

Quarterly Progress Report, October–December 1953. Office of Naval Research Progress Report No. 30.

*Project NR 083–005
Contract N6ori-111(06)
(Geophysics Branch)*

*Project NR 083–068
Contract Nonr-233(04)
(Geophysics Branch)*

*Project NR 086–003
Contract Nonr-233(05)
(Field Projects Branch)*

*Project NR 087–029
Contract Nonr-233(17)
(Field Projects Branch)*

— ii —

— 1 —

Introduction

This report describes the results of unclassified research conducted during the quarter, October through December, 1953, at the Scripps Institution of Oceanography under contracts with the Earth Sciences Division, Office of Naval Research.

Two of these contracts (N6ori-111(06) and Nonr-233(04)) are with the Geophysics Branch, the other two (Nonr-233(05) and Nonr-233 (13)) with the Field Projects Branch.

Project NR 083–005, Contract N6ori-111(06)

Waves and Currents

Nearshore Temperature Fluctuations—Arthur, Blair

The temperature recorder at Oceanside Pier was removed early in November, but the recording from Scripps Pier thermistors will be continued. The Scripps recordings have been virtually

uninterrupted since the beginning in June 1953. Some interruptions have occurred in the Oceanside recording because of difficulties experienced with the recorder pen. Nevertheless, sufficient days of records have been accumulated to show that the sample plot of temperatures reproduced in the April-June Progress Report(SIO Ref. 53-52) is typical. Temperature "dips" occur frequently at both La Jolla and Oceanside during the summer and fall as shown on the sample.

An analysis of the data is in progress. In addition to the temperature records from the ends of the two piers, surveys of temperature along the Oceanside Pier and along ranges in the vicinity of Scripps Pier are being utilized.

Internal Waves in the Atmosphere of 5-10 Min. Period—Munk, F. Snodgrass

The time constants in the recording of wind speed and direction have been lengthened to make these recordings more suitable for the study of internal waves in the atmosphere of 5-10 min. period. The microbarograph has been made more sensitive and the filter changed from a low pass to a band pass type.

Long-Period Ocean Waves—F. Snodgrass, Munk, Blair

The equipment for measuring long-period ocean waves at sea is nearly complete. Tests are scheduled during the latter part of January and the first part of February. The purpose of these tests will be to study: (a) the relationship between long-period ocean waves and the depth of the water (between the depths of 20 to 500 ft), (b) the relationship between long-period ocean waves and aerological disturbances over the Pacific Ocean, (c) the relationship between long-period ocean waves and long-period atmospheric pressure fluctuations near shore.

— 2 —

Equipment to be used in this study and the status of its development is as follows:

(a) Near-shore long-period ocean wave recorder. A two-stage hydraulic-filter pressure head with a strain-gage transducer and a thermistor temperature compensator. The pressure head will be installed in shallow water at Scripps Pier or at Oceanside. The unit will be buried approximately 18 in. in the bottom by Aqua-lung divers to decrease the temperature fluctuations. A breather tube will extend through the sand into the water to pick up the pressure fluctuations of the long-period waves. This unit has been completed and has been tested at the end of Scripps Pier.

(b) Deep-water long-period wave recorder. The basic unit is a vibratron pressure transducer that measures total absolute pressure from 0 to 500 ft of water. Recording will be made with a digital printer that records the number of cycles in a ten-second period or by recording the beat frequency produced by comparing the gage frequency to a stable oscillator. This gage has been constructed and tested in the laboratory.

(c) Matched electrical filters. These are filters for the nearshore and the deep-water wave recorders to shape the frequency response curves. Filters for the nearshore recorder have been completed and tested; filters for the deep-water recorder are now being constructed.

(d) Orbital current meter. Anemometers built by the North American Instrument Company have been tested for sensitivity and stability and found to be satisfactory. An order has been placed for a two-component unit and the manufacturer is assembling a modified unit for use in sea water. These units will be suitable for recording orbital currents with velocities as low as one centimeter per second. The two-component unit will enable the determination of wave direction.

