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OCEANOGRAPHIC RESEARCH AT THE SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, APRIL 1932 TO APRIL 1933

T. Wayland Vaughan

Introduction

The buildings and equipment of the Institution mentioned in the first part of my report for last year were completed near the end of the summer, 1932, and after that date the increased facilities for research immediately began to bear fruit. The work in chemistry, experimental biology, and the study of marine bottom-deposits have profited greatly during the past 12 months, and evidence of this is shown in the statements which follow.

The general program of the Institution has not changed. Therefore, the topics under which accounts of the researches at the Institution are given remain as they were in the report for last year.

Sources of oceanographic data

As in the past the boat Scripps was used at local stations for taking temperature-observations, for obtaining water-samples for chemical analysis, and for collecting plankton-samples. A number of experiments were made with various types of apparatus for taking bottom-samples and for obtaining at the lower levels water-samples for bacterial examination.

An intensive study of the circulation and the physical and chemical conditions in a submarine valley near the Institution was made. This investigation gave a number of interesting results. For example, the physical and chemical conditions of the water at all or most depths often showed a marked change over a period of a few hours. Sometimes these changes gave evidence of a horizontal movement of the water-mass and sometimes an upward movement. The direction and intensity of the currents in the valley apparently varied with the tide, though in an irregular manner.

A considerable amount of material and data have been obtained and are now being obtained from Naval vessels in cooperation with the Hydrographic Office of the United States Navy. Temperatures and water-samples for salinity-determinations were obtained by the U.S.S. Hannibal on a cruise from Philadelphia to the Canal Zone, and while engaged in survey-work in the Caribbean near Panama, and in the Gulf of Panama in the Pacific. While in the Gulf of Panama, R. H. Fleming of the Scripps Institution was on board the Hannibal and carried out 423 determinations of oxygen at 85 stations, and collected 500 samples for salinity-determinations, 60 bottom-samples, and 60 plankton-samples. On April 10 the Hannibal left for the west coast of Costa Rica where Fleming will continue the same kind of work as was carried out in the Gulf of Panama. It is also hoped that it will be possible to extend the program so as to include determinations of a certain number of plant nutrients. The work off the coast of Central America is considered especially valuable in view of the fact that practically no previous work has been undertaken in that locality and that complex hydrographic conditions obtain there.

The Institution has continued to receive water-samples and records of sea-surface temperatures and meteorological data from the Scripps-Institution and Balboa piers, from Pacific Grove, Hueneme, Farallon Islands, Blunts Reef and Columbia River Light Ships, Scotch Cap, and the Lighthouse Tenders Lupine and Rose. The records from the last five sources have been received largely through the cooperation of the Bureau of Lighthouses. Information has also been supplied by the United States Naval Transports, the vessels Guide and Pioneer of the Coast and Geodetic Survey, and the Grace Line ships plying between Valparaiso and Central American ports. The Institution has a water-thermograph installed on its own pier, on the Los Angeles Steamship Company's S.S. Calawaii, which makes fortnightly trips from Los Angeles to Hawaii, and on the U.S. Lighthouse tender Lupine.

The numbers of observations of different kinds are entered in Table 1.

A water-thermograph loaned by the Scripps Institution for a limited trial was installed on the Panama Pacific Company steamer Pennsylvania, plying between New York and San Francisco. A similar instrument, purchased by the Scripps Institution, has been in operation on the steamer California of the same company for more than a year, and the steamer Virginia has been equipped with a water-thermograph for more than two years. All of these thermograph-records will be worked up and filed at the United States Weather Bureau in Washington, D. C., according to arrangements made with the Chief of the Bureau. These records will be loaned for a limited time, in order that copies may be made.

