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OCEANOGRAPHIC WORK AT THE SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA, LA JOLLA, CALIFORNIA, JULY 1, 1931 TO APRIL 18, 1932

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Buildings and equipment

The land of the Institution consists of a 177-acre tract on the sea-front about two miles north of the village of La Jolla. Prior to March 1, 1931, there were on this land one laboratory building, two floors, 75 by 48 feet; a museum-library building, two floors and about a three-quarter basement, 60 by 60 feet; a reenforced concrete pier 1,000 feet long and 20 feet wide; a wooden aquarium 24 by 48 feet with 18 tanks; several service buildings and garages, temporary structures; 24 wooden cottage residences; and a research boat 64 feet long, 18-foot beam, 22 tons net capacity (about 50 tons gross), equipped to work to a depth of about 1,000 fathoms and with a cruising radius of about 1,000 miles.

About March 1, 1931, construction of an additional laboratory building, Ritter Hall, was begun. This building is 100 by 46 feet and has three floors. With the necessary installations it cost $120,000--$40,000 contributed by the State, $40,000 by an anonymous donor, and $40,000 by the Rockefeller Foundation. Although the building is not very large the installations for oceanographic work represent the most modern type. Provisions within the building are made for work in dynamical oceanography and marine meteorology, a variety of chemical investigations, bacteriology, and physiology. Two rooms are particularly designed for work in special problems of physics, including one room for spectrometry. On the ground floor there are rooms supplied with running salt-water for the culture of marine organisms on a rather large scale, several rooms in a photographic suite, machine-shop and boiler-room, store-room for oceanographic instruments, transformer-vault, and some vacant space which may later be utilized according to the needs of the Institution. On the roof there is a pent-house and outside it there are exposed instruments of several types, the automatic recording-devices of which are in the rooms devoted to physical oceanography and marine meteorology.

In addition to the funds for the new laboratory building, the State Legislature at its last session made a special appropriation of $40,000 for the improvement and renovation of the Institution's property. This was supplemented by a special contribution of $2,000, making a total of $42,000. By means of this fund it has been possible to do many things, one of which was to replace the old salt-water system by a reenforced concrete tank, which holds 60,000 gallons, and to lay both afferent and efferent pipes of pure lead. The tank will supply water to the physiological section of Ritter Hall, the rooms on the lower floor of the old George H. Scripps Laboratory, and the aquarium. The interior of the George H. Scripps Laboratory has been remodeled so as to take care of four of the Institution's projects, namely: Biology of fishes, to which about one-half of the lower floor is devoted; marine sediments, to which about three and a half unit-rooms are assigned; phytoplankton; and foraminifera. Four unassigned rooms may be utilized by visitors. In addition to the $162,000 for new construction, improvements, and renovation, by careful planning about $9,500 was made available from the regular funds of the Institution for additional equipment. Therefore, within about 14 months over $170,000 have been expended in improving the Institution, mostly its facilities for scientific research. In addition to its own scientific staff between 20 and 25 visiting investigators can be accommodated.

From this brief summary statement I think that it will be obvious that the Institution has a very fine set-up. For the kind of investigations in which it is engaged I do not know of any that has better laboratory facilities, but its boat equipment is not adequate for extensive high-seas operations.

Program

The work of the Institution is arranged as a series of interlocking projects, but because of the impossibility of any one person being able to be an expert in all the fields of oceanography a certain amount of sectionizing of the activities is necessary. The different investigations under way at the Institution will, therefore, be outlined

in a sectional way, but it must be borne in mind that there is at the Institution scarcely any investigation which does not require the cooperation of several groups.

