OCEAN CURRENTS

IN RELATION TO

OCEANOGRAPHY, MARINE BIOLOGY, METEOROLOGY AND HYDROGRAPHY.

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At the Second International Hydrographic Conference, at Monaco, in October-November, 1926, among many other interesting questions discussed, one was raised by the Delegate of Peru, who introduced a resolution calling on this Bureau to make a special study of ocean currents, but the Conference decided that this question was properly the work of the individual Hydrographic Offices themselves. The Delegate of Peru doubtless had in mind the troubles of his country in 1923 when the Humboldt current, on the west coast of South America, for some unaccountable reason, had been deflected from its regular course bringing about a sudden, temporary, abnormal and disastrous climatic change in the whole region.

The resolution made by the Committee on the "Work of the Bureau", which was adopted by the Conference on this subject, was as follows :

"Regarding the study of oceanic currents, which was suggested by the Delegate for Peru, it was generally agreed that such study should be left to the various Hydrographic Offices who were at present actively pursuing these investigations, for it was considered that such an investigation by the Bureau is beyond the capabilities of the staff."

With all due deference to this expressed view of the Conference, it would seem that the study of ocean currents is, on the contrary, largely an international rather than a national problem, and that real activity in this study is limited to a very few of the Hydrographic Offices.

In the discussion of the future work of the Bureau, two of the Delegations only were of the opinion that this Bureau should not concern itself with questions or methods of navigation, or with improved navigational instruments, other than those bearing directly upon the study of Hydrography. The general sentiment of the Conference was, however, that the work of the Bureau should not be too restricted, as it was realised that questions overlap and that in the study of kindred subjects there should be the greatest co-operation between the various international organisations.

At the Conference also Professor Odon de Buen formulated a tentative proposal of the Spanish Government that the headquarters of the International Hydrographic Bureau should be moved to Malaga, Spain. It appears that the Spanish Government has in mind the construction of three large buildings, for the headquarters of the study respectively of Oceanography, Marine Biology (fisheries) and Hydrography. There is further contemplated a conference hall for the use of the Conferences of the three organisations. It would seem desirable to include in this, or in any similar proposal, the association of Maritime Meteorology with the study of Oceanography, Marine Biology and Hydrography, as the work of these sciences overlap and their close association would produce mutually beneficial results. There already exist several organisations whose co-operation in the study of the sea would be of the greatest benefit, such as (1) the International Council for the Exploration of the Sea, (2) the Section of Oceanography of the Geodetic and Geophysic Union, which is a branch of the International Research Council, and (3) the Oceanographic Institute, at Paris, founded by the late Prince Albert I[er] of Monaco.

The *Marine Observer*, published by the British Meteorological Commitee, in London, in its issue of January, 1927, says :

"Now all good methods of accurate navigation are of great importance to Marine Meteorology because, for one thing, the better determination of the set and drift of currents is important, while astronomical observation is necessarily affected by meteorological conditions and wireless direction finding may be the more necessary because of adverse atmospherical circumstances such as fog, mist, snow or heavy rain. The "Marine Observer" reaches many seamen besides those of our regular corps. Articles by officers of ships fitted with new types of compasses, direction finders, revolution indicators, patent logs, sounding machines and so forth, besides new barometers and meteorological instruments would do more than tend to promote accurate meteorological observation, they would help to improve navigation generally, while furthering meteorology in its aid, and so we urge those who are so fortunate as to be shipmates with new instruments which they can without bias recommend as simple of manipulation and accurate in practice to contribute articles upon them. It is the expert user of an instrument whose views should count and which will be valued."

There is an insufficient knowledge of ocean currents for meteorological purposes, because these currents involve changes in surface temperatures. Possibly it is only the surface temperatures which interest meteorologists, but Oceanography requires a knowledge of the temperatures from the bottom of the ocean to the surface. Unfortunately, deep sea thermometers often fail to function and are easily broken, and they require time for lowering, hauling up, reading and re-setting for each temperature taken. There is need for an automatic thermometer to record temperatures at different depths in the ocean while the thermometer is being lowered or raised, because this would save time and increase the number of observations.

The question of the distribution of ice in the polar regions and the output is of interest from every consideration. In the Antarctic 10, 20, 30 or 40 square miles of ice sometimes will break off and float away as a single berg. This ice affects temperature and determines somewhat the distribution of atmospheric pressure throughout the whole region.

Rainfall has been predicted in Southern California from a study of the ocean temperatures of the preceding summer, but this method is absolutely unscientific. It is like predicting weather from sun spots. There are reasons for differences in the weather from season to season and from year to year, and it remains to determine the various elements which enter into the question in each and every specific case. There is a tendency to generalise from very limited data. It is thought that the elements which enter into the problem vary in percentage from time to time, but it is probable that differences in seasons are largely due to differences in ocean temperatures. In other words, as about five-sevenths of the earth's surface is water, it is not unnatural to attach the greatest importance to the oceanic distribution of temperatures to understand storms. Temperatures and salinities at sea surface, with their annual and accidental variations, must be studied as a basis of meteorological forecasts. For one thing, the whole world wants to know how tropical cyclones originate, or, in other words, what causes them to come into existence?

From what do they derive their circular motion ? What determines the direction they shall take ? This is of far-reaching importance, not only to mariners, but to people on the coast and in the interior.

Oceanography, properly considered, embraces, among other things, Marine Biology, Maritime Meteorology and Hydrography, all three of which may be regarded as affecting human existence, but, in general, Oceanography is popularly assumed to be concerned with marine biology only ; Hydrography to concern itself with questions which directly affect navigation only ; Meteorology to concern itself with a possible influence upon human activities. In a general way, however, one might say that Oceanography concerns itself with the physical features of the ocean, and Marine Biology, Meteorology and Hydrography with applied science or their practical value in the daily life of the peoples of the world. In other words, Marine Biology has to do commercially with fisheries, Meteorology with safety of life at sea and Hydrography with information of particular value to merchant shipping.

MARINE BIOLOGY.

In the chemical constituants of sea water alkalinity is of importance to animal life, either too little or too much being fatal. Other questions of importance as to the chemical constituants of sea water are the sources and distribution of oxygen nitrogen and hydrogen-ion concentration. Physical oceanography, soundings, temperature salinities and currents are fundamental to the study of marine biology as affecting life in the sea. A knowledge of the chemistry of the ocean, the contour of the bottom, the shapes of shore lines, the ocean temperatures and the movement of ocean currents are of practical value to the fishing industry.

Mr. Austin Clark, of the Smithsonian Institution, says :

" Upon what factors does fish life depend ? As an example, take the Cod. The Cod is our most important fish. Cod can exist only in cold water and then only where their food is plentiful. They feed on bottom living scavengers, mostly crustaceans and echinoderms. There must be abundant food to support the Cod. What do these feed on ? They consume mostly dead organic matter which in the cold waters frequented by the Cod is preserved as in an ice box. This dead organic matter is from two main sources. Uncountable billions of small organisms in the upper layers of water are continually dying and falling to the bottom when the larger are discovered by the scavenging croustaceans, and the smaller, mixing with the mud, are digested out of it by the mud swallowing echinoderms. What feeds these billions of small organisms? The minute plants, diatoms, peridineans, and others, form the basic food upon which the ocean life exists, with the help of sunlight forming organic out of inorganic substances. What supports these plants? Materials derived from rivers, washed out of the soil, gases taken from the air in cold rough weather, and the dead bodies of sensitive southern creatures brought up by the Gulf Stream and killed by cold? The other source of food for the crustaceans and echinoderms that serve as food for Cod is the dead bodies, sometimes the living bodies of the bottom living types, sea-fens and similar things among which they live. These are fed, however, from above. Near the coast the detritus from the sea-weeds on the shores, especially where it occurs the eel-grass, is a very important food, especially for bivalve molluscs and through them for echinoderms, crustaceans, and the Cod.

"Thus intelligently to understand the Cod, we must be familiar with the contacts of all the other creatures in the seas in which it lives; with the effect upon them of different temperatures and light; with the physical and chemical effect of storms and calms; with the quantity and quality of the nutrient materials delivered by the rivers; and with many other things."

The haphazard nature of fishing will take on a more definite commercial aspect with the study of oceanography to assist it. The NORWEGIAN Hydrographic Office produces its charts to aid incidentally the fishing industry. Such charts must be on a sufficiently large scale to show the various banks and deep waters, and should contain numerous soundings indicating the character of the bottom out to the 300 fathom limit. Rough, rocky or coral bottom has to be avoided by trawlers. The set and strength of currents over fishing areas is of importance to fishermen in setting their gear. The hand-lead is an important adjunct to the fishing business, as the character of the bottom not only checks his position, but sometimes determines what character of fishing he shall do. On Norwegian charts there are ranges which indicate to the fishing boats the location of certain particular fishing banks. The location of sunken wrecks is also important in the fishing industry as indicating good spots whereat to fish or something to be avoided. (See U.S.H.O., Pilot Charts, 1927).

The great oceanographer, Sir JOHN MURRAY, expressed his opinion that the animal and plant resources of the ocean probably exceed those of the land.

In the hope of aiding in the co-operation of the various International Organisations in the study of Oceanography in general, and ocean currents in particular, the newly elected President of this Bureau has accepted the Vice-presidency of the Physical Oceanographic Section of the Union of Geodesy and Geophysics, of which Professor ODON DE BUEN is the President. The latter informs this Bureau that, at the meeting at Prague, August 28th to September 11th 1927, of the Union of Geodesy and Geophysics of the International Research Council, there will be considered and discussed, at the suggestion of the Oceanographic Section, the question of standard methods and instruments used in the study of the sea with a view to holding an exhibition of all instruments used in the exploration of the sea. Governments, Societies and Institutions interested in Oceanography will be invited to send to the International Exhibition samples of any instruments which they may have, not only of historical interest, but those especially of more recent and up-to-date types. This Special Publication of this Bureau is issued with a view to paving the way for a much more complete and comprehensive treatment of this important question by some one better qualified to do so, and as its contribution to the Meeting at Prague in September next.

