deep.
5. R. Révelle, H. E. Seuss, 1957 Tellus IX, p 19. UN forecast decade 1960-69.
6. Assume all carbon not in rocks liberated at uniform rate over 10⁹ years.

Since the rates of exchange between the shallow and the deep ocean are an order of magnitude greater than the rates of net gain or loss, the ocean will be approximately in steady state. Assuming a turnover time of 2000 years, disturbances in alkalinity will decay with time constant of about 50 years, while variations in CO_2 will decay with a time constant of about 350 years. The longer time required for the decay of the CO_2 disturbance is the result of the exchange of CO_2 between the surface of the ocean and the atmosphere. The above considerations were valid only before the industrial revolution. At the present time we are adding CO_2 to the atmosphere-ocean system at a rate comparable to the rate of exchange between the surface and the deep ocean.

We must also investigate how the surface of the earth responds to changes in the total alkali and CO_2 content in the atmosphere ocean system. The weathering of carbonate and non-carbonate rocks on land, the removal of CO_2 and alkalinity from the ocean by carbonate precipitation, and the inclusion of alkalinity in silicate sediments are the important mechanisms. Table 2 is a correlation chart showing the interrelationships between the chemistry of the sea, climatic factors, and rates of change in the atmosphere-ocean system. A plus sign indicates positive correlation. For example, a high partial pressure of CO_2 in the atmosphere leads to a high rate of carbonate and non carbonate weathering. A minus sign implies a negative correlation. For example, a high sea level will lead to a low rate of carbonate weathering because shallow carbonate areas are covered by sea water, and because the gradients near the coast are small. Primary correlations are in large symbols; secondary correlations are in small symbols. The rate of sea level change is correlated to sea level in a clockwise circular way. The rate of rise is zero at high and low sea level stands, and is a maximum in the transition from low to high sea level.

It can be seen that the rates of change in ocean chemistry have primary and secondary correlations of opposite signs. For example, carbonate weathering is increased by increases in CO_2 concentration and decreased by higher temperature and higher sea level. The high CO_2 pressure in the atmosphere however would lead to a higher temperature and a higher sea level stand. To ascertain the net effect on the rate of carbonate weathering, it is, therefore, necessary to have an estimate of the actual primary relationships.

TABLE 2

CORRELATION CHART

	pH	CO ₂ concentration	CO ₃ ⁼ concentration	Temperature	Sea Level	Rates of sea level rise
pH	+	-	+	-	-	↷
CO ₂ Concentration	-	+	-	+	+	↷
CO ₃ ⁼ Concentration	+	-	+	-	-	↷
Temperature	-	+	-	+	+	↷
Sea Level	-	+	-	+	+	⊙
Rate of Sea Level Rise	↷	↷	↷	↷	⊙	+
Rate of Carbonate Weathering		+		+	+	
Rate of Non-carbonate Weathering		+		+	+	
Rate of Carbonate Precipitation			+	+	+	
Rate of Non-carbonate Alkalinity Removal	+			+		-

Physical Chemistry of Sea Water - Weyl, Connors, Duedall

The partial equivalent volumes of sodium chloride in pure water and some salts in sea water have been measured. The results agree with data by others and are internally consistent. The data obtained to date are shown in the following table.

The partial equivalent volume of Sodium Chloride:

$$V = A + B \quad C \text{ ml/equiv.}$$

	A	B	t°C
Our Results	12.78 \pm 0.06	19.4 \pm .8	0.80
Zen (1)	13.1	19.08	0°
Others	12.36 - 13.45		0°

The partial equivalent volumes in ml/eq of some salts in artificial sea water S = 30.13°/oo at 0.80°C.

	Na ⁺	K ⁺	K ⁺ - Na ⁺
1/2 SO ₄ ⁼	6.72 \pm 0.06	17.60 \pm 0.12	10.88 \pm 0.18
Cl ⁻	16.04 \pm 0.11	26.63 \pm 0.08	10.59 \pm 0.19
Cl ⁻ - 1/2 SO ₄ ⁼	9.32 \pm 0.17	9.03 \pm 0.20	

(1) E-an Zen, Geochim, et Cosmochim. Acta. 12, 103 (1957)

Measurements of the partial equivalent conductance of salts in sea water have been started with a transformer ratio bridge. Difficulties were encountered in mixing sea water with salts in the laboratory. Due to evaporation, the conductance of the solutions would change by four parts in 10⁴ without any addition of salt. To overcome this problem, a special "wet chamber" was constructed in which the temperature is controlled and the humidity is maintained near saturation. All solutions are mixed in this chamber, and the prepared solutions

are covered by a layer of oil before they are returned to the laboratory. In this way it is possible to keep the conductance of the solutions constant to four parts in 10^5 . The partial equivalent conductances of sodium chloride in sea water of 34.430 ‰ salinity at 25.0°C was found to be $79.6(4) \pm 0.77 \text{ cm}^2/\text{eq ohms}$.

Chemical Reactions in Sea Water - Pytkowicz, Kester

Equipment for potentiometric titrations, utilizing a vibrating reed electrometer, has been installed and is being tested. This equipment will be used for the determination of the dissociation constants of weak acids in sea water.