Sources of oceanographic data

The arrangements for receiving oceanographic data at the Institution are extensive. Since the first of last July the Institution's boat has made 23 trips, 30 vertical sections, and 450 temperature-records. On water-samples collected by it there have been 450 determinations of salinity; 450 of pH, PO_4, and SiO_2; 200 of NO_2, NH_3, and total nitrogen; 300 of CO_2 and carbonates; 100 of boron; and 20 of calcium. Two hundred and fifty plankton-samples were collected. Besides the collections and records made on the boat Scripps the Institution has received water-samples and records of sea-surface temperatures and meteorological data from its own pier and Balboa, Pacific Grove, Hueneme, Farallon Islands, Blunts Reef and Columbia River lightships, lighthouse tenders Rose, Lupine, and Sequoia, and from Scotch Cap, Alaska. The Bureau of Lighthouses has rendered valuable service in getting both data and collections. Information has also been received from United States Naval transports, the vessels Guide, Discoverer, and Pioneer of the Coast and Geodetic Survey, the Escuela Naval at Callao, Peru, and the Grace Line ships plying between Valparaiso and Central American ports. The Coast and Geodetic Survey steamer Pioneer has made for the Institution a number of careful vertical sections in the vicinity of the Hawaiian Islands. Besides recording temperatures at successive depths, it collected water-samples and a number of bottom-samples. The Institution has a sea-water thermograph installed on its own pier, the Los Angeles Steamship Company's Calawaii, and the United States Lighthouse tender Lupine. Arrangements have been made for the installation of thermographs on the Panama Pacific Company's steamers Pennsylvania, California, and Virginia.

Since July 1, 1931, 3,545 salinity-determinations were made at the Institution; 10,717 records of sea-surface temperatures, 9,498 records of winds, and 5,366 records of air temperatures were received.

Physical oceanography and marine meteorology

The investigations in these fields are in charge of Prof. G. F. McEwen. Ships' reports of sea-surface temperatures and winds from an area of about 50 one-degree quadrangles in the San Francisco section, 1898 to 1931, inclusive, have been utilized to determine monthly averages for selected groups of quadrangles. These results are ready for use with other surface-data in the eastern North Pacific for investigating surface-drift and problems of seasonal weather-forecasting.

The preliminary work of summarizing serial observations at Station 2, five miles west of the Institution's pier, has been completed. Weekly and monthly averages of all shore-station data have been brought up to date, and mimeographed copies are available for distribution. Tabulation of surface-observations at sea according to 30-minute quadrangles and weeks or months has continued as usual, and the data have been plotted on charts.

Dr. McEwen has very nearly completed two papers of a theoretical nature. One presents a theory relating ocean surface-drift to surface-temperatures and solar radiation. This is an extension of his previous work, "Ocean temperatures, their relation to solar radiation and oceanic circulation." He has also obtained a solution of the differential equation of the vertical distribution of temperature and salinity. This solution holds for sufficiently large intervals of time and depth to be of material aid in applying the theory, especially to the problem of determining normal values of temperature and salinity. The results of these theoretical investigations form the basis of two papers, one on surface-drift, the other on upwelling, in preparation for the Fifth Pacific Science Congress.

Professor McEwen prepared the chapter, "A summary of basic principles underlying modern methods of dynamical oceanography," for the volume on oceanography in the series of bulletins, "Physics of the Earth," being published by the National Research Council. He also aided in the translation and preparation for press of a manuscript in German by Dr. Arnold Schumacher on "A survey of present knowledge of oceanic circulation based upon modern physical and chemical observations."

Other work at the Institution is a paper entitled "A sinker method for the determination of specific gravity" by N. W. Cummings, which has been published as No. 5, volume 3, technical series, of the Scripps Institution of Oceanography Bulletin. Mr. Burt Richardson has the following papers either ready or nearly ready for press: A computation of the transmission-coefficient of the Earth's atmosphere from the insolation-records of the eight United States stations; A comparative graphical study of the insolation-records of Pasadena (1926-28) and La Jolla (1928-32) with seven other United States insolation-stations for the same period of time; A description of a photoelectric recording apparatus for measuring fogginess; Results of studies at the Scripps Institution of the transmission-coefficient according to depth of sea-water made during the summer of 1931, and the penetration of light in sea-water; A method for computing the amount of evaporation of sea-water from a tank by changes in salinity, with experimental results obtained on board the Scripps, August 13-24, 1928.

Mr. Richardson's work on the penetration of light into sea-water has been one of the important recent investigations at the Institution. A summary of his results is given separately.

The investigations in meteorology at the Institution include, besides Mr. Richardson's meteorologically significant researches, a study by Mr. Horace R. Byers on the problem of air-masses and fronts of the North Pacific Ocean. Dr. McEwen and Dr. A. F. Gorton have continued their efforts to discover a basis for long-range weather-forecasting in the region of southern California. Particular attention was paid to the cyclical characteristics of ocean-temperature and air-temperature records and to the interrelation of temperature and precipitation discovered by Brückner and elaborated by Schuman. It appears that the ocean-temperature during the "upwelling" period is less significant for forecasting purposes than the general trend of temperature during the eight months preceding the opening of the rainy season.