OCEANOGRAPHY.

Dr. George W. Littlehales has defined oceanography as follows:

"Oceanography comprehends investigations which deal with the form and divisions of all of the marine areas on the surface of the globe; the winds that blow over the surface waters; the contour of the ocean bed from the sea level down to the greatest depths; the temperature, density, salinity, the circulation, the physical and chemical properties of sea water; the currents, tides and waves; the composition and distribution of marine deposits; the nature and distribution of marine organisms at the surface, in the intermediate waters and on the floor of the ocean; modifications brought about in living things by the conditions of their existence; the relations of man to the ocean in the development of commerce, fisheries, navigation, hydrography and marine meteorology. All this vast assemblage of knowledge which embraces some aspects of astronomy, geography, geology, physics, chemistry and biological sciences, makes up the modern science of oceanography."

As about five-sevenths of the earth's surface is covered with the waters of the ocean; as the physical condition of these waters and their circulation largely determines the weather and climate over land areas and consequently the productivity of the soil; as the food and other plant and animal resources of the ocean at present unexploited are enormous; as these resources have not been fully used by man because of a lack of knowledge of their extent and the practicable means of applying them to economic use; as the indications are that the products of the land will not be able to keep pace with the increase in population, thus requiring a greater exploitation of the resources of the sea ; and as the first requisite to practical scientific study in oceanography is a knowledge of the shapes of the ocean basins, the contours of the bottom, and the depths of the water in different places, the practical and scientific study of oceanography should be undertaken systematically and through international co-operation.

In a preliminary way, the writer has, through the Bureau's Circular Letter N° 21-H of 5th June 1924, collected from the various Governments a terminology in each language for the submarine relief of the ocean basins, giving the officially adopted designation of the following forms : —

I. **PRIMARY OR FIRST MAGNITUDE FORMS.**

1. **Forms of the margins of the oceans :**
   Continental shelf, Continental Talus, Insular shelf, Insular talus.
2. **Depressions in the bottom of the High Seas :**
   Basin, Trough, Trench, Deep.
3. **Elevations in the bottom of the High Seas :**
   Rise, Ridge and Plateau.

II. **SECONDARY OR SECOND MAGNITUDE FORMS.**

1. **Elevations :**
   Crest, Shoal, Bank, Reef, Pinnacle and Spur.
2. **Depressions :**
   Caldron, Furrow and Valley.

The Bureau, through its Circular Letter N° 40-H of 24th December 1926, is seeking to obtain a designation, in all languages, for that part of the sea shore which lies between high water mark and low water mark of the zero of the tidal datum. All this is in anticipation of the great development in the sounding out of the floor of the ocean through the new and improved methods of echo sounding.

Dr. G. W. Littlehales says :

" In the foundation upon which the future super-structure of oceanography is to be raised, there must be a configuration of the basins which are the containers of the oceans and in other branches of science as well as in oceanography. The mapping of the two-thirds of the earth's surface which is covered with water is doubtless of an importance second only to the importance of mapping the one-third which is comprised in the land areas. Of course, it is realised that some important elements of the knowledge of oceanography cannot be ascertained in detachment from the localities to which they appertain and hence that eventually the necessities of the knowledge of oceanography will require that all parts of the ocean shall be visited for purposes of observation."

Dr. David White of the U. S. Geological Survey, said recently with regard to echo sounding and other deep sea sounding:

"A study of the detailed configuration of the ocean bottom, with the mapping of its topography, will bring to light most important facts as to the history and present movements of the floors of the existing seas. It will reach directly to one of the leading problems of geology, — that of the permanency of the ocean basins. It is generally accepted that the ocean basins are permanent. The question is subject to examination and confirmation.

"Through the detailed mapping of the topography of the ocean bottom, we will almost certainly bring to light systems of mountain ranges, ridges, terraces, escarpments, and benches, old shore lines, uplifts, submarine volcanoes, fault scarps, peneplains, *etc.*, showing deformations of the ocean bottom and indicating much of its history, particularly in later geological times. We know very well that in the Caribbean region and in the region of the Indian Ocean there are sedimentary formations, of which fragmentary samples are now uplifted and exposed, laid down at different geological periods. There is a great land mass or continent within the area of Malaysia, now mostly under the sea. It is folded and terraced and is now undergoing deformation. The proposed mapping should give us the data from which to work out portions, at least of the history of the changes in shape, size and in depth of the oceanic basins, all of which are determined by deformation and uplifts or subsidences of the land masses which underlie and border these basins.

"Submerged shores, — *i. e.* drowned coast lines and beaches, are known to be present. These bear an important relationship to the raised and exposed shore lines, benches and peneplains, and form part of the history of the continental movements. Some of these movements are relatively recent and are even now in progress. They are tremendously important as bearing on continental configuration, ocean currents, land connections present and past, past and present climates, and the distribution of life in former periods, as well as at the present day.

"The detailed mapping of the bottom of the seas should furnish invaluable data not only as to former land connections effected through changes of the shore lines or by uplift of one area or another, but as to the changes in the epi-continental seas in regions now submerged; also as to oceanic currents and inter-oceanic connections during the past, by which marine life migrated during one period or another, and by which the present distribution of sea life is accounted for. It will at once be seen that these studies must have an important bearing, both upon the climates of the past and upon present climate. They should go far toward explaining the relatively equable climatic conditions of the Tertiary, as well as of certain periods earlier in geologic time. They should open the door to the better understanding of the phenomenal distribution of the ancestors of the living mammals and land plants, extending into the polar regions in periods as recent as the Miocene. The question bears upon continental outlines, character and extent of oceanic currents, relative elevation or even the absence of mountain chains now existing, the former existence of mountains that have disappeared and the extent and drainage of the epi-continental seas. It will be recalled that we are now in a period of approximately maximum elevation of mountain ranges, such as the Cascades, the Andes and the Himalayas; that the continents are, in general, largely emerged, the coast lines being driven far out toward the edges of the continental shelves, and that the epi-continental seas are largely eliminated. Coast lines are moving upward or downward in different parts of the world, probably with greater activity than is geologically normal. The mid-Atlantic coast and the Gulf coast of North America is subsiding. The Mississippi embayment is undergoing depression and possibly, faulting. An intensive study of this embayment may result in information leading to modifications in the policies of Mississippi River improvement and flood control.

At a Conference on Oceanography which was held in Washington in 1924, the following problems were considered as important to take up in any oceanographic study or by any expedition, governmental or otherwise, that might be organised in the future :—

"The shapes, contours and depths of ocean basins; the distribution of temperatures, densities and salinities on the surface and in the depths of the oceans, together with the periodic or other changes which occur; evaporation and precipitation (rain, fog, snow) over sea and land areas; the distribution and periodic changes in atmospheric pressures and winds; the ocean currents and the vertical circulation of ocean waters; the chemistry of sea-water, the hydrogen-ion concentration, and the sources and distribution of nitrogen, *etc.* in the sea; the changes in the size and shape of the bottoms of the seas, such as shifting of shore lines, warping of the margin of the continents and submarine upheavals and dislocations; nature and composition of the formation of the sea bottom; previous land connections, and changes in existing connections between continents; areas and features of submarine volcanism and earthquake movement; sedimentation; the penetration and diffusion of light in sea water under various conditions and its bearing on plant and animal life; the distribution of the intensity of gravity; the distribution, relative abundance and inter-relation of the various forms of plant and animal life; visibility under different conditions of the atmosphere; height, length and velocity of ocean waves and location and extent of fields of static and electro-static disturbances and investigations of other forms of atmospheric electricity."

EXPLORING EXPEDITIONS OF THE LAST 50 YEARS.

During the last 50 years or more the following oceanic explorations have taken place. They are given in the form of a table, showing the names of the countries of origin alphabetically arranged, names of vessels engaged and duration of the explorations. The summary shows that all of them had their inception subsequent to the year of 1868. Some of then circumnavigated the globe, and all of them covered a wide geographic range :—

Austria :
Pola (1891-1910).

Belgium :
Belgica (1897-9).

Denmark :
Ingolf (1895-6).

France :
Travailleur (1880-3).
Talisman.
Caudan (1895).
Français (1903-5).

Germany :
Gazelle (1874-76).
National (1889).
Valdicia (1898-9).
Helgoland (1898).
Gauss (1901-3).
Planet (1906-14).

Great Britain :
Lighting (1868).
Porcupine (1869-70).
Challenger (1873-6).
Investigator (1887-1902).
Discovery (1901-4).
Peake (1901).
Scotia (1902-4).

Holland :
William Barents (1878-84).
Siboga (1899-1900).

Italy :
Washington (1881-2).
Vettor Pisani (1882-5).

Principality of Monaco :
L'Hirondelle (1885-8).
Princesse Alice I (1891-7).
Princesse Alice II (1895-1916).

Norway :
Voningen (1876-8).
Fram (1893-6).
Gjoa (1903-5).
Michael Sars (1900-20).

Russia :
Vitiar (1894-95).

Sweden :
Vega (1878-80).
Antactic (1901-3).

United States :
Albatross (1883-1920).
Blake (1876-97).
Narragansett (1871-3).
Tuscarora (1873-6).
Thetis (1895).
Nero (1900).

A CRUISE OF THE "ARMAUER HANSEN" IN THE EASTERN NORTH ATLANTIC.