Antarctic Oceanography - Pytkowicz

R. M. Pytkowicz participated in Cruise 14 of the USNS Eltanin, and collaborated with the physical oceanography group of the Lamont Geological Observatory in studies of Antarctic oceanography.

Oxygen-phosphate relations were used to locate accurately a southward flowing branch of the Antarctic Intermediate Water, and a method was developed to study the composition and mixing rates in Antarctic waters.

The specific phosphate (inorganic phosphate/salinity) of young ice was determined and found to be 30-37% of the value for average surface sea water. This suggests that Antarctic Bottom Water, formed during freezing, may be enriched in phosphate. Sea ice samples were also collected for the determination of the specific alkalinity.

The calcium carbonate saturation at in situ pressures was estimated for the 160°W section. The waters were found to be supersaturated down to 500-1000 meters, and undersaturated at greater depths. The supersaturation of the surface layers decreased to the south due to lower temperatures and to the increase in carbon dioxide content as the oxygen minimum layer rises towards the surface.

Sea water samples were collected for the determination of horizontal specific alkalinity gradients. These samples will be used to extend the results from Cruise 3.

Removal of Alkalinity from Sea Water by Clays - Deffeyes, Weyl

A study has been initiated on the input and output of alkalinity to the oceans through silicate weathering and through the marine precipitation and alteration of silicates. A recalculation of several hundred published analyses of rocks, minerals, and weathering products showed that marine sediments have a wide range of "alkalinity" content. Some sedimentary products, such as kaolinite, represent complete liberation of the alkali and alkaline earth oxides which tend to increase the alkalinity of sea water. Other sedimentary minerals such as chlorite, vermiculite, and saponite, contain more alkali and alkaline earth oxides than the rocks from which they came. Therefore, the circumstances which determine the sedimentary minerals can either increase or decrease the alkalinity of the oceans.

The largest silicate flux in the oceanic chemical system is the weathering, transport, and sedimentation of clay minerals. During the summer of 1964 some preliminary experiments were made on the uptake of alkalinity from sea water by typical soil clays from western Oregon. The clays were stirred in sea water and NaOH was added from a burette to maintain constant pH. Roughly one milliequivalent of base per gram of soil was necessary to hold the pH constant over the first few days. A preliminary X-ray diffraction examination of the clays after the treatment showed that the alkalinity was probably taken up as $\text{Mg}(\text{OH})_2$ layers between the clay silicate sheets, producing a chlorite-like structure.

Because of these encouraging results, a more detailed investigation of alkalinity adsorption by clays will be made. In addition, an attempt has been initiated to demonstrate the adsorption of alkalinity by clay minerals in the plume of the Columbia River.

MARINE RADIOCHEMISTRY AND RADIOECOLOGY

Instrumentation - Osterberg

Two additional ND-130AT gamma ray spectrometers were received and placed into operation. AEC funds provided one unit complete with oscilloscope, punch tape reader and readout, power supply, typewriter, and a 5x5-inch NaI(Tl) crystal detector (with well). This new unit and another one with similar specifications are mounted in a large console and read out through a common Tally tape punch, IBM typewriter, and Houston X-Y recorder, by means of switching network (Figure 1). These two spectrometers are used for AEC research.

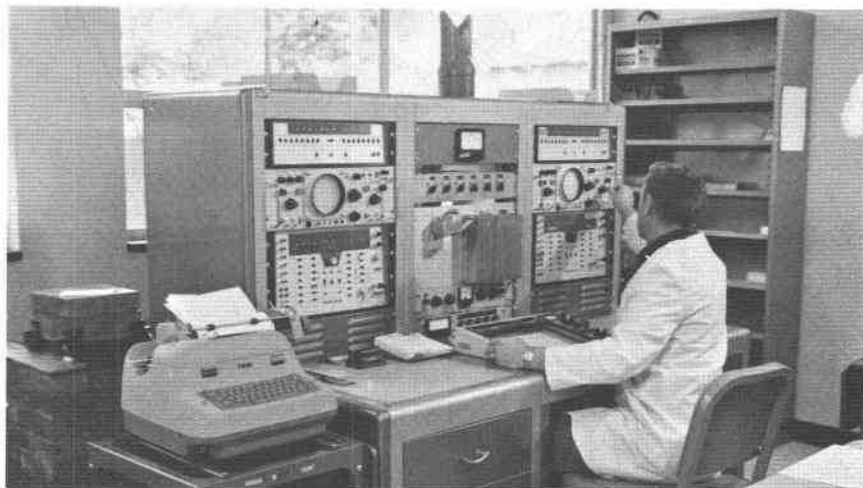


Figure 1. Gamma-ray spectrometer

The second new analyzer, which includes somewhat less readout equipment and a 3x5-inch solid crystal detector, was provided by a USPHS training grant. This instrument is mounted in a portable unit for use both in the laboratory and in the field. In the latter case, it is combined with a 3x3-inch NaI(Tl) crystal in an in situ sediment probe. A special 2x4-1/2-inch crystal has been ordered to follow the diffusion of Cr^{51} in sea water off the mouth of the Columbia River. Graduate students receive first priority in the use of this instrument.

A new least squares spectrum analysis program has been developed for the IBM 1410 computer. A type-to-card converter is on order to facilitate data reduction.