(e) Water temperature recorders. Water temperature will be recorded at the deep-water pressure head and 20 ft above the pressure head. Water temperature at the nearshore recorder will also be recorded. Standard thermistor recorders will be used and are now being constructed for the deep-water unit. Nearshore units are now in operation.

(f) Tsunami recorders located at Scripps Pier and at Oceanside, which have been in operation for several years, will also be used as a source of data.

Variations in Sea Level—Groves

The sea level analysis has been carried out for many new tide stations, and we now have three consecutive months of simultaneous "sea level" records for nearly every control tide station on the United States west coast. Also, simultaneous tide records were analyzed for some Channel Islands temporary stations and mainland stations. The results show that the coherence between adjacent stations

— 3 —

is of the order of a couple hundred miles both along the coast and perpendicular to the coast.

Continued efforts have been made to find a better weighted average for use in analyzing the tide gage data. A method based on a least squares technique has been concluded; the final results determined a weighted average which is inferior with respect to tidal elimination to the one presently being used. Another method has been devised which gives indications of being more successful, and some of the computations have been carried out.

Decompression Gage—Munk, Groves

A somewhat detailed report on the design considerations of a decompression gage has been completed and is being prepared for distribution by the Publications Division.

Measurement of the Roughness of the Sea Surface from Photographs of the Sun's Glitter. Part III: The Interpretation—Cox, Munk

This report is now being prepared as AF Technical Report No. 4. The abstract follows:

In this part we attempt to interpret the results given in Part II in terms of models having simple wave spectra. The observed nearly Gaussian distribution of slopes is inconsistent with a spectrum consisting of a few discrete frequencies but can be accounted for by a continuous spectrum of arbitrary width. The observations cannot, however, exclude an interpretation in terms of a large number of discrete frequencies. The observed skewness and peakedness are believed to be non-linear effects, and are not treated. The observed ratio between up/down- and crosswind slopes can be interpreted in terms of two wave "beams" intersecting at 70° , or a single wide beam subtending 130° . These values apply to the relatively short waves that contribute largely to the slope spectrum. The observed linear relation between mean square slope and wind speed follows, in form and to an order of magnitude, from a spectrum proposed by Neumann on the basis of wave amplitude observations. A spectrum proposed by Darbyshire cannot be reconciled with the observed slope distribution. Compared to Neumann's spectrum, Darbyshire's predicts far less high frequency energy, and it is this high frequency (but not capillary) energy which is decisive in the slope distribution. When Darbyshire's data are fitted to a spectrum of the Neumann type, the resulting mean square slope is in close agreement with our measured values. The mean period of the Neumann slope spectrum increases linearly with wind speed but is already 2.5 sec at a wind speed of 5 m sec^{-1} , and the capillary waves do not contribute heavily. The corresponding curvature spectrum, however, is largely concerned with capillary waves, and the rms curvature equals 0.07 cm^{-1} independent of wind speed. Measurements of curvature will provide a critical test of the Neumann spectrum at high frequencies. The observed reduction in mean square slope

— 4 —

by a slick may be accounted for by assuming that the slick forms an inextensible surface against which waves (Neumann spectrum) are dissipated by molecular viscosity. Some difficulties of this interpretation are stated. It is pointed out that the distribution of surface particle acceleration (in units of g) is closely related to the distribution of slopes. The total mean square acceleration increases linearly with wind speed and reaches a value of $(0.4g)^2$ at a wind speed of 14 m s^{-1} .

Submarine Geology

Submarine Canyon Depth Changes—Shepard

Between 30 November and 15 December a submarine slide took place in the Sumner Branch of Scripps Canyon and to a lesser extent in South Branch. This slide was first reported by Aqua-lung swimmers from Scripps Institution who had become familiar with the characteristics of the canyon head. They reported that the sand and kelp on the canyon floor lay some 20 ft below the portion of the walls that is covered with marine growth, suggesting that a slide had recently uncovered this area and perhaps produced some scouring. In no place had the entire fill been removed. On 28 December an echo-sounding survey of these canyon heads was made and changes were found in all of the lines along Sumner Branch and Intermediate Branch (see Shepard, *Amer. Geoph. Union*, Vol. 32, pp. 405–418). The maximum change was 9 ft, with a deepening from 23 to 32 ft. A maximum of 5 ft of change occurred in South Branch. It was impossible to check the changes of larger magnitude which were reported by the Aqua-lung swimmers because these were observed in the narrow gorge where echo sounding is impossible

owing to wall reflections. The interesting feature of this recent slide is that it was concentrated in a branch which has been moderately stable during previous slides which have centered in South Branch. Before the slide the Aqua-lung swimmers had been reporting that the heads of the rock gorges were being filled with sediment at a rapid rate. In order to check future slides in the gorges, some stakes have been driven into the wall which will allow measurements to the canyon floor.