In a book entitled "*Eastern North Atlantic*", recently published in Oslo, in 1926, the scientific results of cruises made by the ARMAUER HANSEN, in 1913, 1914, 1922, 1923 and 1924, are published. These cruises extended as far south as Madeira and to longitude 30° W., some 700 miles to the westward of Ireland. The ship was a small yawl of 56 tons burden with auxiliary motor only used occasionally. The oceanographical observations were mainly made by HELLAND-HANSEN, but previous cruises of Dr. NANSEN, in 1910, in the "FRITHJOF" are embodied in the book. Dr. NANSEN found water of Mediterranean origin mixed with the Atlantic Sea water as far north as Ireland. From the density of the water, currents were calculated for different water layers by means of Bjerknes' theory and are shown on a number of charts, and during the course of 1913 cruise some interesting current measurements at various depths were made from an anchored boat on the banks around Rockall, an isolated rock some 200 miles north-west of Ireland. At a depth of 2 metres a rotary tidal stream was found continuously varying and completely reversing every six hours, the type of tidal stream which is characteristic of the sea over isolated banks. These tidal streams were complicated by wind drift of the uppermost water strata superimposed upon the tidal streams.

Coast Guard Bulletin N° 14, dated December, by Lt. Commander E. H. SMITH, U. S. Coast Guard, published by the Government Printing Office at Washington, is entitled *"A Practical Method for Determining Ocean Currents,"* and is a very valuable treatise because it has been compiled from a series of lecture notes made by its author when taking an advanced course on Oceanography under Prof. BJORN HELLAND-HANSEN, Geo-Physical Institute, Bergen, Norway. The work is based upon "*Dynamic Meteorology and Hydrography*" by Prof. V. BJERKNES, published by the Carnegie Institution, Washington, 1910-11. A copy of the Coastguard Bulletin N° 14 should be in the hands of all who are interested in the origin and method of observing ocean currents.

THE GERMAN SOUTH ATLANTIC EXPEDITION ON BOARD THE "METEOR".

The work of the German South Atlantic expedition on board the "METEOR" in almost entirely limited to hydrographical and meteorological observations, made at numerous positions between South America and Africa, the various positions being chosen so as to allow the best use to be made of Bjerknes' theory in calculating currents at various levels of the consequent circulation of the water masses. Besides these, numerous observations have been made at a number of other positions on the voyage out from Germany.

With regard to scope of observations, besides the distribution of temperature and density, from which the probable circulation of water in the ocean will be calculated, observations of hydrogen-ion concentration, of the oxygen, carbon dioxide, gold, silver, phosphate and nitrate content of the water are provided for, and a method has been devised and used for measuring the rate of evaporation from the surface of the sea. Measurements are made of the waves encountered by a stereophotographic method, and echo-soundings are carried out by three different systems, from the results of which the production of a very complete bathymetric chart will doubtless be possible. Microplankton organisms collected at the various stations are being examined and their quantity measured on board. Regular meteorological observations are made on board and to a height of above 15 kilometres by means of pilot ballons and kites, while at the various ports visited the local geological formation has been investigated.

OCEANOGRAPHIC CRUISES OF THE "POURQUOI-PAS ?".

From 1920 to 1926 the French undertook a series of cruises for the scientific exploration of the sea, using the vessel "POURQUOI-PAS ?" under the command of Docteur CHARCOT. The operations took place principally in the Channel, in the North Atlantic and on the Porcupine and Rockall Banks. Details of these cruises have been given in the *"Annales Hydrographiques"* under the title of *"Rapport Préliminaire sur les Campagnes effectuées par le "Pourquoi-Pas ?", (Preliminary Report on the cruises undertaken by the "Pourquoi-Pas ?")*. (See Volume for 1923, pages 99 to 155, and Volume for 1924, pages 1 to 89).

A model of oceanographic research is that which has taken place recently in the Sea of Japan, a report of which has been published by the Imperial Fisheries Institute, in August, 1926, at Tokio, entitled *"Annotation of the Oceanographical Research"*, Vol. 1, N° 1. This report outlines the "Hydrographical features of the Japan Sea," and is edited by Prof. H. MARUKAWA and T. KAMIYA, the former of whom studied oxygen quantity, the hydrogen-ion concentration and the plankton. The whole report embodies the results of oceanographical and fishery investigations in collaboration with the Hydrographic Office of the Japanese Navy Department; and incidentally describes the form of the Japan Sea basin and the northern and southern outlets. The study discloses that over half of the basin is deeper than 2,000 meters; that the straits which connect it with the other seas and with the Ocean are very shallow and narrow; and that, in the middle part, from the south to the north, there lies a great submarine ridge. The report describes the various currents of the Japan Sea and its outlets; the distribution of water temperature and specific gravity; the distribution of oxygen and hydrogen-ion concentration, and the plankton. The report is published in English, is accompanied by numerous plans and is a model form for such research. It reflects great credit upon the scientific attainments of the Japanese who have been engaged upon this work.

In a study made by the Hydrographic Department of the Imperial Japanese Navy, in July, 1926, a model, in relief, was made by the Tugaru Kaikyô. It is a "U" shape strait, 60 miles in length and from 10 to 15 miles in breadth, connecting the Sea of Japan with the Pacific Ocean. The currents in this strait are oceanic and tidal, and are very complicated. The oceanic currents being generally stronger than the tidal, the currents almost always flow to the East at a velocity varying with the phase of the tides, the maximum velocity being about 6 knots. The results of a survey made from June to September 1924, were studied and checked by means of a model on a scale of 1/150,000. This model was immersed in a large rectangular tank (1 m. × 1 m. 5), filled with water up to the water-line of the model. To give motion to the water in the tank, a fresh supply of water was poured into the tank at its western end from another tank by syphons at a constant rate. A quantity of fine aluminium powder was scattered over the surface of the water to observe the motion of the water, and photographs were taken of the tidal stream.

We are here, however, concerning ourselves principally with ocean currents.

CAUSES OF OCEAN CURRENTS.

The restless sea is never still and even in the calmest weather silent forces are operating to keep it in motion. There is a tendency to attribute the movement of ocean currents to some one predominant cause, whereas the question is really a complicated one requiring scientific investigation based on adequate data. Many of the world's great minds have pondered the question. Leonardo de Vinci attributed ocean currents to differences in the temperature, and in the density of the water. Benjamin Franklin mapped the Gulf Stream in 1812 and outlined its causes. Alexander von Humboldt, in 1816, ascribed ocean currents to differences in temperature and densities ; to the periodic melting of polar ice ; to variable evaporation of different areas of the ocean surface ; and to differences in atmospheric pressure. Commodore M. F. Maury contributed much to the world's knowledge of ocean currents by the methods of observation he so successfully inaugurated. Since his day the problem has been studied by many able minds, but the cry is always for more definite data.

In considering the causes of ocean currents we may divide them into two groups, those within the water itself, *viz.* variations in density, temperature and salinity, caused by the heat of the sun, evaporation, rainfall, rivers, melting ice, *etc.*, and those from without, such as atmospheric pressure, friction of the wind, attraction of the sun and moon, rotation of the earth and geographical configuration of the coast lines. Then we must consider that sometimes the causes of ocean currents are working against and modifying each other, and at other times operating in conjunction with each other.

It would be valuable if we could assign percentages, or the proportion, in which the causes of ocean currents act in producing each of the great permanent currents of the ocean, such as surface friction of the prevailing winds causing motion in the surface layers of the water ; atmospheric pressure ; rotation of the earth ; difference in temperature of the sea water in the vertical and horizontal planes ; salinity or differences in density or specific gravity ; daily ocean tides ; evaporation ; fresh water from rivers or from polar ice, *etc.* Such a treatment of this question can only come about through the co-operation of various Governments or international organisations in collecting further data as to the basis for this study. It is not a question for Hydrographic Offices but the League of Nations, through one of its active Committees, might contribute to such organisation.

The set and drift of ocean currents has been mapped in a general way from records of the drift of bottles, wrecks and icebergs, but especially from reports of masters of ships, giving the differences between the dead reckoning and the observed positions as probably due to ocean currents. Of course, in these differences are included errors in navigation, errors in the patent log, variations in the speed of the ship, leeway, poor estimate of the distance run, foul bottom of the ship, *etc.*, not due to ocean currents. There remains a mass of such data in existence in various countries, consisting of extracts from ship's logs, which has never been tabulated owing to lack of money to employ the necessary staff to plot the data. It would be interesting and valuable to this Bureau to get a statement from every country or organisation of what data it has in its possession, which has not, so far, been thus utilised, because what has been accomplished from this source may be considered only as a reconnaissance. Very much remains to be done. The problem is an international one, and hence largely concerns this Bureau.

Accompanying the vertical rise and fall of the sea due to the attraction of the sun and moon, a horizontal movement also takes place, known as tidal currents. These are of several types, such as rectilinear or reversing type, (such as in most inland bodies of water) ; the hydraulic type, such as those in straits connecting two large bodies of water ; the rotary type, such as are found in the open sea and along the coasts ; wind driven currents of a temporary nature, produced by the effect of friction of local winds on the surface of the water, which are so frequently upsetting to navigation, and, lastly, the permanent currents and counter-currents comprising the main oceanic circulation. The tidal currents are periodic, while the permanent and counter currents are due to definite and persistent causes. It is desired to know exactly what are these causes and how far they enter into and complicate the periodic tidal currents to produce occasional or accidental currents, which are so puzzling and dangerous to the navigator, and it is in this field that the most promising and important work of the Hydrographic Offices of the various countries would seem to lie. The JAPANESE Hydrographic Office is engaged in a careful study of these wind driven coastal currents from Sakhalin Islands to Hong-Kong, the results of which are published monthly. The Coast and Geodetic Survey of the United States has for some years past been making observations from light vessels stationed along the coasts which show that with wind driven currents there is a deflection to the right of the wind direction and that the velocity of the current varies proportionately with and is from 1½ to 2 % in knots of that of the wind velocity. The direction is, moreover, modified by the bottom configuration, by bottom friction and by the form on the coast line. The general law so far deduced is that, on the Pacific coast, the current velocity is about 2 % in knots of the wind velocity, and, on the Atlantic, 1½ %, while on the Atlantic coast the current, instead of setting with the wind, sets about 20° to the right of the wind direction, and on the Pacific coast about 15° to the right.