Nekton - Percy, Osterberg, Wyandt, Larsen, Dickson

Zinc-65 activity has been determined on 50 samples of mixed species composition. These represent animals collected by midwater trawling during both day and night periods at a single station over the outer continental slope. In addition, 13 one-meter net samples and 29 single species samples, representing common fishes, squids, crustacea, and other macroplankton, have been radioanalyzed for gamma emitters. The Zn^{65} activity per gram of the midwater trawl sample shows a decrease with depth. Seasonal variations, with peak activity in the summer months, are only apparent in the upper 500 m. Examination of tissues from a fin whale captured off Oregon indicate that marine mammals have about the same levels of Zn^{65} as small fish.

Livers from albacore tuna collected over the past three years have also been analyzed. Those collected off San Diego appear to contain almost as much Zn^{65} and perhaps more Mn^{54} than those found near the Columbia River.

Benthos - Carey, Osterberg, Larsen, Hancock, Dickson

One hundred twenty-six samples have been analyzed for gamma emitters. These samples include 15 sediment samples and 25 species of benthic invertebrates from a variety of habitats from 50 to 2800 meters. Most of the short half-lived fission products have disappeared from these benthic samples. Sea cucumbers from 2800 meters now show peaks due to Mn^{54} , Cs^{137} , Ce^{144} , and what appears to be Sb^{125} . Zinc-65 is not apparent in deeper organisms, although it is generally present in all animals from depths down to 1500 meters.

Distinct differences in spectra of different classes of animals are becoming apparent. For example, starfish are generally lowest in radioactivity, usually containing only a trace of Zn^{65} . Sea cucumbers contain the most radioactivity of all animals that were examined.

An interesting anomaly is a sea anemone from 2100 meters. Its spectrum most nearly resembles that of high grade uranium ore. This phenomenon is the subject of further investigation.

In general, spectra of benthic animals do not resemble the spectra of the mud in which they live. Bi^{214} and K^{40} are generally much higher in the sediments.

In Situ Probe Studies - Jennings, Osterberg, Fredrick

The gamma ray probe used to measure radioactivity in the water was modified for use as an in situ sediment probe (Fig. 2). Depth to which the probe can be operated is limited to 180 feet, the cable length. Thus, all areas of the estuary can be reached with the probe. Generally, a small (28-32 feet) fishing boat is chartered, a portable generator is used to power the spectrometer, and spectral data are recorded on punch tape. The tape is then used in the laboratory to drive an X-Y recorder (after log to linear conversion in the spectrometer). Graphical techniques provide relative values of the several gamma emitters present. Ten minute counting times are used. Zn^{65} , Cr^{51} , K^{40} , Mn^{54} , and Co^{60} are the isotopes most commonly observed.

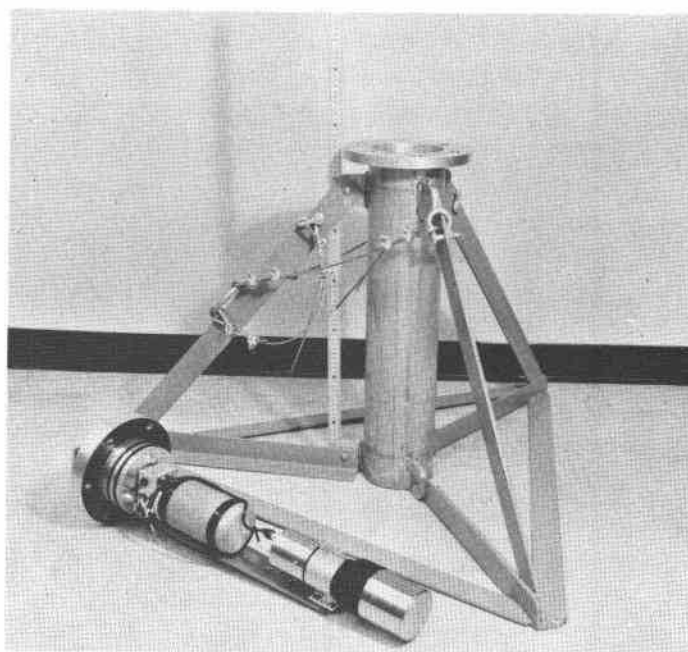


Figure 2. In situ sediment probe

Dissolved Organics - Cronin, Johnson, Cutshall, Osterberg

Petroleum ether was used to extract dissolved organics from 520 gallons of Columbia River water collected at Astoria. The water was filtered and extracted in 50 gallon lots using 12 gallons of ether per lot. The ether was distilled and used a number of times. Final volume of the distillate was about two quarts. Sub-samples show that this dark brown liquid contains fatty acids. Portions of the extract were labeled with radioactivity from the Hanford reactors, indicating the ability of the organics to complex with certain radionuclides.

Geochemistry - Cutshall, Johnson, Osterberg

Freshly collected sediments were eluted in the field, and the elutants returned to the laboratory for analysis. Suspended particulates were filtered from river water and processed in the same way.

Cutshall received a summer fellowship from the AEC to pursue his research at Hanford Laboratories. His studies of the electro-dialysis of sediments to remove gamma emitters will be incorporated into his thesis research.