Table 1--Numbers of oceanographical observations listed by Scripps Institution of Oceanography

Element	U.S. Navy transports	U.S. Lighthouse tenders	U.S. C. and G.S. ships	Scripps stations 1 and 2	Shore, La Jolla to Scotch Cap	Grace Line ships[a]	U.S. Navy	Supplementary data Lower Calif.	Total
Salinity	.....	192	(172)	(232)	2,868	.....	(96)	81	3,641
Water-temperature	4,078	800	(282)	(232)	2,975	2,000	(96)	81	10,544
Air-temperature	424	650	.....	.....	365	.....	....	..	1,439
Wind	4,078	900	.....	.....	2,138	2,000	....	..	9,116

[a] Valparaiso to Central American ports.

Note: Where entries are enclosed in parentheses () the observations are subsurface.

Physical oceanography and marine meteorology

G. F. McEwen has charge of the investigation in these fields. The ships' reports of sea-temperatures and winds, from an area of about 50 one-degree quadrangles in the San Francisco Section, 1898 to 1931, inclusive, used to determine monthly averages for selected groups of quadrangles, have been used with other surface-data in the eastern North Pacific for investigating surface-drift and the problem of seasonal weather forecasting.

Summarized serial observations of temperature, salinity, and pH at stations 1 and 2, 10 and 5 miles west of the Scripps Institution's Pier, have been corrected and mimeographed. Values are entered at half-month time-intervals and for 19 depths from the surface to 100 meters. Weekly and monthly averages of all shore-station data have been worked out to date, and mimeographed copies are available for distribution. Blueprints of seasonal curves plotted from weekly averages are also available for distribution. The tabulation of surface-observations at sea according to 30-minute quadrangles and weeks or months has been continued and entries on charts kept up to date.

McEwen has completed the theoretical part of two papers, and work is progressing on applications of the principles to data on hand. One paper presents the results of a re-examination of his theory first published in 1919 on the relation of horizontal drift to sea-surface temperatures and solar radiation. More convenient formulae have been developed and revised values of coefficients have been worked out using later observations with particular reference to the North Pacific. The other paper presents a solution of the differential equation of diffusion or conduction used as a basis for computing vertical velocity and turbulence, and includes appropriate tables for application to ocean-data. Further work is being done in the general field of turbulence suggested by McEwen's paper, published in 1929, on "A mathematical theory of the vertical distribution of temperature and salinity in water under the action of radiation, conduction, evaporation, and mixing due to the resulting convection." In connection with seasonal weather-forecasting, he has developed a method of forecasting monthly surface-temperatures at the Scripps Institution's Pier.

A good deal of interest has been shown relative to our investigations of seasonal weather-forecasting. Forecasts of seasonal precipitations at La Jolla during the midsummer upwelling-period correctly indicated an excess or deficit in practically three-fourths of the years from 1923 to 1931, but the divergence of computed and observed values in 1931-32 pointed to the need of a broader and more flexible index. Studies of the correlation between the precipitation or runoff and the ocean-temperatures of various months showed that a better fit might be secured by using values for certain months preceding as well as following the summer period.

The computations were performed by the ordinary least-squares method (Doolittle

solution), also by a related method in which the element predicted is expressed as a joint function of two temperature-factors.

These new formulae resulted in a much better verification than previous ones, when applied to the chief rainfall and runoff areas in Northern California. For the Huntington Lake district rainfall, and the Owens River runoff, an agreement of sign of the departures was noted in 13 years out of 16. When air-temperatures at San Diego were substituted for ocean-temperature at La Jolla, as an index, the error increased by several per cent, probably on account of the inherently variable nature of the former.

Investigations of possible weather-cycles have been continued, and evidence has accumulated in favor of certain cycles, that is, five and one-half years, and the longer Brückner cycle of about 30 years. Data on air-temperature, precipitation, stream-flow, and lake-levels in both North and South America have been used by Gorton in these studies.