A report by a fisherman that lobster traps had been displaced in the head of La Jolla Canyon with the buoys carried below sea level was checked by a survey of the ranges in this area. Here no soundings had been made since 12 May. During this interval all valleys showed a slight fill, the maximum found being 4 ft. Some of the shallow valleys had been completely obliterated by the deposition. Apparently the displacement of the lobster traps, if due to a slide, was a minor feature which did not compensate for the rather large fill which had taken place in the six-month interval.

Beach Ripples—Shepard

In the last report it was noted that backwash ripples on the beach had been very scarce near Scripps Institution. It was noted that with the retreat of the beach berm in the early fall, these

— 5 —

ripples became far more common. It is believed that this change is not the result of the larger waves but due to the decreasing slope of the beach resulting from the erosion of the berm. Confirmation of this idea has come recently from the development of a relatively steep section of the Scripps beach near the sea wall. Here backwash ripples have been virtually non-existent, whereas they are found in the gentler slopes of the beach exposed by low tide.

Marine Chemistry

Iron in Marine Waters—Lewis, Goldberg

The work has been completed and a paper has been prepared for submission to an oceanographic journal. The results give a value of about 10 micrograms/liter of iron in the deep oceanic waters with about half in a particulate phase and the remainder able to pass through a Goetz membrane filter.

Manganese in Marine Waters—Lewis, Goldberg

Values for the particulate manganese content have been determined for deep-sea waters (0.2 micrograms/liter). As with iron, the particulate manganese is defined as the manganese retained by a Goetz molecular filter. The analyses of soluble manganese have so far met with difficulties that are unresolved.

Phosphate in Marine Waters—Koide, Goldberg, Wooster

The analyses of total and inorganic phosphate made on Trans-Pacific Expedition are being compiled for publication.

Fluorometric Analyses—Lewis, Goldberg

Fluorometric analyses of certain elements in sea water (beryllium, aluminum, zirconium, titanium, etc) appear to be the most sensitive approach. The Beckman DU spectrophotometer is being converted to a fluorometric apparatus for such determinations. The unit (monochromator of the Beckman Instrument and an ultraviolet light source with the photomultiplier attachment as the pickup) has been assembled and tested. Present indications are that it will be satisfactory both as a laboratory and sea-going instrument.

Project NR 083–068, Contract Nonr-233 (04)

Observations Using Self-Contained Diving Gear—Scott, Murray, Short, Inman

The program of underwater observations by swimmers equipped with self-contained diving gear is being continued. The activities of this program are reported below.

— 6 —

a) Measurement of sand-level changes with reference rods.

Measurement of the change in sand level at five stations in the La Jolla area, which was initiated last spring, is being continued (Progress Report No. 29). The amount of cut or fill at each station is determined by comparing the length of rods which protrude above the bottom with their length on some previous occasion. As anticipated, changes in shallow water have been relatively great. Six reference rods which had been placed in the bottom at a point where the water depth was 18 ft below MLLW were lost. Their loss was observed on 23 November, 1954, following a period of high waves. It is estimated that the sand level at this point decreased by approximately 2 ft. However, changes in sand level at stations, where the depth is 30 ft or greater, have not exceeded 0.1 ft.

b) Observation of sand movement and ripple formation.

The observation and measurement of ripples have been extended to include two coarse sand areas, in water depths of 30 and 50 ft, where the median sand size is approximately 0.3 and 0.5 mm respectively. The observations at these stations are being made in addition to ripple measurement from the five reference rod stations described above. Inclusion of the coarse sand stations extends the range in sand size from approximately 0.1 to 0.5 mm and allows the evaluation of the effect of sand size on ripple parameters. In general, the ripple wave length ranges from about 0.2 ft where the median sand size is 0.1 mm, to about 3.0 ft where the sand

size is 0.5 mm. The heights of the ripples range from about 0.02 ft in the very fine sand to approximately 0.5 ft in the coarse sand.