Estuarine Collections - Haertel, Heimermann, Cross, Larsen, Osterberg

Monthly collections from three stations in the Columbia River estuary have been continued. One sampling site is in quite salty water off Chinook Point (6.5 nautical miles upstream); another is in essentially fresh water off Harrington Point (19.5 nautical miles upstream); and the third is in intermediate water off Astoria (13 nautical miles upstream). Several interesting observations have been made. A "hot particle" similar to that reported by Cutshall and Osterberg (1964) was observed. However, this particle was removed from the digestive tract of a fish (sucker). A concentration of scandium-46 in a small copepod (*Eurytemora hirundoites*) was also noted. This radionuclide had not been previously reported in animals. Chromium-51 was quite prominent in the spectrum of an amphipod taken in a 22-foot otter trawl.

Stable Trace Element Analysis - Cronin, Johnson, Osterberg

Stable trace element levels in several samples were determined by two techniques: (1) Atomic absorption spectroscopy, using our new Perkin Elmer Model 303; (2) Neutron activation, using the "swimming pool" reactor and associated gamma ray spectrometry facilities at Washington State University, Pullman, Washington. Atomic absorption spectrometry appeared the more favorable technique for the first series of transition elements (Co, Mn, Fe, Zn, etc.). Contamination is a major problem, however.

BIOLOGICAL OCEANOGRAPHY

Benthic Ecology and Systematics - Carey, McCauley, Alspach, Hancock

Three cruises were undertaken during this period, yielding 23 quantitative anchor dredge samples, 15 otter trawl, and 9 Smith-McIntyre bottom grab samples from stations on the shelf, slope and abyssal plain.

An opening-closing device has been developed to minimize washing of the sample at the deeper stations. It is now undergoing testing and evaluation. Gear is under development for quantifying the collection by trawls of the larger epibenthos. Odometers and a beam trawl will be added to the program.

Laboratory analyses of the collections continue. Polychaete worms, gammarid amphipods, echinoids, holothurians, scaphopods, and amphineurans are reaching the final stages of description and identification. At least 15 species of amphipods and one amphineuran species new to science have been collected. Distribution of 80 species of polychaetes, 30 species of gammarid amphipods, and 8 species of echinoids show similar trends on the shelf, slope, and abyssal plain. Sampling data, including numbers of species and abundance, are being compiled. On the average, five samples from one station are necessary for sampling most of the species present.

Animal Sediment Relationships - Carey, Hancock

Analyses of organic carbon and particle size of the sediment have been completed for all quantitative anchor dredge samples to date. These data are being processed, and correlations with the faunal distributions and abundance will be evaluated. Organic carbon content of the sediment is most closely associated with the clay fraction. Both are lower on the inner shelf and highest in the valley on the upper slope. The organic carbon is slightly higher on the plain than in the outer shelf sediments. Abundance of infauna, e. g. , polychaetes, increases with the increase in clay and organic content.

Polychaete Distribution in Yaquina Bay - Morrison, Carey

A study of the polychaete worm distribution in the lower part of Yaquina Bay was undertaken in July 1964. The samples were taken with a Smith-McIntyre grab sampler. Seventy-one samples have been

taken at five different stations in the bay. Also four samples have been taken from a station approximately 1.5 miles offshore.

The main interest, at present, is in the distribution of two species of Nephthys, and the relation of this distribution to various physical-chemical factors.

Plankton Inventories at Yaquina Bay - Frolander

The weekly sampling program has been continued. Quantitative and qualitative net tows were taken, and observations of temperature, salinity and dissolved oxygen were made at both the surface and the bottom.

A special 36-hour survey was made in July to sample summer conditions in Yaquina Bay. Zooplankton were collected hourly and physical parameters were observed every half hour at each of two stations in the bay.

Samples collected in the weekly sampling program and in the special survey continue to be analyzed both volumetrically, by vacuum displacement, and by counting techniques. Data ledgers have been kept up to date, and analyses of data have been underway. A computer program has been designed to perform routine calculations of zooplankton counts. This program will soon be put into operation.

Many technical graphs have been plotted during this period using data from both the weekly sampling program and the special surveys. These plots provide graphic information on the populations present in the bay and the processes which affect them.

Oceanic Trematode Studies - McCauley, Eagle

During the six month period April 1964 through September 1964 an additional 42 fish were examined for their parasites. Both digenetic and monogenetic trematodes have been collected from fish as deep as 2850 meters. A total of seven species of trematodes have been identified as established species, and another ten species are believed to be new. Species descriptions are in preparation for these.

Hydroid Ecology - McCormick, McCauley

Hydroids from offshore Oregon have been studied to determine species distribution, bathymetric relationships, and interspecific relationships. Further taxonomic work has been done on the hydroids collected. A total of twenty-six species of hydroids have been found. Twenty-five species were identified to genus (one tentatively), and seventeen of these were identified to species. Four species were epizoic on mollusks. Bathymetric ranges were extended for eight species, and eastern Pacific ranges were extended northward or southward for four. This is the first report from Oregon or off the Oregon coast for twelve species.

Energy and Element Transfer in the Lower Marine Food Web - Small, Curl

A technique using Zn^{65} has been tested for prediction of instantaneous assimilation rates of Calanus finmarchicus IV. The results agree with those obtained by the classical method of measuring ingestion and egestion rates and obtaining assimilation (energy flow) by the difference. The method needs to be tested against a second classical method whereby growth and respiration are summed to give assimilation. Also, it needs to be tested over varying environmental conditions, and for different grazing animals. Euphausia pacifica is now being used to see if the assimilation techniques can be employed with a somewhat larger crustacean.