Chemistry

The investigations in chemistry are in charge of Dr. E. G. Moberg. They have comprised, besides routine determinations of salinity, pH, PO_4, and SiO_2, a special investigation of carbon dioxide in sea-water and the seasonal variation of base and carbon dioxide at various depths. From the results of measurements of carbon dioxide, titrable base, and hydrogen-ion concentration, under both natural and experimental conditions, a study of the buffer-mechanism of sea-water was made. This mechanism was concerned with the solubility of calcium carbonate and with a number of chemical equilibria of biological and geological importance. Papers giving the results of these investigations have been prepared by Messrs. Moberg and Greenberg and Miss Esther Allen. Dr. P. L. Kirk of the Division of Biochemistry of the University of California Medical School has adapted a micro-method for the rapid determination of calcium in sea-water. It gives results which are accurate to about one per cent. The method is described in a paper now in press by Kirk and Moberg. Mr. M. W. Harding has made a special investigation of the boron-content of sea-water, and Mr. R. H. Fleming is conducting an investigation of the various types of inorganic and organic nitrogen compounds in the sea. Determination of nitrate, nitrite, ammonia, and total organic nitrogen have been made on water taken at various localities and depths throughout the year. Particular attention is being paid to the several substances which are in solution in sea-water and may serve as plant nutrients.

Biology

General--It should be remarked under this head that an endeavor is made to relate the biological phenomena to the physical and chemical conditions in the sea. Besides such factors as temperature and oceanic circulation, the different substances dissolved in sea-water exert important influences on life in the ocean. The investigations of Mr. Richardson on the depth of penetration of light is obviously of fundamental significance. The biological projects at the Institution exceed seven. They will be briefly outlined in the following notes.

Bacteriological investigations--The bacteriological investigations at the Institution until November, 1931, were carried on by Dr. Gee. His researches embraced three aspects. First, an endeavor was made to obtain information regarding the ocean zones of micro-biological activity. Approximately half of the micro-organisms culti-

vated from ocean-water and bottom-mud were bacteria. Moulds, actinomyces, and yeasts constituted the remainder. The maximum activity was in the mud. The surface zone of activity was found not to exceed about 25 meters. Second, studies were made to ascertain the suitability of culture media. Experiments indicated that the bacteria present in sea-water may exceed by a thousandfold the number that can be obtained by the use of conventional culture-methods. Third, considerable time during the year 1930-31 was devoted to the study of lime deposition in the sea and the role that bacteria might play in the process. Since many marine bacteria are ammonia producers they may be accessory factors in calcium deposition, but it has not been established that ammonifying bacteria are significant agents in precipitating calcium carbonate in the ocean. Attention was paid to the displacement of the calcium equilibrium in sea-water by passing CO_2-free air through the water. By this method a precipitate of aragonite was obtained. This subject will be reverted to in discussing the work on the investigations of marine bottom-deposits of the Institution.

On January 1, 1932, Dr. C. E. ZoBell became the Institution's microbiologist. He is making experiments on different kinds of media in order to ascertain those most effective for the culture of marine bacteria. He is making daily determinations of bacteria in sea-water samples collected from the Institution's pier with reference to factors which may influence their distribution. Temperature, rainfall, chemical composition of the water, solar radiation, oceanic circulation, and biological conditions are being considered. The principal bacteriological investigations, however, are on the role of micro-organisms in the nitrogen cycle in the sea. These include experiments in isolation, determination of relative abundance, and studies of the physiological activities of denitrifiers, nitrogen-fixers, nitrifiers, ammonifiers, and others, using modified soil-bacteriological methods.