H. R. Byers' study of the air-mass of the North Pacific, which was begun a year ago, has been continued and is practically finished. The past year has been devoted chiefly to a detailed analysis of all available free data, including soundings by aeroplane made by the United States Navy at San Diego (California), Sand Point (Washington), and Pearl Harbor, Territory of Hawaii, and sounding-balloon data from Batavia. In addition, the Scripps Institution with the aid of the Astrophysical Observatory, California Institute of Technology, conducted a series of aeroplane-soundings in the Los Angeles area during February and the first two weeks of March 1933. Free-air wind data obtained from pilot-balloon observations at stations in and bordering the Pacific have been analyzed in detail. The data have all been studied in accordance with the principles of the Norwegian school of meteorology. Careful analyses of synoptic charts of the North Pacific have been made for a three-and-one-half year period.

Burt Richardson continued his studies of radiation, including the penetration of light into sea-water, and N. W. Cummings, in a week's time available, completed checking the routine salinity-determinations by the gravimetric method in use at the Scripps Institution, and he found them to be satisfactory (error 0.02 o/oo). Routine chlorine-determinations usually agreed with gravity-methods within the same error.

During the year eight papers were published and eleven more were prepared for publication by the members of this section of the Institution's work.

Chemistry

The investigations in chemistry, which are in charge of E. G. Moberg, have consisted mainly of analyzing sea-water for various substances determined in former years and of reducing and preparing for publication the analytical data previously obtained. Among the substances involved in this work may be mentioned oxygen, hydrogen-ions, carbon dioxide in its various forms, ammonia, nitrate, phosphate, nitrite, silicate, calcium, boron, and chloride.

From information available at this Institution and in the literature relative to the quantities of carbon dioxide, titratable base, and hydrogen-ions, and from the results of boron-determinations made here, a study of the buffer-mechanism and of the dissociation-constants of carbon dioxide in sea-water has been made in collaboration with D. M. Greenberg and R. R. Revelle. It has been found that the behavior of the buffer-system in sea-water is markedly modified by the boron compounds, which occur in quantities equivalent to about 4.5 mg of boron per liter. It has been shown that in sea-water the second dissociation-constant of carbonic acid apparently changes with pH and this change has been attributed to the presence of boron compounds.

The recognition of the rôle played by boron in the buffer-mechanism of sea-water has been of importance in the work carried on by R. H. Fleming and R. R. Revelle on the solubility of calcium carbonate in sea-water. The results of repeated experiments, in which aragonite was precipitated from sea-water by raising the pH by the removal of CO_2, confirmed the opinions of previous investigators that, under tropical conditions of temperature, sea-water of pH about 8.20 is saturated with calcium carbonate. The

activity-coefficient of the calcium-ion in water of salinity 35 parts per thousand is found to be about 0.3. Equilibrium is attained very slowly and precipitation in supersaturated sea-water may continue for months. The principal factor in the mechanism seems to be pH, which in turn is controlled largely by the carbon-dioxide content. Salinity and temperature within certain limits are of minor importance.

It has previously been reported that the manometric blood-gas apparatus of Van Slyke has been adapted to the determination of the total carbon dioxide in sea-water. During the past year attempts have been made to determine also the oxygen-content by this apparatus, but, so far, the results have been less accurate than in the case of carbon dioxide, principally because the maximum oxygen-content of sea-water is only about one-tenth that of the carbon dioxide.

During the summer Max Greenberg, a student in biochemistry at the University of California, made a study of the applicability of a new colorimetric method for determining silica of sea-water. In this method the chief reagents are ammonium molybdate and amino-napthol-sulphonic acid. It was found to be more sensitive than the method of Dienert and Wandenbulcke, the one now commonly used, and consequently more suitable for surface-water where the silica-content is too low to give a good test with the old method. However, it was necessary to dilute the deep samples in order to reduce the intensity of the color.

At the present time an investigation of the distribution of oxygen and of certain nutrients in the Gulf of Panama and off the west coast of Costa Rica is being carried out by R. H. Fleming on board the United States Navy survey-vessel Hannibal. The results so far indicate an upwelling of subsurface-water in the Gulf of Panama and the oxygen-data agree in general with those previously obtained by the Dana and by the Carnegie in the same region.