Phytoplankton Ecology - Curl, Small, Hardy

In situ productivity studies continue at NH-25, though operations were suspended while the R/V YAQUINA was being readied for operation at sea. Species identification and isolation of new species for culture continue in the laboratory. Analyses of three years' data are to begin shortly.

Marine Microbiology - Morita

Current investigations deal with the basic nature of psychrophilic bacteria and the response of psychrophilic bacteria to various temperatures. At temperatures above the maximum growth temperature (20°C) of Vibrio marinus amino acids leak out the cells. Presumably

this reflects the leakage of amino acids from the amino acid pool. Hence, it contributes to the reason the cells cannot withstand moderate temperatures of 20 to 30°C.

Other studies also indicate that malic dehydrogenase (an essential enzyme of the TCA cycle) also leaks out of the cells exposed to moderate temperature.

Investigations have now begun on the effect of low temperature and hydrostatic pressure on deamination reactions by cells of Vibrio marinus.

Distribution and Ecology of Oceanic Animals - Pearcy, Hebard, Hubbard
Forss, VanArsdale

Studies of the seasonal and geographic distribution of oceanic animals in relation to their environment have been extended by the addition of 35 more collections with the Isaacs-Kidd Midwater Trawl and 24 meter net collections during the past quarter. Previous collections along the three latitudinal series of hydrographic stations are in the final stages of analyses: the copepods are identified to genus; species identification of euphausiids are nearly complete; salps, shrimps, cephalopods and fishes are all identified, except for the most recent collections. Manuscripts dealing with the distribution and occurrence of these groups are in preparation.

An IBM program has been initiated which will permit calculations of the relative abundance of the various taxa from the subsamples examined.

Vertical Distribution and Migration Studies - Pearcy, Renshaw,
Laurs, Forss

A total of 87 samples, made with opening-closing meter nets or a cod-end device on the midwater trawl, were obtained at various depth intervals within the upper 1500 m during daylight and darkness as a continuation of our study of the depth distribution of oceanic animals. Catches of common species of mesopelagic fishes per unit surface area have been calculated, and evidence for vertical migration and avoidance has been evaluated. Analyses of the vertical distribution of chaetognaths, mysids, shrimps, and cephalopods are in progress. Preliminary examinations indicate migration of some species and a general decrease in biomass with depth.

Effects of Upwelling in the Biomass of Trophic Levels - Laurs, Percy

Laboratory analysis of midwater trawl and one-meter net plankton samples has continued through out this period. The fishes, squids and larger macroplankton have been sorted from 74 midwater trawl and 72 plankton net samples. These samples have also been subdivided to an appropriate size for the removal of small macroplanktonic forms.

Species identification of fishes from midwater trawl samples is in progress. Salps, euphausiids, and copepods will also be identified from these collections.

EDUCATIONAL PROGRAM

Summer Program in Oceanography - Lane, Fowler, McCauley

A six-week program in oceanography, principally designed for high school science teachers, was offered by the department during summer school. The program consisted of the following courses:

- Oc 432 Physical Oceanography. Physical processes in ocean and estuaries; some field work.
- Oc 501 Research (Field Work in Oceanography) Methods and procedures for data collected at sea. Five days will be spent at Newport and aboard the R/V ACONA.
- Oc 441 Biological Oceanography. Physical, chemical and biological factors characterizing marine environment; factors controlling plant and animal populations; methods of sampling, identification and analysis.
- Oc 561 Geological Oceanography. Sedimentation, bottom topography, erosion, shorelines and physics; sampling and analysis of marine sediments.

Field work consisted of orientation of instruments used in oceanography, a time series study in Yaquina Bay, and a half-day cruise on the ACONA, in addition to some visits to various beaches.

Seventeen students took part in the program. The Link Foundation provided full tuition fellowships for three of these students, as well as defraying some of the costs of the field work. Two of the three students who received fellowships and several other students who took part in the program have decided to continue their studies in oceanography.

Students Receiving Degrees

During the past year one Doctor of Philosophy degree and ten Master's degrees have been granted by the department. The following students were awarded these degrees.

Jackson O. Blanton. M.S. Physical Oceanography (Pattullo)
Thesis: Energy Dissipation in a Tidal Estuary

Curtis Collins. M.S. Physical Oceanography (Pattullo)
Thesis: Structure and Kinematics of the Permanent Oceanic Front
off the Oregon Coast

Ford A. Cross. M.S. Biological Oceanography (Small)
Thesis: Seasonal and Geographical Distribution of Pelagic Copepods
in Oregon Coastal Waters

Earl W. Davey. M.S. Biological Oceanography (Curl)
Thesis: The Enzymatic Measurement of Primary Production

Adrian Matson. M.A. Chemical Oceanography (Park)
Thesis: Dissolved Silicate in Waters off Oregon and in Four
Adjacent Rivers

William B. North. M.S. Geological Oceanography (Byrne)
Thesis: Coastal Landslides in Northern Oregon

Verrill J. Rinehart. M.S. Geophysics (Dehlinger)
Thesis: Investigation of Twelve Earthquakes off the Oregon and
Northern California Coasts

Howard J. Russell. M.S. Biological Oceanography (Frolander)
Thesis: The Endemic Zooplankton Population as a Food Supply for
Young Herring in Yaquina Bay

Robert L. Smith. Ph.D. Physical Oceanography (Burt)
Thesis: An Investigation of Upwelling Along the Oregon Coast

Sargun Tont. M.S. Biological Oceanography (Pearcy)
Thesis: The Bone Structure of Some Marine Vertebrates

James H. Whitcomb. M.S. Geophysics (Berg)
Thesis: Seismic, Gravity, and Magnetic Survey of the Marine
Geophysical Range, Newport, Oregon

Of the ten students receiving Master's degrees, five are currently engaged in a Ph.D. program, either in this department or at other universities. Dr. Smith is continuing as a member of the staff in Physical Oceanography.