Phytoplankton--Prof. W. E. Allen has continued his investigations of photoplankton as in the past. He is now, however, trying to relate his studies of seasonal, geographic, and bathymetric distribution to the results obtained by studies of the depth of penetration of light and the distribution of plant nutrients in the sea-water. The investigation of phytoplankton, therefore, has become a cooperative enterprise between those who are working on the organisms themselves and those who are engaged primarily in the study of the physical and chemical conditions in the sea. Professor Allen and Miss Cupp have completed a large memoir on the plankton-diatoms of the Java Seas which has been sent to Professor Delsman, the Director of the Marine Station in Batavia, for publication. Professor Allen has also reported on a collection of Australian diatoms sent to the Institution by Prof. W. J. Dakin of the University of Sydney. Miss Cupp has for several years been engaged on the study of the ranges of variation in the frustules of the different species of diatoms found in the northeast Pacific. She is considering variation with reference to a number of physical and chemical features of the sea.

Foraminifera--The investigations of foraminifera at the Institution are in charge of Dr. T. W. Vaughan. Besides studies of certain fossil foraminifera, that are of geological significance, there are two other aspects to the investigations. One is the study of the ecologic relations of different foraminiferal faunas and of foraminifera as contributors to marine bottom-deposits. Investigations of this kind overlap the study of marine bottom-deposits. An investigation in which the Institution is concerned is one by Mr. M. L. Natland along a section from Long Beach, California, to Catalina Island. Mr. Natland has already been able to define several different foraminiferal faunas according to ecological conditions. Another aspect of the researches has been the study of the life-history of some of those species of foraminifera which are abundant in the vicinity of the laboratories of the Institution. Mr. E. H. Myers, besides observing the asexual production of individuals, has made for the first time permanent preparations and photo-micrographs of the zoospores, including their conjugation, in the sexual stage of *Tretomphalus bulloides*. He has substantiated a claim of long standing by observing all stages in the metamorphosis of this species from a bottom-dwelling form into a pelagic form. He maintained successive cultures for eighteen months.

Fishes--Almost from the foundation of the Institution occasional studies have been concerned with one or another phase of fish biology. Within the past few years, this field of investigation has been given the status of a definite section of the Institution's work, under charge of Dr. F. B. Sumner, and a portion of George H. Scripps

Laboratory has recently been remodeled and equipped for this purpose. The studies thus far undertaken or contemplated relate chiefly to the physiology or ecology of these organisms, with special reference to the effects of changes in one or another environmental factor. The life-histories of certain local fishes have also received attention.

Mr. N. A. Wells is at present engaged in comparative studies of oxygen-consumption in marine fishes, as affected by age, sex, species, temperature of water, and perhaps other factors. These studies involve quantitative determinations of oxygen in samples of water taken from containers in which the fishes are kept under controlled conditions of temperature and rate of water-flow.

For about two years Dr. Sumner, in collaboration with N. A. Wells, has been making experiments, as well as microscopic studies, upon pigmentary changes in the guppy (Lebistes reticulatus) when reared upon various backgrounds. This investigation involves the preparation of histological sections and the taking of microphotographs of these and of areas of the integument of entire fishes, both living and dead. Marked changes, not only in the visible shade, but in the actual amount of black pigment (melanin), have been determined.

Dr. Sumner and Dr. Fox have commenced an investigation of the yellow and orange colored carotinoid ("lipochrome") pigments of Fundulus and other marine fishes, with particular reference to possible quantitative and qualitative differences due to environmental causes.

Mr. P. S. Barnhart has recently published a paper entitled "Notes on the habits, eggs, and young of some fishes of southern California," in which he records some of his numerous observations, made during his long connection with the Institution's staff.

Physiology of marine invertebrates--There has been added to the Institution a Section of Physiology for the study of the interrelationships between marine invertebrates and their environment. Dr. D. L. Fox was placed in charge of the Section, and assumed his duties at the Institution on September 1, 1931. During the latter part of December, 1931, and the first half of January, 1932, Dr. Fox conducted experiments at Berkeley in collaboration with Dr. H. F. Blum of the Division of Physiology of the University of California Medical School on light-response in the brine flagellate Dunaliella salina with respect to wave-lengths. Dr. Fox's work in conjunction with Dr. F. B. Sumner has already been mentioned. Dr. Fox has also initiated studies on the oxygen-deprivation tolerance, and more especially on the desiccation tolerance of certain marine sipunculid worms. Indications are that these animals, which provide hardy, interesting material for laboratory study and culture, tolerate a great oxygen-deficit for several days if kept in sea-water, and succumb to desiccation at a rather clearly definite limit which lies, on an average, between 40 and 50 per cent loss of total water. It is expected that studies of salt-concentration, within the organisms and in the surrounding medium, will be made as parallels to the water-content investigation.