During the early part of 1932 H. W. Graham of the Carnegie Institution of Washington spent several months at the Scripps Institution analyzing the chemical data obtained on the last cruise of the Carnegie and preparing reports on these data for publication. In collaboration with Noberg, six manuscripts were prepared dealing with various phases of the chemical work carried out by the Carnegie.

During the year seven papers on work done in the chemical laboratory of the Institution were published and 12 more were prepared for publication.

Biology

Marine microbiology--These investigations have been in charge of C. E. ZoBell. Assisted by Mrs. Catherine B. Feltham, he has studied variations in the bacterial population as influenced by depth, distance from land, sunlight, tides, ocean-currents, water-temperature, and rainfall. Though informative, these determinations will have to be continued for several years before definite conclusions can be formulated because of the multiplicity of complicating factors. The typical marine conditions in the vicinity of Scripps Institution proves that this location is almost ideal for studying marine microbiology. At least 73 different pure cultures of bacteria and actinomyces have been isolated from sea-water or bottom-deposits and characterized. Studies on the cultural requirements show that marine bacteria are quite unlike fresh-water bacteria, indicating the existence of specific marine bacteria which are foreign to other habitats.

ZoBell has investigations in progress on the rôle of bacteria and related micro-organisms in the nitrogen-cycle in the sea. The distribution, relative abundance, and factors which influence the activity of nitrogen-fixers, ammonifiers, nitrifiers, denitrifiers, and urea-splitters have been considered. Insolation and ultra-violet radiations were found to influence nitrification in sea-water. Sampling devices have been improved.

Mrs. Thelma Wells has been making corresponding observations on the distribution, characteristics, and physiological activities of yeasts and molds. Nutrient media and special methods for studying marine fungi have been developed. Results indicate that yeasts and molds are less numerous than bacteria, but they play an important rôle in the decomposition and transformation of organic matter in the sea.

Over 50 different pure cultures of molds, and four of yeasts have been isolated from sea-water and bottom-muds.

Since December 1, 1932, Miss Esther Allen has been investigating the occurrence of micro-organisms on submerged surfaces by direct microscopic observation. Preliminary experiments indicate that bacteria and to a lesser extent actinomyces and diatoms precede by several hours or even days the attachment of barnacles, hydroids, bryozoa, and other organisms. This direct method of observing the microbial flora which adheres to submerged slides offers another approach to the study of marine bacteria. Already several bacterial types have been noted which have not been recovered by concurrent cultural methods. Bacteria have been isolated which are definitely thigmotrophic. The cause of their antecedence over fouling organisms on submerged surfaces is now receiving attention.

During the year two papers were published and two papers were prepared for publication by the members of this section of the Institution's work.

Phytoplankton and the fouling organisms--W. E. Allen and Miss Easter E. Cupp have been engaged on work as follows:

(1) Computations and tabulations have been completed for the total diatoms in the ten-year series of daily collections of phytoplankton at southern California piers, and several graphs have been finished. Progress has been made on similar treatment of a single species, *Nitzschia seriata* Cl., and a part of the work on dinoflagellates in the same series has been done.

(2) A report on the catches by the boat in 1928 has been finished.

(3) Studies of the species characters of plankton-diatoms and the ranges of variations in specific characters have been continued, and several hundred drawings with notes on geographic and seasonal conditions having influence on abundance and character of growth have been added during the year.

(4) Pier collections of phytoplankton in the southern California region, daily for 14 years, are being continued, although series in other regions are being closed. The Institution's Pier seems to yield fairly representative evidence concerning annual, seasonal, or other gross cyclical and periodic fluctuations in fundamental conditions of existence of organisms in the Gulf of Santa Catalina.

(5) Cooperation with W. R. Coe of Yale University in studies of "fouling organisms" has been continued. Allen has devised improved apparatus for suspending collecting plates in the sea while organisms are growing on them. Allen has conferred with C. E. ZoBell concerning the initiation and progress of experiments by Miss Esther C. Allen, under ZoBell's direction, on the formation of films or deposits on submerged surfaces in the first 24 to 48 hours.