TIME AT SEA

APR	MAY	JUNE	JULY	AUG.	SEPT.
Geology 3		Drogue 2 Phyto	Phyto 2	Nekton	
	Geophysics			Phyto Geology 2	
Phyto 2	Geophysics 3		Geophysics 4	Buoy 1	
Hydro 14		Nekton 5	Buoy 1	Benthos 6	
	Geology 4		Hydro 6		
		Benthos 5	Students 1	Geophysics 5	
	Benthos 5		Hydro 6		
		Geology 5		Geology 4	
Nekton 6	Nekton 2		Buoy 1		
	Drogue 3	Phyto	Nekton 4		
25	18	19	25	19	0

R/V ACONA

TOTAL DAYS AT SEA : 106

1 APRIL 1964 TO 30 SEPTEMBER 1964

FACILITIES

Research Vessel ACONA

The ACONA spent 106 days at sea during this six-month report period. Data were collected for research in all phases of oceanography. Five geology cruises, two hydrographic surveys, four geophysics cruises, one dredge cruise, and several biological studies of benthos, nekton, and phytoplankton were completed. OSMIP-I, an anchored data-collecting buoy, was also placed 13 miles at sea off Newport, Oregon, in 49 fathoms of water and was tended several times by the ACONA.

In September the ACONA was transferred to the University of Alaska to help in the development of their oceanography program.

Research Vessel YAQUINA

R/V YAQUINA was commissioned on 28 September 1964, in Portland. Dr. Richard Bader, National Science Foundation, presented the vessel; Governor Mark Hatfield accepted for the State of Oregon. The vessel will commence operation in October. Her three large



oceanographic winches, eight modern laboratories, and improved sea-keeping qualities add significantly to the research capabilities of the Department of Oceanography. YAQUINA is 180 feet long, 666 gross measurement tons (800 displacement tons), speed 12 knots, 6,500 nautical mile cruising radius, and has quarters and lifesaving gear for a total of 40 persons.

Oceanography Building

The building has been completed and is now occupied by the entire staff. Formal dedication and open house have been scheduled for 5 November 1964.



Coastal Marine Science Laboratory

The Oregon State Highway Commission has completed work on the underpass and access roads leading to the laboratory and dock area. Construction on the main laboratory building is continuing and is expected to be completed in early December.

NEW STAFF

Captain ELLIS B. RITTENHOUSE, USN (Ret.) joined the department staff in July as Associate Professor of Oceanography. In his capacity as Marine Superintendent, he supervises the marine operations of the department. He holds a bachelor of science degree from the U. S. Naval Academy and a Master's degree in Business Administration from Ohio State University.

Captain Rittenhouse brings 30 years of experience as a Naval officer to the department, from graduation from the U. S. Naval Academy in 1934 to his retirement as Captain, U. S. Navy, in 1964. His naval duties included command of PT boats, destroyers, a destroyer division, an amphibious command ship, and an amphibious squadron.

Dr. KENNETH S. DEFFEYES, has been working with Dr. Weyl during the summer and will join our staff permanently in December. Dr. Deffeyes comes to us from the University of Minnesota where he was an associate professor of geology. As an undergraduate Deffeyes majored in geological engineering at Colorado School of Mines, and at graduation in 1953 he received the Coolbaugh Prize for undergraduate work in chemistry. Master's and doctoral theses, done under F. B. Van Houten at Princeton, were on the mineralogy of sediments deposited in alkaline lakes in Nevada. The Ph. D. was received in 1958.

His research collaboration with Dr. Weyl began when both men were employed at Shell Development Company of Houston, Texas. Their primary interest is in processes which determine the stability of ocean chemistry.

Dr. GUNNAR BODVARSSON, a visiting professor at Oregon State University from Iceland, will do part-time research and teaching in geophysics for the year 1964-65. He is a theoretical geophysicist, specializing in geothermal measurements, and will participate in theoretical and geothermal studies. He is teaching a seminar on mathematical problems in geophysics.

VISITING SCIENTISTS

- April 18, 1964 Dr. Hans-Eric Reineck, Senckenberg Institute, Wilhelmshaven, Germany. "Layered Sediments of Tidal Flats, Beaches, and Shelf Bottoms"
- June 9, 1964 Dr. Edward Purcy, Associate Professor of Geology, Rice University, Houston, Texas. "Carbonate Deposits off British Guiana"
- June 26, 1964 Dr. Katsuko Saruhashi, Meteorological Research Institute, Tokyo, Japan. "Strontium-90 and Cesium-137 in the Marine Environment"
- July 1, 1964 Dr. Mary Belle Allen, Kaiser Foundation Research Institute, Laboratory of Comparative Biology.
- July 2, 1964 Dr. Franklin Sogandares-Bernal, Department of Zoology, Tulane University, New Orleans, Louisiana.
- September 18, 1964 Dr. Joel W. Hedgpeth, University of Pacific Marine Station, Dillon Beach, California.