Miscellaneous--Prof. W. R. Coe of Yale University conducted studies of the seasonal attachment and rate of growth of sedentary marine invertebrates and algae at the Scripps Institution pier, and has published his results in the Scripps Institution Bulletin technical series (v. 3, No. 3, 1932). He has also published in the same scientific series a report on gonad development and sexual cycles in the California oyster (Ostrea lurida).

Dr. W. W. Lepeschkin, while a visitor at the Institution in 1930, conducted investigations upon some influences of light and poisons on marine copepods. The results of his work are published in the Institution's bulletin (tech. ser., v. 3, No. 2, 1931). He is of the opinion that exposure to direct rays of sunlight decreases the resistance of certain copepods to the toxic action of such a poison as mercuric chloride, and that short exposures to the ultraviolet portion of the solar spectrum may increase the resistance of the organisms toward the poison.

Considerable work has been done on corals at the Institution during the past twelve months. Mr. John W. Wells, a Storrow Fellow in Geology, spent three months at

the Institution; and then transferred to the United States National Museum in Washington. Reports on corals have been made to Rev. Father Gherzi, S.J., Zi-ka-wei Observatory, Shanghai, on a collection from Pratas Shoals between the Philippines and Formosa; on a rather large collection from the Japanese islands in the Pacific, the latter collection being of special interest because it was largely made by the Emperor of Japan; and on a collection made in the Pearl Islands, Midway Group, by Dr. P. S. Galtsoff. T. W. Vaughan, in association with J. W. Wells, is preparing for the Handbuch der Palaäozoologie, being edited by Professor Schindewolf in Berlin, the section on hexacorals. This work will comprise reviews of all hexacoral genera and discussions of such topics as morphology, development, physiology, and ecology of the organisms.

Marine sediments

The investigations on marine sediments have been organized by Dr. T. W. Vaughan in cooperation with several others, mentioned below. One of the principal projects has been the continuation and extension of the investigation of calcium-carbonate sediments begun by him in Florida in 1907, and prosecuted by him in cooperation between the Department of Marine Biology, Carnegie Institution of Washington, and the United States Geological Survey until he transferred his residence to California in January, 1924. The investigations as they have been developed have comprised three methods of attack, the first of which is a study of the carbon-dioxide and calcium relations in sea-water. This work has been done partly by those associated with the chemical investigations at the Institution (particularly by Dr. E. G. Moberg, Dr. D. M. Greenberg, Dr. P. L. Kirk, and Miss Esther Allen), and it has been done partly by Dr. Gee in connection with his bacteriological investigations. It is not practicable in a report such as this to give even a synopsis of the results. It can merely be mentioned that, besides a short abstract entitled "The relation of the buffer-mechanism of sea-water to the solubility of calcium carbonate," by D. M. Greenberg and E. G. Moberg, contained in the report of the Committee on Sedimentation of the National Research Council for this year, at least three other papers by Greenberg, Moberg, Esther Allen, and P. L. Kirk are now in press. The following two sentences may be quoted from the abstract above mentioned:

> "This is of significance in the solubility of calcium carbonate since it shows that when from gross analytical figures there is indicated an apparent supersaturation, there may actually be a large under-saturation. Moreover, a knowledge of the activity-coefficients will make it possible to calculate the true state of affairs, since on the basis of thermodynamic theory, the true solubility product, that is, the product in terms of the activity of the ion-components, is a true constant, independent of the chemical state of the solution. The present study represents a step toward the working out of the whole problem."

A second method of attack has been, in collaboration with the Carnegie Institution of Washington, a renewal of the attempt to evaluate bacteria as possible agents in the precipitation of calcium carbonate in the ocean. Dr. Haldane Gee has contributed an abstract of an investigation by him entitled "Characteristics of bacteria from the Florida Keys," to the report of the Committee on Sedimentation for this year. Besides this abstract Gee has published or has in press between ten and a dozen other papers. A few of his conclusions may be quoted. With reference to the bacteria he says:

> "The physiological behavior of the individuals was, however, similar in two important aspects. Almost all the organisms produce ammonia, and none has yet been found to produce carbon dioxide. Consequently the bacteria studied thus far are factors aiding the precipitation of calcium carbonate from the sea-water."