(6) A report has been finished on a small series of surface collections of phytoplankton (mainly diatoms) taken between San Diego and the Galapagos Islands by the Templeton Crocker Expedition of the California Academy of Sciences.

Three papers on the work listed above are in preparation.

Foraminifera--T. Wayland Vaughan, assisted by W. Storrs Cole and Donald W. Gravell, completed a number of papers on Tertiary and Cretaceous larger foraminifera from the Gulf States, Mexico, the West Indies, Central America, and northern South America. Five papers were published during the year and three are awaiting publication.

Earl H. Myers has been making extensive cultures of species of foraminifera found in the vicinity of the Institution. The status of his researches is embodied in the following statement:

Specimens of the pelagic *Tretomphalus bulloides*, the adult stage of the bottom-dwelling *Discorbis globularis*, have been observed almost daily throughout the winter in cultures started August 16, 1932. The last *Tretomphalus* from the sea were collected

November 10, 1932. No other specimens have reappeared to date, April 10, 1933. During the pelagic Tretomphalus stage, the individuals discharge their cargoes of zoospores from three to 23 hours after appearing at the surface. The empty test usually remains afloat during the second day. At times due to extraneous reasons, tests have been known to remain afloat for weeks. This may account for records of Tretomphalus in latitudes where the temperature is too low for its normal development (the thermal requirements for this metamorphosis can and will be checked experimentally). It is interesting to note that culture-conditions which have proven favorable over a period of months for the development of the above-mentioned stage have failed to give any indication of the fate of the thousands of zoospores liberated in the same containers. Methods have been devised and equipment purchased that should give a positive answer to the normal fate of these so-called zoospores.

Patellina corrugata in cultures exhibits two methods of reproduction, first by producing viviparous young and second by plastogamy, in which the protoplasms of from two to five individuals unite to form a common mass, that later gives rise to young similar in all respects to the viviparously produced young above mentioned. The cytological observations on this form agree in all respects with those of Schaudinn.

Discorbis patelliformis also produces viviparous young. Two or three individuals of this generation when about two-thirds grown fuse as in Patellina, and in a few instances have produced young similar to the parents. However, the great majority of paired tests are completely filled with tri-flagellated organisms within 12 hours of the time the tests have fused. This observation has been made hundreds of times, over a period of three years. Many cytological preparations have failed to give any conclusive evidence as to the origin of these flagellates. Efforts to rear these zoospores (?) on either solid or liquid media have not yet been successful. Budding as a method of reproduction reported by Heron-Allen and others, and based on poor circumstantial evidence suggested undoubtedly by reported observations on certain monothalmous forms, does not occur in the rotaliform species.

Discorbis sp. has been in culture for two years. Pedigreed cultures of this species have been maintained for nine consecutive generations. Under optimum conditions individuals will mature and reproduce in from 21 to 35 days. It is not uncommon to isolate, at one time from a single dish, as many as 2,000 one-day-old young. The first day the three chambered viviparous young remain clustered closely under the parent test and may be easily removed with a pipette.

Spirillina vivipara is readily cultured if the specimens are periodically washed with a stream of water. This is necessary to prevent the substrate of diatoms and bacteria from choking out the foraminifera. A few small gastropods help to maintain a clean substrate. Patellina must be handled in the same manner.

Triloculina circularis is not so prolific as Discorbis sp., but many thousands have been reared over a continuous period of two years. Only the megalopsheric stage occurs in culture.

Calcituba polymorpha has been cultured from the original stock culture for more than two years and sub-cultures are easy to make and maintain. Schaudinn's observations on this species have been neither substantiated nor contradicted.

Bulimina sp. in cultures over a period of two years has reproduced by the thousands. Only one stage occurs and no plastogamy has been observed.