PUBLICATIONS AND PAPERS

Publications

- Berg, J. W., R. Gaskell, and V. J. Rinehart. Earthquake energy release and isostasy. *Bull. Seismol. Soc. Am.* 54(2): 777-784 (1964)
- Berg, J. W., and G. E. Papageorge. Elastic displacement of primary waves from explosive sources. *Bull. Seismol. Soc. Am.* 54(3): 947-959 (1964)
- Berg, J. W., Lynn D. Trembly, and Phillip R. Laun. Primary ground displacements and seismic energy near the Gnome explosion. *Bull. Seis. Soc. Am.* 54(4): 1115-1126 (1964)
- Burt, Wayne V. Education looks to the sea. *Undersea Technology.* 5(7): 16 (1964)
- Byrne, J. V. An erosional classification for the northern Oregon coast. *Annals of the Association of American Geographers.* 54: 329-335 (1964)
- Byrne, J. V. Review of "Marine Geology of the Pacific" by H. W. Menard. *Geotimes* 9(2): 23-24 (1964)
- Byrne, J. V. The oceans: a neglected mining frontier. *The Ore Bin.* 26(4): 57-59 (1964)
- Collwell, R. R., and Morita, R. Y. Reisolation and emendation of description of Vibrio marinus (Russell) ford. *J. Bacteriol.* 88: 831-837 (1964)
- Cook, K. L., M. O. Halverson, J. C. Stepp, and J. W. Berg, Jr. Regional gravity survey of the northern Great Salt Lake Desert, and adjacent areas in Utah, Nevada and Idaho, *Bull. Geol. Soc. Am.* 75(8): 715-740 (1964)
- Cutshall, Norman and Charles Osterberg. Radioactive particle in sediment from the Columbia River. *Science.* 144(3618): 536-537 (1964)
- Eagle, Rodney J., and James E. McCauley. Collection of helminths from marine abyssal fishes. *J. Parasitol.* 50(3): 37 (1964) (abstract)

- Lane, Robert K. Estimating evaporation from insolation. Am. Soc. of Civil Engineers. 90(HY5): 33-41 (1964)
- Laurs, R. Michael and J. E. McCauley. A new acanthocephalan from the Pacific Saury. J. Parasitol. 50: 569-571 (1964)
- Maloney, N. J., and J. V. Byrne. Sedimentary rocks from the continental shelf and slope off the central coast of Oregon. The Ore Bin 26(5): 76-81 (1964)
- McCauley, James E. Gastropod larvae from the brood pouch of an arctic shrimp. Trans. American Micros. Soc. 83(3): 290-293 (1964)
- Osterberg, C., J. Pattullo and W. Percy. Zinc-65 in euphausiids as related to Columbia River water off the Oregon coast. Limnology and Oceanography. 9(2): 249-257 (1964)
- Osterberg, C., W. Percy, and H. Curl. Radioactivity and its relationship to the oceanic food chain. J. Mar. Res. 22(1): 1-12 (1964)
- Park, Kilho. Electrolytic conductance of sea water: effect of calcium carbonate dissolution. Science. 146(3640): 56-57 (1964)
- Park, Kilho, G. H. Kennedy, and H. H. Dobson. Comparison of gas chromatographic method and pH-alkalinity method for determination of total carbon dioxide in sea water. Anal. Chem. 36: 1686 (1964)
- Pytkowicz, R. M. Oxygen exchange rates off the Oregon coast. Deep-Sea Res. 2: 281-289 (1964)
- Slabaugh, W. H., and A. D. Stump. Surface areas from the V/n ratio for marine sediments. J. Physical Chemistry. 68(1251) (1964)
- Weyl, Peter K. The solution alteration of carbonate sediments and skeletons. Approaches to Paleoecology. p. 345-356 (1964)

Data Reports

Collver, M. M. and Peter Dehlinger, Oregon State University
seismological bulletin No. 1 (July 1 to September 30, 1963)
Data Report No. 14 9 pp. Department of Oceanography
Oregon State University, Corvallis Oregon.

Collver, M. M. , and Peter Dehlinger. Oregon State University
seismological bulletin No. 2 (October 1 to December 31,
1963) Data Report No. 16, 4 pp. Department of Oceanography,
Oregon State University, Corvallis, Oregon.