The large size of the ripples in coarse sand permits direct observation of grain motion and selective sampling of sand from ripple crest and trough. In general, the sand from the ripple crest is slightly coarser, better sorted, and tends to be skewed more toward coarser particle sizes than sand from the adjacent ripple troughs.

c) Instrument development and fabrication.

A method of lithifying sand in situ on the bottom, using plastic resins, is being perfected. An improved case for underwater motion picture cameras is nearing completion.

Bottom Heat Flow Measurements—MAXWELL

Four separate papers, to be submitted to the Bulletin of the Geological Society of America for publication, are being prepared. These papers contain a full account of the work which was done on the Mid-Pacific Expedition, each paper covering a separate phase of the heat flow work. The tentative titles of the papers are:

— 7 —

- 1) A Probe for the Measurement of the Thermal Gradient in Deep-Sea Sediments—A. E. Maxwell, J. M. Snodgrass, J. D. Isaacs.
- 2) A Theoretical Analysis of the Deep-Sea Temperature Probe—E. C. Bullard, H. G. Ferris.
- 3) The Measurement of the Thermal Conductivity of Some Deep-Sea Sediments—D. W. Butler
- 4) Heat Flow Through the Sea Floor—R. R. Revelle, A. E. Maxwell.

In addition to Mid-Pacific work, thermal conductivity measurements were initiated on cores taken during the Capricorn Expedition at the nine stations where temperature gradients were measured in the bottom mud. Preliminary equipment designed for this purpose was tested and proved successful. Four cores were measured initially to determine if the heat flow values were similar to those obtained on the Mid-Pacific Expedition. These measurements gave conductivities consistent with those obtained by Butler using the divided bar method. However, differences in the thermal conductivity at different depths indicate that a more thorough examination of the conductivity as a function of depth is in order. These differences appear to be related to the stratification of the sediments, but additional measurements are needed to confirm this.

An evaluation of the transient needle method for measuring the thermal conductivity of deep-sea sediments was made by the Physics Division of the National Physical Laboratory, Teddington, England. They report, "It seems to be a method to which further attention should be given,

particularly as it appears likely to provide a relatively easy means for determining the thermal conductivity of insulating materials at low temperatures."

— 8 —

Project NR 086-003, Contract Nonr-233(05)

Trans-Pacific Expedition

On 30 November 1953 R/V SPENCER F. BAIRD returned to San Diego, bringing the expedition to a close. Departing from San Diego on 22 July 1953, the BAIRD steamed 14,884 miles in the North Pacific Ocean and deep Bering Sea ([see Track Chart, Fig. 1](#)). The major scientific program of the expedition was a study of the relationship between the major circulation features of the North Pacific, the distribution of physical and chemical properties, and the distribution of plankton and nekton.

The following scientific observations were made:

- 1) One hundred and thirty-two oceanographic stations were occupied, of which 55 were to depths of 1500–2000 m, 13 to depths of 2000–3000 m, 33 to depths of 3000–4000 m, and 10 to depths of greater than 4000 (the deepest was to 6300).
- 2) Five hundred and sixty-two bathythermograph observations were made using the 900-ft instrument.
- 3) Two hundred and thirteen geomagnetic electrokinetograph observations were made.
- 4) A three-hourly record of surface weather was kept. Surface temperature was recorded continuously on a thermograph.
- 5) Approximately 1800 salinity samples were titrated on board ship using the Automatic Chlorinity Titrator. Replicates of these samples are being titrated by the Japanese Hydrographic Office, using the Knudsen method.
- 6) Analyses for dissolved oxygen content were made on all stations. Analyses for dissolved phosphate and silicate were made on about 60 stations. Analyses for total phosphorus and for total iron were made on 12 stations.
- 7) On two stations, samples of dissolved gases were taken from a vertical series of water samples; on one set of samples the O^{18}/O^{16} ratio will be determined, on the other set the nitrogen/argon ratio.