Gee's work was confined to an investigation of the aerobic organisms, but, as he says, the anaerobes should also be investigated. Gee undertook at Tortugas an experiment in precipitating calcium carbonate by passing CO_2-free air through water at a temperature of 30° C and at an initial salinity of 36.1 per mille, from which biological activity had been eliminated. The artificial precipitate was composed of aragonite needles and rosettes, but precipitation did not take place until a salinity of about 39 per mille

and a pH of about 9.3 had been attained, a pH beyond any known in normal sea-water. Subsequent to Gee's experiments Messrs. R. R. Revelle and R. H. Fleming have had similar experiments in the chemical laboratory at the Scripps Institution by reducing the water to a salinity of 37.8 per mille and conducting the experiment at a temperature of 30° C. They obtained a precipitate similar to the one obtained by Gee, except that the aragonite needles and the rosettes were larger than those in his precipitate, and in addition to them there were spherulites, which were actually more numerous than needles and rosettes. Again, however, precipitation did not take place until a pH above 9.0 had been attained. Immediately after the precipitation the pH of the water dropped to about 8.9, which was still above normal. Additional laboratory experiments are contemplated to determine the effect of increase of salinity on precipitation.

The third attack on the problem has been the detailed study of numerous bottom-samples according to more or less established procedure, that is, mechanical analyses, chemical analyses, and descriptions of the separates. Mr. E. M. Thorp, who has already published a paper entitled "Descriptions of some deep-sea bottom-samples from the western North Atlantic and the Caribbean Sea" (Scripps Inst. Oceanog. Bull., v. 3, No. 1, 1931), has devoted many months to the description of something over two hundred samples collected by T. W. Vaughan in Florida and the Bahamas. Vaughan has already described a number of these samples and has given much information on sizing, chemical composition, and organisms, and one set of samples from the vicinity of Cocoanut Point, Andros Island, was described in great detail by M. I. Goldman. Description of the entire collection has not yet been finished, but it is approaching completion. The results of the descriptive work will obviously be correlated with the investigations of chemical conditions in the sea, the possible role of bacteria, and other organic and inorganic processes. It is scarcely to be expected that the entire problem will be solved, but important advance has certainly been made in understanding the complex phenomena. One of Mr. Thorp's findings in both the bottom-deposits and the residue of the Bahamian oolites, after treating the material with 0.2 N hydrochloric acid, is that there is an appreciable amount, but less than one per cent, of mineral fragments of volcanic origin.

In connection with these investigations, it may be mentioned that T. W. Vaughan, in association with E. M. Thorp, is making a compilation for an account of the classification and the nomenclature of calcium-carbonate sediments.

Another project under way at the Scripps Institution is the study of the deep-sea sediments of the Pacific Ocean. Besides the large number of samples collected by the Coast and Geodetic Survey vessels, especially between Panama, Canal Zone, and the latitude of San Diego, the Institution has received all of the samples collected by the Carnegie during its work in the Pacific. The mechanical analyses of the samples were finished about a year ago, and the chemical analyses, made by Sharp-Schurtz Company, were completed some months later. Mr. Roger R. Revelle is now engaged in describing the different samples. He will assemble and correlate all the data on the samples. Subsequent to the receipt of the Carnegie samples the Coast and Geodetic Survey Pioneer has made an additional collection of deep-sea samples in the vicinity of the Hawaiian Islands.

The Institution has also received from the Pacific considerable additional collections of shallow-water calcium-carbonate deposits which are more or less associated with coral reefs. One of the collections was made by Dr. P. S. Galtsoff on Pearl Reef, Midway Islands, of the Hawaiian group.

Conclusion

With reference to the scientific program of the Institution it will be remarked that, notwithstanding the rather large number of research projects, there is scarcely one which is isolated from other researches at the Institution. The investigation of marine bottom-deposits is a good illustration of how in one group of phenomena all of the different aspects of the ocean are concerned. In order to understand any marine bottom-deposit we must consider the physical oceanography, chemistry, with particular emphasis on physical chemistry, and the organisms. An endeavor has been made to develop a unified program.

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