The collecting of data as to currents and the heavy expense in publishing current observations results in very few current tables and current predictions being issued by the various Hydrographic Offices of the world, but navigators, in coastal waters, should always study the tide tables as indicating the probable direction of the flood and ebb tidal currents, while duly taking into consideration the direction of the wind as affecting them. For instance, the U. S. Coast Survey makes current predictions and publishes, in advance, annually, current tables for the Atlantic and Pacific coasts of the United States, containing, in addition to data on coastal currents, the predicted times of slack water for every day of the year at 19 important stations in inland waters where the velocity of the current is considerable. Time differences are given, by means of which the mariner may determine the time of slack of the current at some 1,100 other places by reference to one of these 19 standard stations.

Of course, one of the best known ocean currents is the Gulf Stream, and the writer can recall, as a youth, being thrilled by MAURY's

Physical Geography of the Sea, which commenced with these graphic words :

"There is a river in the ocean. In the severest drought it never fails and in the mightiest floods is never overflows. Its banks and its bottoms are of cold water, while its current is of warm. The Gulf of Mexico is its foundation, and its mouth is in the Arctic Seas. It is the Gulf Stream. There is in the world no other such majestic flow of waters. Its current is more rapid than the Mississipi or the Amazon, and its volume more than one thousand times greater."

This pioneer book of Commodore MAURY has been the inspiration for study and research which has profoundly influenced the maritime world, just as Admiral MAHAN'S *"Influence of Sea Power"* has influenced the study of history.

As has been previously stated, it would be valuable if we could assign percentages to the various causes of each great ocean current, but as this is not practicable, with our present knowledge, it may be well to outline briefly some of the elements of the problem.

THE INFLUENCES OF THE EARTH'S ROTATION.

Both currents of air and currents of sea water are affected by the earth's rotation, those in the Northern Hemisphere being deflected to the right, and in the Southern Hemisphere to the left, the deflection varying with the latitude, the maximum being at the Poles, and minumum at the Equator. The difficulty in determining the direct influence of the rotation of the earth on ocean currents is complicated by tidal effects, by wind friction and by coastal configuration usually entering into the problem, but observations of such influence have been made in both the Baltic and in the Mediterranean, where some of these other causes have been occasionally eliminated by favourable conditions. One of the best illustrations of the influence of the coast line on ocean currents is that of the Gulf Stream, or Florida current, which originates in the region of the North East Trades, (known variously as the Northern Equatorial Current, Caribbean Current, Florida Current and the Gulf Stream), and which passes parallel to the North coast of South America, through the Leeward Islands of the West Indies into the Caribbean Sea, and the Gulf of Mexico, emerging into the North Atlantic between Florida and Cuba.

The temperature of the Northern Equatorial Current is raised by the direct heat of the sun in the Caribbean Sea and the Gulf of Mexico, but how far the difference in temperature accounts for the increase in velocity of this ocean current is a problem which would be interesting to determine, because much increase in velocity must be due also to the configuration of the Gulf of Mexico and other causes. The Northern Equatorial Current only averages about 10 miles a day, whereas in the narrowest part of the Florida Straits the so-called Gulf Stream reaches a velocity of from 100 to 120 miles per day, which is that of the swiftest river of the world, but there are periodic variations in direction and strength of the current at this point due to the phases of the moon, the greater declination of the moon changing the axis of current to the left, and the lesser declination changing it to the right. With higher declination the current broadens, and with lesser declination it contracts. When the current broadens there is a decrease in temperature and *vice versa*. With prevailing northerly winds the force of the current is much increased, but with a barometric depression over the Gulf of Mexico, the reverse is the case and the water rushes into the Gulf of Mexico. Northerly winds are met with when there is a barometric maximum over the Gulf of Mexico, or over Texas or Louisiana. Further observations and study are required.

According to BENJAMIN FRANKLIN, trade winds force the Northerly Equatorial Current through the Caribbean Sea and the Gulf of Mexico, out through the Florida Straits into the Atlantic. Other theories claim that the Florida current, or Gulf Stream, is due primarily to the differences in density between the Gulf of Mexico and the neighbouring oceans. As the Gulf Stream comes north into the Atlantic along the coast of the United States, it follows the 200 meter curve, and is bounded on the left hand by a cold wall of water, sharply marking both in temperature and colour the exact edge of the Gulf Stream, but, on the other hand, the right hand limit of the current is not so well defined either in temperature or colour.

THE PART PLAYED BY DENSITY.

The cold surface waters of the polar regions sink to the bottom of the ocean on account of their greater density. This bottom layer moves towards the Equator, while in the tropical regions the heated surface waters move towards the Poles.

The evaporation of the surface water in the equatorial regions increases the density of the sea water and this contributes to the flow of the equatorial currents. At depths of 2.000 fathoms and over the waters of all oceans are very cold and but little above the freezing point of fresh water; the theory being that there are submerged polar currents much below the surface. Dr. JENKINS, in his *"Text Book on Oceanography"*, says :—

"As a rule currents in narrow waters connecting oceans and seas are due to differences in sea-water density. In high latitudes, where the rainfall is high and evaporation relatively low, fresh water plays a part, causing a raising of the water-level. The converse holds good in lower latitudes. In the absence of wind and tide — *i. e.*, on quiet days at neap-tides — two distinct currents are observed in narrow straits, the upper moving to the region of water of higher density; that is, in the Straits of Gibraltar and Bab el Mandeb from the ocean to the sea, and conversely in the Bosphorus and Cabot Strait. The rotation of the earth causes a deflection of the stream to the right in the Northern Hemisphere, so that in the Straits of Gibraltar it is bent to the Moroccan coast.

"In most straits, especially those which open to the ocean, there are strong tides, and these tend to obscure the currents. Observations for the determination of a current should extend for a period of thirteen hours, to cover a complete tide."

Dr. H. B. BIGELOW, of Harvard University, said recently :—

"The two most important things to find out about are temperature and salinity or density. If you get the temperature and the density of the whole mass of the ocean from the top to the bottom you have a very good start, because by the temperature a great many things are determined, and by the salinity the weight of the water is determined. Ocean current are primarily determined by the weight. It was a theory at one time that ocean currents were determined by the wind, but primarily they are determined by the distribution of weight."

PART PLAYED BY ATMOSPHERIC PRESSURE.

When considering the action of wind as causing surface currents by friction, the barometric pressure of the atmosphere is a further factor in causing ocean currents. When the barometer rises on board ship at sea it causes increased atmospheric pressure and the sea level will necessarily be lowered about 20 times the rise of the mercury. Naturally, there cannot be increased pressure over one region of the ocean without a corresponding decrease somewhere else, and any depression of the water level must be accompanied by a similar rise in some other quarter. How far this causes ocean currents to flow is an unsolved problem, but it probably only has a slight effect, except where coastal configuration lends its aid.

The influence of the wind in causing ocean currents by its friction on the surface of the water is well recognised, although there are ocean currents which flow against the prevailing winds. The generally accepted theory is that currents caused by wind friction are only some 5 or 6 fathoms deep.

PART PLAYED BY TEMPERATURE.

One of the pecularities of ocean currents is that each particular one has marked special features of temperature and salinity, which vary but little over wide limits, and which enable these currents to be detected by the sudden differences in the surface temperatures and densities. While the surface of the ocean is heated by the rays of the sun in the daytime, a great deal of this is radiated at night, and therefore the difference in temperature between an ocean current and the adjacent waters is not influenced by the daily heat of the sun, because it affects both equally. The temperature found in ocean currents is not due very much to the daily heating by the sun, but largely from heat acquired at the source of the current contributing to its formation. Temperature influences the density of sea water and undoubtedly causes a vertical motion as well as a horizontal one. Only in the greater oceanic depths, where the salinity of large volumes of water is practically constant, is there any marked variation in density due solely to changes in temperature. Unquestionably changes in salinity are more effective than temperature changes in setting up ocean currents, for a rise in temperature brings about a decrease in density.

PART PLAYED BY THE WIND.

Many authorities attribute ocean currents principally to the effect of the friction of the wind on the surface layers of the ocean, and yet it must be noted that ocean currents sometimes run contrary to the direction of the wind. Unquestionably, wind friction is one of the factors in producing coastal and ocean currents, just as the tides also have their influence, but it remains to be determined, by scientific investigation, just what part wind friction plays.

A very interesting practical application of knowledge of ocean currents was given recently by Major General Edgar Jadwin, Chief of Engineers of the U. S. Army, as follows :—

"In planning harbour entrances on sandy coasts we must take into consideration the direction of currents and the direction of winds, in order that the entrance jetties may be designed and constructed so as to either catch and hold as much of the littoral sand drift as possible, or divert it past the harbour entrance and thus prevent the shoaling of the channel through sand movement. The making of harbour plans is also affected by cost of the work, and instances in which prevailing current and wind directions are of importance in that connection are found in designing harbours where the physical conditions or funds appropriated require that the entrance jetties shall be placed close together. Adverse winds or currents at a narrow entrance of this kind may give an entering ship an unfavourable direction with the possibility of its landing on a jetty. It is essential, therefore, in such instances, to obtain all information possible relative to the normal directions of winds and currents, in order to so locate the jetties that adverse entrance conditions shall be eliminated, or be experienced for periods of minimum length."

Hydrographers are much indebted to harbour engineers for their studies of local currents as affecting construction work, and much data has been collected on this subject. A study of ocean currents is also important in the question of sewage disposition. Many valuable beaches have been ruined by deposition of waste fuel oil and sewage. As has been shown, currents also affect the fishing industry.