— 8a —

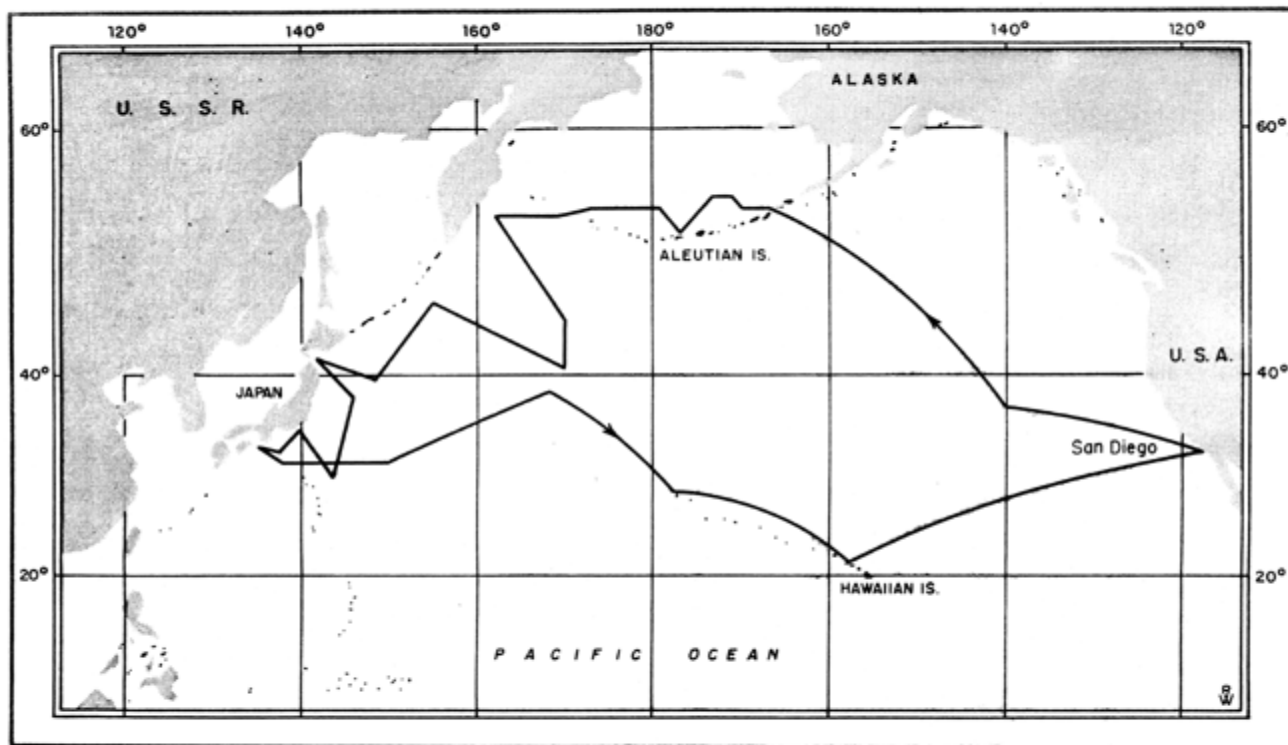


Figure 1. TRANS-PACIFIC TRACK.

Figure 1. Trans-Pacific Track

8) On four stations, studies were made of the carbondioxide equilibrium between the atmosphere and surface water.

9) On about 80 stations, two oblique meter-net tows were made, at 0–150 m and 150–300 m. On 20 stations, three oblique meter-net tows were made, at 0–150 m, 150–300 m, and 300–450 m. On 16 stations, five oblique meter-net tows were made, at 0–150 m, 150–300 m, 300–450 m, 450–600 m, and 0–900 m.