Elphidium crispa reproduces asexually in material recently removed from the sea and will live in culture-dishes in a semi-dormant state for 18 months or more, but high temperatures and other unfavorable culture-conditions prevent normal development of the young. Observations on individuals in cultures agree with Lister's in that the protoplasm gradually recedes from the distal chambers and the nucleus is reduced in size. Schaudinn stated that Elphidium will not reproduce at temperatures above 18° C.

Planulina ornata has failed to remain active in cultures.

Fishes--A summary of the work of F. B. Sumner and his associates during the past year is as follows:

(1) Effects of visual stimuli received from the background upon the formation and elimination of melanin pigment in fishes. In addition to the well-known rapid changes of shade resulting from pronounced changes in the background, it was found that slower changes occur in the number of melanophores and the amount of pigment in each. Such adjustments were not found to be irreversible, however, even in the case of fishes kept for several generations on the same background, when the latter was lighted throughout the entire 24 hours. (Paper by Sumner and Wells, Jour. Exper. Zool., Feb., 1933.)

(2) Determination and quantitative estimation of carotenoid ("lipochrome") pigments, and experiments upon the possible influence of optic stimuli upon these (Sumner and Fox). The colored pigment present in all of the three fishes studied was found to be a xanthophyll ($C_{40}H_{56}O_2$). Except in one instance, the actual amount was not affected by the background, despite pronounced changes in the visible coloration of the fish. In the case of one species, however, a sojourn of three to four months on white resulted in a great reduction in the amount of xanthophyll. The food, a worm containing carotene, not xanthophyll, was constant for all.

(3) Relative effects of different portions of the visual field upon the color reactions of fishes. This is a continuation by Sumner, with recently devised technique, of a line of investigation commenced by him as early as 1910.

N. A. Wells, research assistant of Sumner, has continued his studies of effects of temperature, size, sex, season, etc., upon the oxygen consumption of fishes, a continuation of the work of the past two years, with methods earlier standardized, but variously applied to different related problems. Despite numerous technical difficulties, a number of highly significant correlations have already been revealed. He has shown that fishes may not attain a normal rate of metabolism for many hours after their introduction into an experimental environment (Proc. Nat. Acad. Sci., Sept. 1932).

During the year two papers were published and three are in preparation in this section of the Institution.

Physiology

Physiology--The investigations in this field are in charge of Denis L. Fox. During the summer of 1932, Fox, in conjunction with Florence Peebles of the California Christian College at Los Angeles, studied the morphology, general reactions, and physiological adaptations of the marine sipunculid worm, *Dendrostoma zostericola* Chamberlin. Special attention was given to the intake of sand containing organic matter, the rôle of the cerebral ganglion and nerve-cord in burrowing reactions, the location and sensitivity of various sense-receptors, and the high degree of adaptation toward desiccation and toward oxygen-deficiency. Results of the investigation will soon appear in the Bulletin of the Scripps Institution of Oceanography.

H. F. Blum, of the Physiology Division of the University of California, and Fox studied the light-responses in the brine flagellate *Dunaliella salina* with respect to wave-length of incident light. They found in both the red and green modification of the species, an equal maximum sensitivity to light of wave-lengths between 480 and 530 mμ. The positive phototaxis of either phase is limited to a spectral region between 330 and 550 mμ. The results were published in the University of California Publication (v. 8, No. 3, 21-30, Feb. 1933).

Fox and G. W. Marks have been investigating the hydrogen peroxide decomposing enzyme, catalase, in the California mussel, *Mytilus californianus* Conrad. They have completed one rather intensive piece of work and have another investigation nearly completed. The concentration of catalase was, in general, greater in glandular and highly vasculated tissue, and lower in muscular tissue. Extracts of young animals showed considerably higher catalase activity than those of older individuals. Mussel catalase is apparently inactivated in the presence of atmospheric oxygen. The optimum hydrogen-ion concentration for catalase activity is very close to pH 7. There is a sharp drop on the acid side of the optimum, but only a gradual sloping off on the alkaline side to about pH 8.5. The latter fact would lead one to suppose that the hydrogen-ion concentration found in the ocean where the animals were collected is favorable for the adequate performance of this vitally important enzyme within the animal, the pH of whose tissues is certainly close to that of sea-water. Temperature-