In this brief summary of Oceanography, only the main outlines have been considered as the subject is very broad and covers many ocean studies. Progress in our knowledge has come through economic and political adventure, as well as through conscious and deliberate scientific exploration. While the geological history of ocean basins, their geophysical constitution and the anthropological history of the oceans are all interesting, the value of oceanography in its economic relations to man justifies international co-operative exploration, both from a scientific and a practical standpoint. As a first step in international co-operation it is wise to consider the instruments used in the exploration of the sea, with a view to securing the latest and most effective instruments. For instance, it is difficult to compare the results obtained by the use of various types of current meters, and therefore standard instruments and standard methods will give an international character to individual observations. In furthering the purpose of the meeting in Prague, the following partial and imperfect list of instruments used in marine observations is submitted.

OBSERVATIONS BY A SHIP AT ANCHOR.

A ship at anchor may make the following observations: (1) Depth, (2) Direction of the current, (3) Velocity of the current, (4) State of the sea, (5) Transparency and colour of the sea water, (6) Quantity of solid material in suspension in surface water, (7) Quantity of solid material in suspension in deeper water, (8) Salinity of the surface water, (9) Salinity of the deeper water, (10) Temperature of the surface water, (11) Temperature of the deeper water, (12) Plankton in the surface water, (13) Plankton in the deeper water, (14) Temperature of the air, (15) Barometric pressure, (16) Direction of the wind, (17) Velocity of the wind, (18) Humidity, and (19) Observation of the upper currents of the air by pilot balloons.

CERTAIN INSTRUMENTS USED IN THE EXPLORATION OF THE SEA.

This list does not include instruments used in navigation, in the study of meteorology, in geodetic or marine surveying, or in the study of marine biology, but only those instruments with which we may measure the physical and chemical properties of the sea ; the contours of the ocean basins and beds ; the currents, tides and waves ; the composition and deposition of marine sedimentation, or in general with the topography, geology, physics and chemistry of the ocean. The data as to the instruments which should be used, and the new and improved ones needed are set forth in the form of a questionnaire.

QUESTIONNAIRE.

It is hoped that whoever reads this and can contribute answers to the questions propounded will send them to the International Hydrographic Bureau, with a view to submitting them to the Conference, at Prague, in September, 1927, and especially to assist in the standardising of the methods and results of oceanographic exploration.

I. Instruments used in Ascertaining Ocean Currents.

DRIFT BOTTLES.

(1) What is the best type of drift bottle, and is a new type needed and if so, why ?

Drift bottles, suitably weighted with sand, or otherwise, so as to float just immersed, and containing addressed postcards asking the finder to return them stating the locality and date of finding, have been issued by many organisations for use in ascertaining the drift of ocean currents. Floating bottles have long been used by distressed mariners to give information as to accidents which have befallen them in a given geographical position. All such bottles are liable to give erroneous, or incorrect, or incomplete information due the elapsed time, because (1) they have not drifted in a straight line; (2) if the bottle projects from the water it comes under the influence of the wind; and (3) coming under the influence of various currents, it zig-zags considerably in its course. The late PRINCE ALBERT of Monaco distributed 1,675 weighted bottles of the Richard type in the North Atlantic Ocean in 1885-88, and of these only 227 were recovered. As interesting experiment was made by releasing 10 drift bottles simultaneously from a position in latitude 1° 44 N., longitude 26° 16' W., of which only two were subsequently found, one after 377 days on the east coast of Nicaragua, and the other 196 days after, not far from Sierra Leone on the African coast. The Spanish Institute of Oceanography employs two drift bottles, the lower one being suspended vertically by a long cord from the one floating on the surface, thereby minimising the effect of the wind on the surface bottle. Drifting wrecks, which are charted from reports of shipping to the various Hydrographic Offices, have also furnished some data as to ocean currents but most of these data are unscientific. Valuable results can only come from such scientific work as that now being undertaken by the German "METEOR," or similarly by organised and well equipped expeditions.

The following is the information contained on the bottle paper used by the U. S. Hydrographic Office, Washington:

"(Please use lead pencil). Thrown overboard by (Give name of master or observer); Name...., Vessel...., Date...., Latitude...., Longitude.

"*Instructions to finder:*

Trouvé par (indiquer le nom, date et lieu).
Gefunden von (mane gebe Namen, Datum und Ort an).
Gevonden door (men geve naam, dagteekening en plaats op).
Trovato da (dare il nome, data e luogo).
Hallado por (dar el nombre, fecha y paraje).
Achado por (dar o nome, data e paragem).
Trovita de (skribu nomon, daton k. lokon).
Finder...., Date...., Locality...., Post-office address of finder.

"The finder of this will please send it to any United States Consul, or forward it direct to the Hydrographic Office, Navy Department, Washington.

La personne qui trouvera ce papier est priée de l'envoyer à un Consul quelconque des Etats-Unis, ou de le faire parvenir directement à la Section d'Hydrographie du Ministère de la Marine à Washington.

Der Finder Dieses wirdersucht es irgend einem Konsul der Vereinigten Staaten zuzusenden, oder es dem hydrographischen Amte des Marineministeriums in Washington direkt zugehen zu lassen.

De vinder van dit papier wordt verzocht, het tot een Consul dér Vereenigde Staten, of rechtstreeks naar het Hydrographische Ambt des Departments van Marine te Washington te zenden.

Chiunque trovi questo è pregato d'inviarlo a qualche Console degli Stati Uniti d'America, o di farlo pervenire direttamente alla Sezione d'Idrografia del Ministero della Marina a Washington.

Se suplica á la persona que hallar esto que lo envíe á algun Consul de los Estados Unidos de América, ó que lo remita directamente á la Seccion de Hidrografia del Departamento de Marina en Washington.

Rogo-se á pessoa que achar isto o favor de o enviar á um dos Consules dos Estados Unidos da America, ou de o encaminhar directamente a Seccão de Hydrographia da Reparticão da Marinha em Washington.

Oni petas ke la trovanto sendu la paperon al iu Amerika Konsulo, au rekte al Hydrographic Office, Washington, U. S. A."

FLOATS.

There are two classes of floats used in measuring the strength and direction of ocean currents, (1) those with a line on them which are put out for a certain time and of which the float is pulled in and recovered after the observation, and (2) liberated floats, whose position is plotted out at intervals for direction and the distance observed by instruments. These methods are particularly applicable from observations from lightships or other anchored vessels.

(2) Do you prefer the float and attached line type, or the liberated type of float, and which particular kind of either ?

In the first class the float, or current pole, is attached to a line which measures the distance run in a given fraction of time, the direction of its movement being observed by a compass. The line unquestionably retards the movement of the float and gives only an approximate result.

There are many types of the second class, or liberated floats. The "CHALLENGER" Expedition used a current drag of metal plates at right angles supported beneath the surface by a line attached to a buoy floating on the surface. The buoy in this type is always as small as possible to sustain the weight of the drag and to offer as little resistance to the wind as possible. With this type the result obtained may be the resultant of a surface current carrying the buoy in one direction and a deeper current affecting the drag in another direction. There is also some friction due to the suspending line retarding the motion of the drag.

Another type is the Mitchell coupled float. With this system of double float, the upper float is of the same superficial area as the similar one suspended below it, and two or more of the surface floats may be tied together by a line so as to get the resultant of a number of current impulses. There are several varieties of this type of coupled float, either in the form of bottles or of barrels in which the principle of the equal superficial area of the two floats is maintained. The advantage of this type is that the line supporting the lower float may be varied in length to get the average of the velocity of currents at different depths.

A further variation of the current float is one in which observations are made from a fort on shore, using the range finder to plot the position of a liberated float at frequent intervals. This method was used by the Germans during the War on the coast of Belgium to get data for floating mines, submarines operating, *etc.* The float may be kept in sight for a distance of at least 15 kilometers and accurate results may be thus obtained through long periods of time.

The current float used from a ship naturally requires that the ship shall be anchored. The same is true if a current meter, or other form of measure, is used. Anchoring in mid-ocean is a difficult and dangerous operation, the usual method being to anchor by means of wires attached to weights, using at least three separate wires to keep the ship steady in position. When a ship is anchored in a current and uses only one wire, the observations are practically useless because the ship yaws continuously. It is found that it takes at least three anchors and wires to keep her steady.

PITOT TUBE.

The principle of the Pitot tube is that of a glass or metal tube bent at its lower end at right angles and with a very small aperture at the said lower end. When inserted vertically in the water the level of the water in the tube above or below the surface of the ocean indicates the pressure or suction exerted by a current passing the small orifice on the lower end of the tube. The principle of the Pitot tube is used also for speed indicators for vessels.

(3) What do you consider the best type of Pitot tube and what do you think of it as a method of estimating the velocity of currents ?

CURRENT METERS.

Among the many mechanical current meters we may mention the following types, the list not being by any means complete :

Aimé, Amsler, Arwaidson, Boccardo, Buchanan-Wollaston, Chernikeef (electric log), Ekman, Fleuriais (electric log), Gurley accustic type and Gurley electric type, Harlacher, Makaroff, Pillsbury, Thoulet and Woltmann.

Many of the above instruments are now only of historical interest, as the useful principles which they have developed have been embodied in more recent designs. That of Makaroff was designed by the late Admiral MAKAROFF of the Imperial Russian Navy, when he was a young officer on board the Russian station ship at Constantinople and wishing to observe the currents of the Bosphorus. The deep sea current meter used by Lt. PILLSBURY, U. S. N., for current observations in the Gulf Stream, which he devised in 1876, is thus described in "*Wharton's Hydrographical Surveying*".