- 10) On each station, 50-m vertical tows were made with a 17-cm No. 20 net. Tows were also made on most stations with Clarke-Bumpus samplers. These tows were intended to collect microplankton not retained by the standard nets.
- 11) Twelve hauls were made with the Isaacs-Kidd Midwater Trawl, at depths from 200 fm to 2800 fm.
- 12) Three hauls were made with the High-Speed Diving Dredge, at depths from 710 fm to 2550 fm.
- 13) Studies of the vertical distribution of microbiological organisms were made on 55 stations.
- 14) On 95 stations, samples were collected at five depths for chlorophyll determination and for subsequent examination of the specific make-up of the phytoplankton standing crop. Transparency measurements were made on 10 stations and Steeman-Nielsen productivity experiments were run on 10 stations.
- 15) On all night stations where conditions permitted, surface organisms were collected by dip-net. Records of pelagic birds, whales, schools of fish, etc, were maintained.
- 16) A continuous record of depth was kept, using the EDO echo-sounder. Two crossings of the Aleutian Trench and eight crossings of the Japanese Trench were made, the EDO recording successfully on the 600-fm scale down to 5000 fm. Detailed bathymetric surveys were made in the regions of Bogoslof Island, Bayonnaise Rocks, and Ramapo Deep.
- 17) Landings were made on Bogoslof Island (in the Aleutians) and Bayonnaise Rocks (near Japan) where rocks were collected for chemical and petrographic analysis.
- 18) Fourteen cores were made with a gravity corer, the deepest at 2810 fm.

In addition to 26 scientists and technicians from the Scripps Institution, the following Japanese scientists participated in portions of the expedition: Drs. Chikayoshi Matsudaira (Tohoku University), Sigeru Motoda (Hokkaido University), Albert Y. Takenouti (Hakodate Marine

— 10 —

Observatory), Michitaka Uda (Tokyo University of Fisheries), Hiroshi Niino (Tokyo University of Fisheries), Takao Sakamoto (Tokyo University), and Daitaro Shoji (Japanese Hydrographic Office).

Analysis of Bathythermograms

**Sea Temperature in the Gulf of Alaska and in the North Pacific Ocean—
Margaret K. Robinson**

Work on the analysis of the BT data in this area is nearing completion. The results are now being checked for consistency.

During the past quarter an attempt was made to determine whether or not tongue-shaped isotherms in the northern and western parts of the Gulf of Alaska were real features or caused by adjacent observations being made in different years. The results were inconclusive.

Two statistical studies were made during this quarter. The mean deviation of the raw BT averages from the final smoothed isotherms

$$\left(\frac{\sum f_i x_i}{n} \right)$$

Equation 1

was computed for each month and for all the data. This value was found to be $+0.05^{\circ}\text{F}$. This is not significantly different from 0, and we may conclude that the smoothing introduced no bias into the results. The average absolute value of the deviations

$$\left(\left| \frac{\sum f_i x_i}{n} \right| \right)$$

Equation 2

was found to be 1.3°F , and the root mean square

$$\left(\frac{\sqrt{\sum f_i (x_i)^2}}{n} \right)$$

Equation 3

to be 1.7°F. Both of these values were computed because the frequency distribution was not normal but leptokurtic, i.e., it was more peaked and longer-tailed than a normal distribution. The root mean square value of 1.7°F is 0.3°F larger than a similar calculation made in the study of BT temperatures in the North Pacific area 20–40°N, 125–155°W.

The second statistical study was based on a comparison of 19th century surface temperature observations in the area tabulated and published in 1894 by Makaroff, commander of the Russian research ship, VITIAZ. The comparison was based on 707 temperature observations in 10 different months in 16 different years between 1816 and 1889.

When the data were considered as a whole, the mean difference was found to be -1.7°F and the root mean square of the differences was 3.1°F. Statistical tests show the mean to be significantly different from 0 at the 1 percent level, and the frequency of observations colder than the BT averages, also to be significant at the 1 percent level.

However, when the years and months were considered by themselves, the results were somewhat different. In two years, 1874 and 1889, and in one month, August, the mean difference was not significantly different from 0. In all years except 1874, and in all months except March, August, and December the frequency of observations colder than the BT averages was significant. In March and December, the mean

— 11 —

difference was positive and there were significantly more observations warmer than the BT averages at the 1 percent level.