Schatz, C. E. , and Peter Dehlinger. Oregon State University
seismological bulletin No. 3 (January 1 to March 31, 1964)
Data Report No. 17 Department of Oceanography, Oregon
State University, Corvallis, Oregon (In press)

Papers Submitted

Blanton, Jackson O. and W. Bruce McAlister. Energy dissipation
in a tidal estuary. American Society of Civil Engineers

Burton, S. D. , and R. Y. Morita. The influence of catalase and
cultural conditions on Beggiatoa. J. Bacteriology

Burton, S. D. and R. Y. Morita. Utilization of acetate by Beggiatoa.
J. Bacteriology

Cook, K. L. , J. W. Berg, Jr. , and Daniel Lum. Seismic and
gravity profile across the Northern Wasatch trench, Utah.
Society of Exploration Geophysicists, Refraction Volume
(Special Issue)

Curl, Herbert, Norman Cutshall and Charles Osterberg. Uptake of
Cr(III) by particles in sea water. Nature

Dehlinger, Peter. Reliability at sea of gimbal-suspended gravity
meters with 0.7 critically damped accelerometers. Journal
Geophysical Research

Frolander, Biological and chemical features of tidal estuaries.
Water Pollution Control Federation Journal

Mathemeier, P. F. , and R. Y. Morita. The influence of substrate-
cofactor ratios on partially purified inorganic pyrophosphatase
at elevated temperature. Journal Bacteriology

Morita, R. Y., and P. F. Mathemeier. Temperature-hydrostatic pressure studies on partially purified inorganic pyrophosphatase. *Journal Bacteriology*

Morita, R. Y. Effect of hydrostatic pressure (section b of chapter 13 "The physical environment for fungal growth. Vol. 1 Treatise "The Fungi" Academic Press, Inc.

Moriyasu, Shigeo. On the influence of river discharge on upwelling. *Journal of Marine Research*

Odegard, M. E., and J. W. Berg, Jr. Gravity interpretation using the Fourier integral. *Geophysics*

Park, Kilho. Partial equivalent conductance of electrolytes in sea water. *Deep-Sea Research*

Park, Kilho and Magdalena Catalfomo. Gas chromatographic determination of dissolved oxygen in sea water using aargon as a carrier gas. *Deep-Sea Research*

Pattullo, June and Warren Denner. Processes affecting sea water characteristics along the Oregon coast. *Limnology and Oceanography*.

Pytkowicz, R. M. Calcium carbonate saturation in the ocean. *Limnology and Oceanography*

Pytkowicz, R. M. Rates of inorganic calcium carbonate nucleation. *Journal of Geology*

Renshaw, R. Ward, and William G. Percy. A new cable clamp. *Deep-Sea Research*.

Schatz, Clifford and Herbert Curl, Jr., Tsunamis on the Oregon coast. *The Ore Bin*

Smith, Robert L., Robert K. Lane and June G. Pattullo. Analyses of offshore transport during upwelling off southern Oregon. *Limnology and Oceanography*

Weyl, Peter K., and Iver W. Duedall. An apparatus for determining the partial equivalent volumes of salts in aqueous solutions. *Review of Science Institute*

Weyl, Peter K. On the deep circulation in the Pacific Ocean *Limnology and Oceanography*

Papers Presented at Scientific Meetings

- Byrne, J. V. Exploration and mining on the ocean floor. Presented at the American Mining Congress. September 1964. Portland, Oregon
- Cutshall, Norman. Use of fallout radionuclides to determine runoff from rain. Presented at Oregon Student Conference. April 1964. Eugene, Oregon.
- Cutshall, Norman. Chromium-51 in the Columbia River and its environs. Presented at the American Society of Limnology and Oceanography. June 1964. Vancouver, British Columbia.
- Eagle, Rodney J., and James E. McCauley. Collection of Helminths from marine abyssal fishes. Presented at American Society of Parasitologists. August 1964. Boulder, Colorado.
- Johnson, Vernon. Exchangeable radionuclides in Columbia River sediments. Presented at Oregon Student Conference. April 1964. Eugene, Oregon.
- Kulm, L. D., and J. V. Byrne. Sediments of Yaquina Bay, Oregon. Presented at Conference on Estuaries April 1964. Jekyll Island, Georgia.
- Morita, R. Y., and L. J. Albright. Low temperature-hydrostatic pressure studies on the growth and morphology of Vibrio marinus, an obligate psychrophile. Presented at the American Society of Limnology and Oceanography. July 1964. Miami, Florida.
- Morita, R. Y. Microbiology of estuarine and nearshore water. Presented at Marine Disposal Engineering Training Program. U.S. Public Health Service. July 1964. Seattle, Washington.
- Osterberg, Charles. The implications of radioactive pollutants, present and future. Presented at Symposium on "Aspects of the not-so-exhaustible sea." American Society of Limnology and Oceanography. June 1964. Vancouver, British Columbia.
- Osterberg, Charles. The composition of sea water. Presented at Water Pollution Control Training Program, U.S. Public Health Service. July 1964. Seattle, Washington

Park, Kilho and H. H. Dobson. Gas chromatographic determination of dissolved oxygen in sea water using argon as a carrier gas. Presented at the Pacific Division, American Society of Limnology and Oceanography. June 1964.

Park, Kilho. Effects of dissolved gases and calcium carbonate dissolution on the electrical conductance of sea water. Presented at Japanese Oceanographical Society. September 1964. Sapporo, Japan.

Park, Kilho. Gas chromatographic determination of dissolved gases in sea water. Presented at Japanese Oceanographic Society. September 1964. Sapporo, Japan.

Pytkowicz, R. M., Calcium carbonate in the ocean. Presented at American Geophysical Union 45th annual meeting. April 1964. Washington, D. C.

Small, L. F. Energy transfer in lower marine trophic levels. Presented at American Institute of Biological Sciences. August 1964. Boulder, Colorado.