> "The instrument is first lowered to the required depth, and when ready is put into action by means of a heavy weight, or messenger, travelling down the supporting line and striking on a metal plate, thus closing the jaws of the levers and enabling the instrument to begin working. The rudder is then free to revolve inside the framework and take up the direction of the current; the small cones can revolve on their axes and register the number of revolutions, while the compass needle is released and free to take up the north and south line. On the despatch of a second messenger, which strikes on the top of the first and forces the jaws of the levers open, every part of the machine is simultaneously locked. Having noted the exact time of starting each of the messengers, the time during which the instrument has beep working at the required depth is known, and from this the velocity of the current can be calculated, the number of revolutions having been recorded, while the direction is shown by the angle between the compass needle and the direction of the rudder."

The late Admiral PILLSBURY, as a Lieutenant commanding the "BLAKE" for making observations in the Gulf Stream, anchored her with three wires to keep her steady, in position. His experience and methods have been very useful in making subsequent observations. Several of the above-named meters are now in use and giving excellent results. There is, on the market, a new Swedish type of current meter which "will record observations for a period of two weeks without attention, recording the observations photographically each half hour. This meter has been used in Sweden at the depth of 400 meters". The latter is a distinct advance on all other mechanical recording types.

(4) What is the best type of mechanical recording current meter, where can it be purchased and at what price?

WIND FRICTION.

One of the causes of ocean currents is that of winds on the surface of the water causing the upper layers to slowly take up its motion and approximate direction through friction. The observation of the force of the wind is a meteorological problem and is usually made by an anemometer of some sort.

(5) What is the best instrument or means of determining the velocity of the wind at sea as affecting ocean currents?

II. Methods of Sounding.

LINE SOUNDING.

In the development of methods of ascertaining the depth of the sea progress has been very gradual, from the hand lead to the deep sea lead and then to the piano wire and windlass type of deep sea sounding machine. In the various types of the latter it is necessary to detach the weight or lead on striking the bottom in order to shorten the time and lessen the work of recovering the line or wire. In all cases of such sounding it is sought to obtain at the same time a specimen of the bottom. With the hand and deep sea leads this has been accomplished by what is called "arming the lead", *viz.* filling a conical cavity in the bottom of the lead with mutton tallow to which a sample of the bottom adheres to be brought to the surface for examination. With the heavier types of lead for deep sea sounding, first of all with hemp lines, various devices were used on the heavy end of the lead, such as a metal cap, to bring up a sample of the bottom. This was the system used by the "CHALLENGER" and the "GAZELLE", but, in 1854, Lt. J. M. BROOKE, U. S. Navy, invented a cylindrical metal tube cup, which projected some inches through and below a cylindrical hole in the solid shot, which, on a striking the bottom, automatically drove the cup into the bottom and detached the shot leaving it on the bottom, while the cup automatically opened and closed bringing up a sample of the bottom. This question of obtaining bottom specimens in sounding is alluded to here to emphasize the fact that, in echo sounding, no information as to the character of the bottom is obtained.

The WILKES' Expedition, in 1840-3, was the first to employ copper wire for sounding, and steel wire was used as early as 1845, while Sir WILLIAM THOMSON later perfected the type of three strand galvanised wire used in his famous and popular sounding machine. Prince ALBERT of MONACO, in the " HIRONDELLE " used a three strand galvanised steel wire of $2^3/_{10}$ m. m. diameter with an accumulator or dynamometer to take the strain off it, but piano wire is now used in all types, and flexible wire is gradually replacing hemp for hand and deep sea leads, as it does not shrink or vary. Among the best known sounding apparatuses are the Bassnet, Belloc, Clausen, Harpoon, Le Blanc, Lucas, Sigsbee, Tanner and Thomson, and the following are some of the types of sounding apparatus which depend upon the principle of compression of air in a sealed receptable : the Hales, Desaguliers, Ericson, Hund, Zigler, Oersted, Jolly, Bamberg, Thomson and Warluzel. There are other types which are on the pressure principle of the Aneroid barometer, the Bourdon tube and the manometer. The advantage of the wire system is that it enables a bottom specimen to be obtained.

(6) What system or type of deep sea sounding by wire is considered the most satisfactory ?

ECHO SOUNDING.

The International Hydrographic Bureau has followed very closely the development of echo sounding, and has issued *Special Publications Nos 1, 3, 4* & *14*, dealing with the Behm Acoustic sounding machine, the Hayes Sonic depth finder, the British Admiralty Echo Sounder, and the Langevin-Florisson Ultra-sonic depth finder. By the MARTI system, in connection with the last named, it is sought to register acoustic echoes automatically and continuously as the ship proceeds. An entirely satisfactory system of continuously registering the results of the acoustic sounding is very much to be desired.

(7) What echo sounding apparatuses are there on the market, or purchaseable; what are the names and addresses of the makers; what are the prices; and what are considered the advantages respectively of each type ?

III. Temperature.

It is important to determine the temperature of the sea, not only at the surface, but at varying depths. Observation of surface temperatures is an easy matter, since it is only necessary to haul in a bucket of water and read the temperature rapidly, but accurately, with a reliable thermometer, using the necessary precautions. For taking temperature at greater depths special apparatus is necessary. The Petersson-Nansen water bottle may be used to collect and insulate water samples from moderate depth and, within limits, gives an accurate reading of the temperature in water samples.

MAURY, in 1852, published through the U. S. Hydrographic Office, the first chart showing isotherms, or lines joining places on the ocean of the same temperature. In general, the warmest water is in 5° N. latitude and the coldest in from 80° N. to the Pole. In the Southern Hemisphere the coldest water is from 75° to 80° S., and there is a parallelism between the isothermal lines and the degrees of latitude. Generally speaking, the temperature is influenced mostly by ocean currents and this is especially noticeable in the tropics. Of the great oceans, the Pacific has the warmest surface water, the Indian Ocean the next, and the Atlantic the least warm. The north end of the Persian Gulf is the warmest water of the oceans: 36° C. (or 97° F.). As the sun's rays do not penetrate much below 150 fathoms, and as conduction of heat plays a very minor part in transmitting warmth from one layer of water to colder water beneath it, the mass of the ocean water is cold, or only about 4° C. (or 39° F.). The warm water is only on the surface, and has a tendency to flow from the Equator to the Poles, and, as the air temperature is largely controlled by that of the sea, variations in the general circulation will probably account for the big seasonal changes which occur. At night the surface water is appreciably warmer than the surface air, and, in the daytime, it is the reverse, but the surface water of the sea seldom has an average daily variation of as much as one degree of temperature. However, the variation in surface temperatures, due to the direct rays of the sun, is much less in the open sea than on the coasts, or in shallow waters, since the temperature of the land raises it. Wind, rain, fog and cloudy weather naturally influence surface temperatures, but their measurement offers very few difficulties. It is the taking of deep sea temperatures which consumes so much time and labour and incurs so much expense. There are various deep sea thermometers of the maximum-minimum and reversing types, of which we may mention those of Cavendish, Collardeau-Walferdin, Miller-Casella, Negretti-Zambra, Richter, Magnaghi, Chabaud and Nansen. There are also thermometers of the meteorological type, enclosed in a metal case to resist ocean pressures, such as those of Bounhiold and Regnard.

What is wanted is an automatic recording thermometer, giving a time and temperature record on a chart, which is at the same time accompanied by a simultaneous depth record made on board ship as the thermometer is raised or lowered in the water. From the two charts a continuous temperature-depth record could then be prepared. It might be too much to expect the design and perfection of a thermometer which will electrically record on deck the different temperatures as it is raised or lowered in the ocean, but it is perfectly practicable to construct a combination apparatus consisting of a non-magnetic metal, pressure-proof and air-tight box, which may be lowered by insulated wire, electrically connected with the ship, the interior mechanism of which box could be operated by pushing a button on deck. The pressure-proof metal box could have, on the outside, a guarded thermometer whose reading could be shown inside the box through a magnifying prism in the wall of the box on the level of its graduations. The box could contain a depth-recording instrument of the aneroid or pressure type, giving the sea pressure through a hole in the metal case. The box could also carry, in a guarded cage underneath it, a current meter and could be made to take the direction of the current by means of a metal current vane on the box. The dial of the current meter could show the velocity on the same face inside the box as the depth indicator, the thermometer and a clock. A small magnetic compass of the liquid type could be installed to show the approximate direction of the current as taken up by the current vane at the time of observation. By means of a magnesium flash and an automatic moving-picture apparatus, set off by pressing the button, a flash light photograph could be taken of all the indications of the instrument at any instant and at any depth desired by the person on deck in control of the lowering and raising of the apparatus. Such an instrument is perfectly feasible, would economise time and labour, and would give accurate results at any depth. At any rate, it is worth constructing and experimenting with such an instrument, the most difficult part of it being to get practical results with the current meter and compass attachments. They might prove too great a complication.

(8) What is the best type of deep sea thermometer for speed and accurancy in determining the temperature of ocean depth, and how operated?

IV. Density.

The least densities of sea-water are encountered in regions near the coast or in partially enclosed waters like the Arctic Ocean, or in enclosed waters like the Black Sea, where fresh water from melting ice or from rivers dilutes the water. In tropical regions of the ocean, where evaporation is greatest, greater densities are encountered. The North Atlantic Ocean attains a surface salinity of over 37 per thousand; the Gulf Stream, 36; the Caribbean Sea, 35.5; and the Gulf of Mexico, almost 37; whereas, on the coast of Greenland, the Polar Current has water under 33 per thousand, and on the Arctic coast of Siberia, 22 or less.