On the basis of these comparisons between the 19th century temperature observations and the BT averages, based on data between 1942 and 1952, the 19th century observations are significantly colder except for 1874, and likewise it appears that there is a difference in the annual cycle, with the 19th century winter months, December and March, being warmer than the BT averages, August being the same, and the other spring and fall months being colder than the BT averages. (There were no observations in January and February.)

Seasonal Variations in Sea Level—Pattullo, Munk, Strong

Nine more calculations of thermohaline tides have been made, using the comprehensive tabulations of Nansen bottle data furnished to us by the Hydrographic Office. This brings the number of sample areas to a total of 46.

Unfortunately, several of the new areas represent only a few months of the year, but in the interests of sampling the oceans as completely as possible, we are using hydrographic data wherever they are available for several seasons. Many of the added locations are in the cold water masses of high latitudes in both hemispheres. Two sets of data, one off Capetown, South Africa, and one near 40°S Greenwich Meridian, provide valuable information about the much neglected water masses of Southern Hemisphere middle latitudes.

Three locations in the northern Indian Ocean are being examined as possible final additions to the study of seasonal changes in specific volume.

Additional Antarctic tide gauge data have been sent to us by the French Hydrographic Office and these have been incorporated into the averages for that region.

Project NR 087-029, Contract Nonr-233(17)

Pelagic Sedimentation—Goldberg, Arrhenius

Routine Processing

Salinity, water content, density measurements have been made in eleven complete cores from Capricorn Expedition. Processing has begun on two of the remaining gravity cores. Dehydration curves as a function of temperature have been studied in 30 samples of the processed cores to enable comparison between analyses made at different temperatures.

Chelative Dissolution

Chelative dissolution of minerals by ethylene diamine tetra-acetic acid (EDTA) has been studied in order to separate the oxide type minerals. Samples of sediments are routinely treated with a 5 percent

— 12 —

solution of EDTA. The treatment has been extended to various pure minerals to determine the amount of dissolution if any. The minerals so far prepared include augite, titanite, rutile, brookite, ilmenite, goethite, lepidocrocite, hematite, magnetite, montronite, biotite, muscovite, olivine, glauconite, and basaltic glass. The treatment has included these minerals separated into various grain-size fractions to ascertain the areal effect on the dissolution process.

Radioactivity

Routine gross beta radioactivity assays have been made in a flow counter on seven cores typical of various sedimentary provinces. The measurements have also been extended to size fractions, chelates, chelated residuals (the latter types have also been divided and studied in size fractions).

Fractionation Studies

The method of size fractionation has been extended down to 0.03 micra by use of the ultra centrifuge and separation in the gravity field. One sample of a Northern Pacific clay has been completely fractionated and four other samples are in the processing stage.

X-Ray Diffraction Studies

Grain size fractions and other samples have been analyzed at the California Institute of Technology. Size distribution and concentration of quartz as well as the low crystallinity of the clays has evolved from this work.

A summary of our procedures and the results thereof on pelagic sediments is being prepared for submission to a scientific publication.

Marine Aerosols—Arrhenius

Samples of marine aerosols from 50 cu m of air collected on the Trans-Pacific Expedition have been investigated by X-ray diffraction and reveal the quartz content is lower than the sensitivity limit of the instrument (a few micrograms /100 cu m). Aerosol samples from Capricorn Expedition have been investigated chemically and revealed marked latitudinal effect of the aerosol concentration (sea salt nuclei) and a vertical gradient of ammonia over the ocean surface.

— 13 —

Publications

Articles Published

Arthur, Robert S. Calculation of Refraction Factor Along a Wave Ray. *Bulletin of the Beach Erosion Board*, Vol. 7, No. 3, pp. 1–12. 1953. Jorgenson, C., and E. Dolgbert. Particle Filtration in Some Ascidians and Lamellibranchs. *Biol. Bull.* December 1953. Patterson, C., E. Goldberg, and M. Ingram. The Isotopic Analyses of Lead in Marine Sediments. *Bull. Geol. Soc. Am.* December 1953.

Articles Submitted

Goldberg, E. D. Marine Geochemistry I. Scavengers of the Sea. Journ. Geol. Rao, Pampapathi,
and E. D. Goldberg. Utilization of Dissolved Calcium by a Pelecypod. Journ. Cell. Compar.
Physiol.