studies showed an optimum catalase activity between 0° and 10° C for 30-minute periods. It has been shown that, up to certain concentrations of the enzyme, the quantity of hydrogen peroxide decomposed is directly proportional to the catalase concentration, and independent of the concentration of the substrate. This finding is in agreement with those of investigators who worked with other catalases.

The velocity-constant for the inactivation of mussel catalase by oxygen is that of a first-order reaction, but since oxygen is one reactant, the reaction must be at least bimolecular, and the pseudomonomolecular character must be the result of a greatly excessive concentration of oxygen over that of catalase. The reaction-rate constant for the inactivation of catalase was determined accurately at several different temperatures, and the Arrhenius equation for the change in the reaction-rate constant with temperature was shown to be applicable.

The investigations of the carotenoid pigments of fishes, jointly with Sumner, have been mentioned.

During the year this section of the Institution published two papers and three papers were prepared for publication.

Marine sediments

In my report to the Section last year I made a fairly full statement of the program of work on marine sediments at the Scripps Institution. Therefore, what is now needed is only an account of developments which have taken place since that report was made.

The importance of the investigations of the buffer-mechanism of sea-water to problems of sedimentation is indicated in the section of this report which deals with the chemical investigations conducted at the Institution during the past year. The manuscript by Greenberg and Moberg and Miss Esther Allen, which was finished a year ago, was not immediately sent to press because the authors were not satisfied with some of the details. The determination of the amount of boron in sea-water by M. W. Harding led to a re-study, both theoretically and by means of laboratory experiments, of the effect of boron on the buffer-mechanism of sea-water. The paper has been revised by Moberg and Revelle and is ready for publication. This paper, in my opinion, represents the most satisfactory treatment which the very intricate problems concerned have yet received.

Although the study of the life history of foraminifera may seem remote from the investigation of marine bottom-deposits, it is really a very closely related subject. Foraminifera are probably the most important group of organisms which contribute material to bottom-deposits. For this and other reasons, such as the knowledge of taxonomy of the group and of the means whereby geographical distribution is effected, it is highly important that we should understand the life history of these organisms. Therefore, although Myers, in his study of the life history of foraminifera, is utilizing strictly biological methods in his investigation, he is also contributing information of value to those who are interested in the geological aspects of the sea.

E. M. Thorp has continued his study of the calcium carbonate bottom-deposits of the Florida-Bahamian region and has virtually finished his description of the samples. In order to get a basis for additional comparisons of such deposits in the Floridian and Bahamian region with deposits in the tropical and sub-tropical Pacific, a study has been made of a series of samples collected by P. S. Galtsoff on Pearl and Hermes reefs, Midway Islands, of the Hawaiian group. A report on these samples is nearing completion.

It was mentioned last year that the deep-sea samples collected by the Carnegie during her work in the Pacific were being studied at the Scripps Institution by Roger Revelle. The following statement gives the present status of the investigation.

The general examination and description of those Carnegie samples which have been mechanically analyzed have been nearly completed. Of the 45 samples which have thus been examined there are 20 globigerina oozes, 13 red clays, 3 diatom oozes, 2 radiolarian oozes, 2 volcanic muds, 3 coprolitic muds, and 1 blue mud. The method of ex-

amination has consisted in identification of the various organic and mineral components of the samples and in the estimation of their relative abundance. Attention is now being paid to specific problems which have arisen in connection with this study such as the determination of the clay and other minerals in the silt and clay grades; identification of heavy minerals, volcanic glass and rock fragments; further mechanical analyses of the fine grades; correlation of chemical and optical analyses; possible dolomitization of the shell fragments in the samples; and mode of alteration of volcanic glass.