It is practicable to make density determinations on board ship with a sufficient degree of accuracy for the measurement of the salinity by the electrical conductivity method, supplemented by careful observations of the temperature of the sample of water at the time it was taken. Accurate densities may be obtained by supplying samples to laboratories on shore with the necessary data accompanying each specimen. The density of the sea water is greater than the total densities of its constituents, as determined by chemical analysis, but the whole question of density is an important one in the study of oceanography, as it may be taken to embrace the question of salinity, refraction, the propagation of sound, penetration of light, transparency, colour and evaporation. Even sonic and ultra-sonic depth-finding are affected by temperature and salinity or density. The rays of sunlight which penetrate the sea are bent by refraction and are sometimes decomposed or broken up into the colours of the spectrum, each colour having a different "radius of action" or effect upon marine life. The sea water, according to its varying salinity, takes on different colours. Salinity and density may be measured by the index of refraction of a ray of light through a sample of sea water in a prism shaped glass bottle, correction being made for temperature. There are many other methods of measuring the density as compared with distilled water at 4° C, (1) by weighing a given volume of sea water, (2) by totally immersing a definite object in a sample of sea water, and weighing its buoyancy or displacement by its change in weight attached to a scale, and (3) by a partially immersed aerometer or salinometer bearing a scale at its upper end, from which may be read the specific gravity of the sample of sea water in the container.

There is an instrument for obtaining solidities and samples of sea water at different depths not exceeding 10 fathoms, in regions other than the open sea, where there is a considerable mixture of water of different specific gravities. The instrument is called the Pycnosonde. It was invented by Dr. D. la Cour, Director of the Danish Meteorological Institute, and is described in the Marine Observer for March 1927, page 55.

As sea water is compressible it is necessary, in designing a pressure meter to indicate depths by density, to make allowance for pressures. Sea water has a mean density of 1.023 as compared with fresh water at 1.000. At ten meters below the surface there is a pressure of one atmosphere, equal to one kilogram per square centimeter. At 9,000 meters there is a pressure of 900 atmospheres, or 900 kilograms, per square centimeter of surface. There are tables which give the coefficient of the compressibility for various pressures, and tables are published giving the relations of density, salinity and temperature. Specimens of deep sea water may be brought up by bottles. Successful types are those by Petterssen-Nansen, and Nansen-Ekman. In the former a messenger is sent down on the wire which closes the lid of the bottle and reverses the thermometer. The bottle itself is vulcanised and insulated against changes of temperature. Some types of bottles are hermetically sealed by a screw, which revolves freely on descending, but, when starting to ascend, the reverse motion of the screw seals the bottle automatically and records the temperature by a reversing thermometer. In many types there is a thermometer inside the bottle. Among the successful types of bottles for bringing up specimens of sea water which may be mentioned, are those of Meyer, Milne, Buchanan, Willie and Richard.

(9) (a) What is the best apparatus, or method, for determining on board ship the density of samples of sea water taken at different depths and different localities ?
(b) Ditto for salinity;
(c) Ditto for refraction;
(d) Ditto for colour;
(e) Ditto for transparency;
(f) Ditto for penetration of light, and
(g) Ditto for rate of evaporation of the surface of the sea.

V. Gravity.

If the land were all levelled, the earth's surface would be entirely covered by water, and if this water were all of equal temperature, then a perfect ellipsoid of revolution would be formed. All meridians of longitude would be equal ellipses, and all parallels of latitude perfect and concentric circles. Everywhere the deep sea lead line would be perpendicular to the surface of the sea, and in line with a radius of the earth. Centrifugal force would be proportional to the gravitational force, whereas, in the actual globe, at it is, the land masses disturb these ideal conditions.

As land is about 2.7 times heavier than water, a deep sea lead in the vicinity of the land will deviate towards the land in response to the attraction of gravity, but the lead line will still be perpendicular to the surface of the sea. This actually means that the surface of the sea has taken up a different position on account of the proximity of the land and due to its attraction. In other words, the sea level is depressed in mid-ocean areas and elevated near the coasts and continents.

Jenkins, in "A Text-book on Oceanography" says :—

"This elevation of the sea surface near the land is termed the 'continental wave'. Not only is the surface of the sea irregular near the land, but also in the open ocean a corresponding irregularity is met with, since each depression of the ocean bottom is correlated with a depression of the sea-level. These irregularities of sea-level can be determined by experiment or can be calculate from theoretical considerations. The pendulum is used for this determination. If a pendulum be swung on the same parallel of latitude over the land and then over the sea where there is a marked depression of the ocean floor, it should swing more quickly in the latter position, where it is nearer the earth's centre."

Gravity determinations at sea were made by Dr. Meinesz of Holland, in the summer of 1923, in a submerged Dutch submarine, using an ordinary Stückrath pendulum apparatus. The newly designed apparatus has three pendulums instead of four, as in the original one, and swings in the same plane, perpendicular to the longitudinal axis of the ship. Photographic records were made by means of an arrangement of mirrors reflecting a beam of light from the middle one of the three pendulums on to each of the two outside pendulums before they reached the recording film. It was assumed that the result was the oscillation of two hypothetical pendulums, free from any effect on the horizontal acceleration of the ship.

These observations are being continued by a Dutch submarine en route to Java through the Panama Canal.

(10) What is the best form of pendulum instrument for making gravity observations at sea ?

VI. Sedimentation.

The study of specimens obtained from the bottom of the sea are of great interest to geologists, fossil-botanists, marine biologists and oceanographers, but not to hydrographers except as to anchorage grounds for ships. In fact, the great working ground of the hydrographer is the continental shelf, which forms about eight per cent of the sea area of the world, and it is this area which receives the inorganic sediments from the land in the form of muds, sands and dissolved chemicals, which are dumped on the sea floor or which increase the salt contents of the ocean. This weight, deposited over the floor also causes a certain amount of instability. Incidentally it also calls, from time to time, for re-surveys of inland waters and the continental shelf.

The unravelling of the history of the continents depends, to a great extent, upon oceanographic studies. Dr. David WHITE, of the United States Geological Survey, says :

" A sedimentation problem, involving the origin of oil shales and of petroleum itself, is that of the deposition of the so-called carbonaceous or bituminous sediments, from which petroleum, natural gases, and other hydrocarbons have been derived by geologic processes. Practically all geologists are agreed that petroleum is generated in the course of the natural distillation under geologic processes of organic material of plant or animal origin in the sedimentary beds of the earth. Whether oil is formed from vegetable or animal matter is, however, a mooted question. There are many economical problems bound up in these investigations ; the deposition of phosphates and some of the metalliferous ores, as well as manganese; the occurence of rare metals; the relations, in sequence and to one another, in deposition, of the carbonates and other salts of common substances, such as magnesium, calcium, potassium, and sodium, and the conditions regulating their varying precipitation in different environments. I would remind you that probably nine-tenths of the iron-ore supplies of the world are derived from sediments laid down in the different geological periods. Are such deposits being formed at the present day ? "

It is related that when Sir John MURRAY was studying the bottom samples from the CHALLENGER, and other materials obtained from various other Government expeditions in all parts of the world, he came across a piece of rock from Christmas Island. On chemical examination it proved to be an almost pure phosphatic deposit. Realizing its value, he induced the British Government to annex it as an uninhabited volcanic island. From this he derived a personal fortune from a concession, and the British Government received in royalties and taxes from the island considerably more than the total cost of the CHALLENGER expedition.

As previously stated, the hydrographer is interested in echo-sounding as determining the contours of the floor of the ocean, and is interested in bottom specimens on the continental shelf. The trouble with echo-sounding is that it does not bring up specimens of the bottom. For this purpose the wire must be used, and a sample of the bottom obtained by means of a cup or dipper dredge.

(11) What is the best form of cup or dipper dredge for obtaining specimens of the bottom in connection with deep-sea sounding ?

VII. Atmospheric Pressure.

The part played by barometric pressure in causing ocean currents is very problematical, as has been previously stated. There are other effects of barometric pressure, however, which are called *seiches* and which consist in lowering the level in the middle of large bodies of water and consequently raising it at the shore line. This, in conjunction with, or in opposition to, tidal undulations, makes a very complicated question of temporary changes in sea-level, which cause a vertical movement as distinguished from a horizontal movement, or a current effect.

The Japanese have investigated this question by means of small models of bays and inland waters submerged in a tank to the right level, with periodic undulations of water produced by means of a pendulum. As tidal effects in enclosed bodies of water, even in as large bodies as the Mediterranean and the Baltic Sea, are barely perceptible, the result of the Japanese study gives more the effect of *seiches* than of tides.

(12) What is the best method of measuring the difference in sea-level due to barometric pressure, (1) in enclosed bodies of water; (2) in the open sea?

VIII. Tides.

As previously stated, the changes in sea-level due to barometric pressure are frequently so mixed up with the undulations of the daily tides that it is difficult to separate the two. Jenkins, in his " Text Book of Oceanography ", says :

" Our knowledge of the tides and tidal streams of the world is still very incomplete. There is a complete lack of tidal observations in the centres of the great oceans. Only in the southern ocean is there a complete water-belt round which it is possible for the tidal waves to travel. These are known as *primary waves.*

" A primary wave sweeping round the southern ocean, passing in succession the southern coasts of Australia, Africa, and South America, may be assumed to give off secondary waves which pass up the three great oceans in a more or less northerly direction. These are *derived waves*, and from them arise the tides along the various coasts which they pass. So long as the tidal undulation travels in great depths it is a simple wave, but when it meets with obstructions it is translated into a wave of horizontal force — *i. e.*, a tidal stream, as distinct from a wave, is produced. Over certain areas the whole body of water oscillates backwards and forwards with the regularity of a pendulum having a stroke of about 6 ¼ hours, the total oscillation being from about 10 to 20 miles backwards and forwards. These oscillations occur simultaneously, or nearly so, over areas widely removed from each other, and appear to coincide almost exactly with the rise and fall of the tide in a given spot."

There are no practical ways of making tidal observations from a moving ship, but both hydrographers and oceanographers are interested in the compilation of all data relating to the rise and fall of tides and flow of tidal currents.

(13) What is the best method of observing tidal undulations?

IX. Waves.

In the main, ocean waves are caused by the wind, otherwise they are called "a swell" or "a roller," and these are usually also caused by a wind, or some other force, such as earthquake shock, at a distance. The study and measurement of wave motion in a scientific manner is more or less recent, as the methods in use in the past were more or less crude, leading to exaggerated result. The chief characteristic of wave motion is that while the waves pass over the surface at considerable speed, the water simply rises and falls with only a slight to-and-fro motion of a rhythmic character. There is a definite relation between the length of the wave from crest to crest, its velocity and the depth of water, but there is no relation between these and the height of the wave. The difference in waves in a deep sea and when they reach shallow water is due to the trough being retarded and the crest tumbling forward. The observation of wave motion is (1) their velocity, (2) their length, (3) their periods, and (4) their height.

JENKINS, in "A Text-Book on Oceanography," says:

"Waves vary in different localities, according to the velocity and direction of the wind. The longest wave recorded is one of 2,600 feet length and 23 seconds period by the French Admiral M. MOTTEZ in the Atlantic Ocean a little north of the Equator in 28° W. Long. The longest waves are usually met with in the South Pacific, where their lengths vary from 600 to 1,000 feet and their periods from 11 to 14 seconds. Waves of from 500 to 600 feet in length are sometimes met in the Atlantic, but the usual lengths are from 160 to 320 feet, and the periods from 6 to 8 seconds. As to the heights of waves there is much conflicting evidence in the records. DUMONT D'URVILLE has recorded a wave 100 feet high in 1837 off the Cape of Good Hope. This was an estimate, not a measurement, and although many seafarers will agree with D'URVILLE, the estimate is probably too high. French marine officers measured many waves according to instructions given by Arago. The highest measured were in February, 1841, near the Azores, when from 42 to 50 feet was recorded. In the enclosed seas the height of waves is much less. Probably in the North Sea waves never exeed 31 feet in height, with periodicity of 9 seconds and wave-length 147 feet (as maxima)."

The best method of measuring the height of waves is that of Admiral PARIS, consisting of a graduated pole, weighted at its lower end and carrying a circular float, which rises and falls with the wave on the pole between observed marks. Another apparatus is that of Froude, which also consists of a graduated pole which floats upright in the sea, and by which the height of the waves may be observed. The Germans have developed up-to-date optical apparatus for wave observations, the latest of which has been designed by Carl Zeiss of Jena, which is a guarantee of its efficiency

The earliest type was called a Stereokomparator, which was followed by an instrument called the Stereoautograph, which was improved upon by an instrument called the Stereoplanigraph. The Carl Zeiss apparatus, mounted on the METEOR, is called the Stereophotogrammetrie. It consists of a portable beam or hollow tube about 6 meters long, which has a large photographic camera on each end, with a small camera on top of each large one. The apparatus is hoisted up horizontally under the fore-yard from 13 to 14 meters above the level of the sea. Each time a picture is taken of the surface of the sea by the large cameras, which are operated by electro-mechanical releasing bolts, the two small cameras are put in action at the same instant. These two small cameras face each other and are operated simultaneously with the large camera, and from the photographs taken the "connecting point of the whole orientation of the system is ascertained horizontally and vertically."

In clear weather photographs are now taken in three directions instead of one, as formerly. The instrument is described in the "Annalen der Hydrographie und Maritimen Meteorologie" for November 15, 1926.

The Meteorological Office of the Air Ministry, London, has just issued a fourth edition of "The Marine Observer's Hand-Book" (1st January, 1927), in which certain explanations, tables and methods of computation are given for observing, non-instrumentally, wind direction, veering and backing of wind, wind force, sea disturbance according to the DOUGLAS Sea and Swell Scale, height, length, period and velocity of waves (see pages 38-48).

(14) What is the best method of ascertaining (1) the velocity of waves, (2) the length of waves, (3) the period of waves, and (4) the height of waves?

X. Magnetism.

The best magnetic observations at sea are naturally obtained aboard a non-magnetic ship such as the CARNEGIE. Volume V of the "Researches of the Department of Terrestrial Magnetism" of the Carnegie Institution of Washington has just been published (January, 1927) giving in detail the magnetic and electric results obtained at sea on the CARNEGIE from 1915 to 1921, including Special Reports discussing particularly sun-spots and annual variations of atmospheric electricity as deduced from the seven years' observations on the CARNEGIE, as well as broad questions in atmospheric electricity.

The Carnegie Institute has been studying the relationship between the disturbances in the Earth's magnetic-electric condition and all the manifestations of solar activity, as well as the disturbances shown by fluctuations in the Earth's magnetism, earth-currents, atmospheric electricity and polar lights. Most magnetic observations must be conducted either from shore or on board non-magnetic ships.

(15) What is the best type of instrument for observing the Earth's magnetism on board ship?

Several important conferences have been held to draw up a tentative program of proposed oceanographic work by the CARNEGIE in addition to a magnetic and electric program already decided upon. The tentative oceanographic program includes the following observations:

"(1) Water samples, with corresponding temperatures down to 2.000 meters, every 200 miles, with provision for occasionally obtaining the data down to the bottom; continuous record of surface temperatures; record of ocean depths every two to four hours by means of the latest and best type sonic depth-finder; bottom samples in connection with water samples; determination of hydrogen-ion, phosphate, nitrate, and oxygen content.

"(2) Shallow-water dredging for diatoms and other plankton or biological specimens; collection of surface plankton, once each day, quantitative, either by strainer or centrifuge.

"(3) Continuous record of wet and dry bulb temperatures at deck level, checked by four-hourly eye-observations with sling or aspiration psychrometer, and supplemented, if practicable, by early-morning, and mid-afternoon observations of temperature and humidity lapse rates from sea surface to masthead, with occasional hourly series to establish the diurnal course of lapse-rates in different parts of the world ; sun and sky radiation measurements by day and night ; carbon dioxide and dust-counts of the air, rainfall, in stabilised gage.

"It is proposed that the first cruise, covering all the oceans and occupying about three years' time, should include work in terrestrial magnetism, atmospheric electricity, marine earth-currents, and the tentative program in oceanographic and meteorological work as outlined above. During this cruise it is hoped that the work in oceanography will have developed to such a point that it will be possible to devote the following three-year period entirely to general oceanography, with special attention to particular problems in selected or restricted areas. Subsequent cruises might alternate between the magnetic, electric, and oceanographic program and the full oceanographic program during the useful life of the vessel.

"To obtain first-hand information in regard to methods and instruments used in oceanographic work, the chief of the section joined the United States Coast Guard vessel TAMPA at Halifax, June 22, and paricipated in the work of the ice patrol cruise over the Grand Banks of Newfoundland, returning to Boston on the TAMPA on July 4. The cruise was of value in emphasizing the desirability and practicability of doing similar work on the future cruises of the CARNEGIE.

SEISMOLOGY AND OCEANOGRAPHY.

Mr. T. W. VAUGHAN, of Scripps Institution of Oceanography, California, says :

" The results of seismological researches are of significance to the student of oceanography in the same way that they are to any other student of general geophysics. The ocean covers about 71 per cent of the surface of the solid. On an areal basis, therefore, 71 per cent of the earthquakes would be expected to originate below sea-level. It is now known that earthquakes are due to deformation in the lithosphere. Although this deformation may result from several kinds of causes, the most important kind expresses itself in faulting, which usually, but not invariably, produces change in level on the two sides of a fault line. Seismological research, therefore, offers assistance in explaining important features in the relief of the sea bottom and certain features of the ocean margins. It is now generally admitted that the continents stand high because they are composed of lighter, and the ocean basins lie low because they are underlain by denser, material. The contact zones between the lighter continental and denser suboceanic masses are sites of earth strains, the marginal continental rocks tending toward upfolding and the suboceanic rocks toward downfolding. We perhaps need not consider the relative merits of whether the continents are overfolded and overthrust on the suboceanic masses or whether the suboceanic rocks are underthrust with reference to the continental margins. These marginal zones are the sites of important earth movements, in them lie the greatest seismic zones of the earth, and they are of critical importance to the oceanographer. Certain facts illustrating the relations indicated are too well known to require more than briefest mention. The Pacific Ocean is margined by mountains from southern Chile northward to Alaska, thence by way of the Aleutian Arc to northeastern Asia, and thence southward to the East Indies and on to New Zealand. On the seaward side of the mountains is the ring of Pacific deeps. The zone between mountains and deeps, and probably involving both, is the circum-Pacific earthquake zone. The zone passes westward by way of the Himalayas to the Mediterranean region of Europe and Africa, and eastward it crosses southern Mexico and follows around the Antillean arcs. Throughout most of the vast region sketched in outline, seismology is an essential part of oceanography. Seismology can be regarded almost as a branch of oceanography, because seismology is one of the most important sources of information on the constitution of the interior of the earth, and it is necessary for understanding important features of the relief of the sea bottom and for interpreting the origin of certain types of shoreline topography. Every oceanographic institution should have as a part of its equipment properly installed and operated seismographs, and these and an automatically recording tide gauge should be tied into the same system for recording time, for seismographs and tide gauges are mutually complementary instruments."

In what has been said as regards instruments for oceanographic observations, nothing definite has been said in regard to instruments for observing evaporation, refraction, penetration of light, transparency, colour, chemical constituents of water, transmission of sound in sea water, conductivity, specific heat, freezing and boiling point, characteristics of sea ice, atmospheric gases in sea water, viscosity, electrical conductivity, radio activity, *etc.* Any data as to instruments for observing these will be glady received.

As originally stated, this article is merely a rough outline for a study which might be made by some one more competent to do justice to the subject.