One of the interesting results which has been obtained from the study has been the definite identification of the clay mineral in the red clays of the North Pacific as a member of the beidellite-nontronite series in which the ratio of SiO_2 to R_2O_3 is as 3 to 1. In this series for a part of the Al_2O_3, Fe_2O_3 is substituted. C. S. Ross kindly checked this determination.

Heavy-mineral analysis of a series of five samples from the northwest Pacific, off the coast of Japan, indicate that the bottom-deposits of this region are derived in part from the products of Japanese volcanic eruptions. Although two of these samples are classified as volcanic muds and three as diatom oozes, all are nearly identical in chemical composition. The percentage of heavy minerals, however, decreases uniformly from the coast of Japan, while the percentage of diatoms and radiolaria correspondingly increases.

Another feature of interest is a group of three samples from the southeast Pacific which have been called coprolitic muds. Two of these, judging by their chemical composition, distance from shore, and depth, would be classified as globigerina oozes were it not for the numerous ellipsoidal and disk-shaped aggregates of fine material which they contain, and for the fact that the larger part of the unbroken foraminiferal shells are those of benthonic genera. The percentage of $CaCO_3$ in both of these is close to 42 per cent. The third sample has only 3 per cent $CaCO_3$, but is similar in other respects. Pellets similar to those found in such abundance in these three samples have been observed as minor constituents of numerous others.

The foregoing statements regarding the work of Thorp and Revelle need to be supplemented. Thorp has already published a paper entitled "Descriptions of deep-sea bottom-samples from the western North Atlantic and the Caribbean" (Scripps Inst. Bull., tech. ser., v. 3, No. 1, 1-31, 1931). After this report had been published it seemed desirable to utilize recently developed X-ray methods to see if the X-ray patterns would make possible the recognition of the minerals represented in the very fine fractions of the sediments. Obviously it was also desirable to have the X-ray investigation include the fine fractions of the deep-sea sediments from the Pacific. We were fortunate in enlisting the assistance of W. H. Dore, Division of Plant Nutrition, College of Agriculture, University of California. Accordingly, a set of samples representing both the deposits in the Atlantic and the deposits in the Pacific were prepared for him. He has already made X-ray exposures of 28 samples and has prepared 56 films. The results have been illuminating but there has been difficulty in interpreting all of the films. Therefore, Dore has undertaken to make X-ray spectrograms of a series of selected mineral standards. Already spectrograms have been made of 13 specially selected mineral species. The work has not yet been finished, but it is progressing and the prospects are good for achieving results of value.

Another line of investigations of deep-sea sediments has been made possible through the generous cooperation of George Steiger of the United States Geological Survey. He undertook to make spectrographic analyses of 100 deep-sea samples and has actually reported on 101 samples. His report includes determinations of B, Ba, Be, Bi, Ge, Sn, and Zn. In his report he says that besides tests for the six metals shown in the accompanying report D 225, plates were made including spectra which will make it possible to examine these same plates later on for Ag, As, Cd, Pb, Sb, Li, and Sr. Additional study of the plates made to see if the elements mentioned by Steiger may be recognized will be attempted. He has submitted a very interesting discussion of the significance of the varying amount of barium in the different samples.

With reference to the Carnegie samples, it may be stated that mechanical analyses of the samples of which the quantity was sufficient were made at the Scripps Institution. Chemical analyses of a selected set of samples were made by Sharp-Schurtz Com-

pany. In addition to the different kinds of examinations above indicated, C. S. Piggot of the Geophysical Laboratory of the Carnegie Institution of Washington analyzed some of the samples for radium, and Parker D. Trask analyzed a set of samples for the organic content. It, therefore, seems that by combining the different lines of work above indicated we shall have as complete information on the Carnegie deep-sea samples as is at present practicable.

During the year four papers were published and four more are being prepared for publication by the members of this section of the Institution's work.

Scripps Institution of Oceanography,
University of California,
La Jolla, California