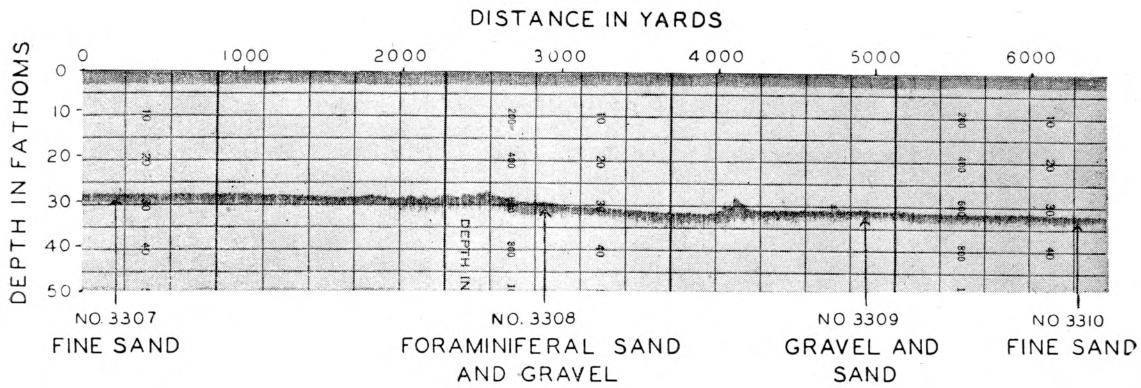

Plate 2.

Recording echo-sounder trace with notations of bottom materials collected by underway sampler. Note that low flat areas consist of fine sediment while irregular hills are of rock surrounded by gravel.

OCEANOGRAPHY IN THE HYDROGRAPHIC OFFICE

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Foreword

(*a*) The numerous discussions between the Delegates to the Vth International Hydrographic Conference indicated the wide divergence of opinion between Member Offices as to the advantages to be gained by including Oceanography in the Hydrographic Offices. Many States Members feel that Hydrographic Offices should limit themselves to matters that are strictly inside the sphere of Hydrography.

(*b*) The following paper indicates the relationship that exists between these two Sciences in U.S. Hydrographic Office and the practical benefits that were produced by Oceanographic Research which resulted in Oceanography being included in the U. S. Hydrographic Organization.

For over a century, the Hydrographic Office (*) has been accumulating, studying, and publishing information pertaining to the study of the oceans, their waters, and plants and animals, and the media forming their boundaries, namely, the atmosphere, the sea bottom, and beaches. The long and sometimes tedious accumulation and tabulation of these data paid dividends in World War II, for the efficiency of naval and amphibious operations depended to a varying extent upon the characteristics of the marine environment. To centralize the work in military oceanography and to maintain a modern oceanographic program during the post-war period, the Navy Department has formally established the Division of Oceanography at the Hydrographic Office. This division also assists in fulfilling the office mission of collecting, digesting, and issuing " timely information calculated to afford the maximum possible navigational safety and facility to ships on the seas and to aircraft operated over areas of strategic interest to the Navy ".

PRIOR TO WORLD WAR I

One hundred and five years ago, Lieutenant Matthew Fontaine Maury(*), United States Navy, was appointed Officer-in-Charge of the Depot of Charts and Instruments by the Hon. Abel P. Upshur, Secretary of the Navy. The science of modern oceanography can be dated from this timely appointment. In his middle thirties, Lieutenant Maury had already acquired fame as a nautical scientist, politician, administrator, and author. During his years of sea duty he had come to believe that the standard practice of the day—simply sailing a ship from port to port by putting out to sea and blindly combating any adverse conditions that might occur—was extremely crude and inefficient. In fact, he believed that if the ways of the sea were analyzed by a central agency, the best sailing tracks between ports could be established on a scientific basis. As there were scores of musty ship's logs stowed in the Depot, Maury's appointment provided him with the opportunity to develop and test his thesis.

By hard work, much of it on his own time, Maury was able to prepare the first " Track Chart " for the North Atlantic, late in 1847. On this chart he had laid down the tracks of vessels whose logs had been analyzed, with symbols for wind, weather, and currents arranged according to seasons. The Track Chart was shortly followed by " Wind and Current Charts ",

(*) See also the article " Hydrographic Office, United States Navy ", by Rear Adm. G. S. Bryan in " The Military Engineer " for October 1944.

actually a set of six which included a Track Chart, Trade Wind Chart, Pilot Chart, Thermal Chart, Storm and Rain Chart, and a Whale Chart. (See figure 1.) These charts synthesized the observations obtained on thousands of voyages. With such charts at hand, the navigator about to start on a cruise could draw quickly on the varied experiences of his fellows, rather than having to rely entirely upon his limited knowledge of world-wide vagaries of current, wind, water temperature, magnetic variation, etc. Phenomenal success resulted from their use. For example, early in 1848, the bark *W.H.D.C. Wright,* the first ship to use the Track Chart, made the round trip between Baltimore and Rio de Janeiro in the time it often took to make the outward passage alone ! It is no wonder that mariners and shipping agencies throughout the civilized world were impressed by the work of the Depot, and for these studies, Maury is often called " The Pathfinder of the Seas ".

In return for the Wind and Current Charts, mariners kept careful daily logs as to the temperature, currents, waves, and other physical characteristics of the ocean, the occurrence of such biological phenomena as whales, discolored water, bioluminescence, sea birds and sea weed, and noted meteorological conditions.

Meanwhile, Passed Midshipman J. M. Brooke, one of Maury's proteges, developed a contrivance that dropped the sounding weight upon touching bottom and obtained a bottom sample that could be reeled in with ease. This was the first satisfactory sounding device that could readily determine the depth and type of bottom deposits of the high seas. The *USS Taney, USS Dolphin,* and the *USS Arctic* were equipped with this gear and assigned to deep-sea sounding work in the North Atlantic.

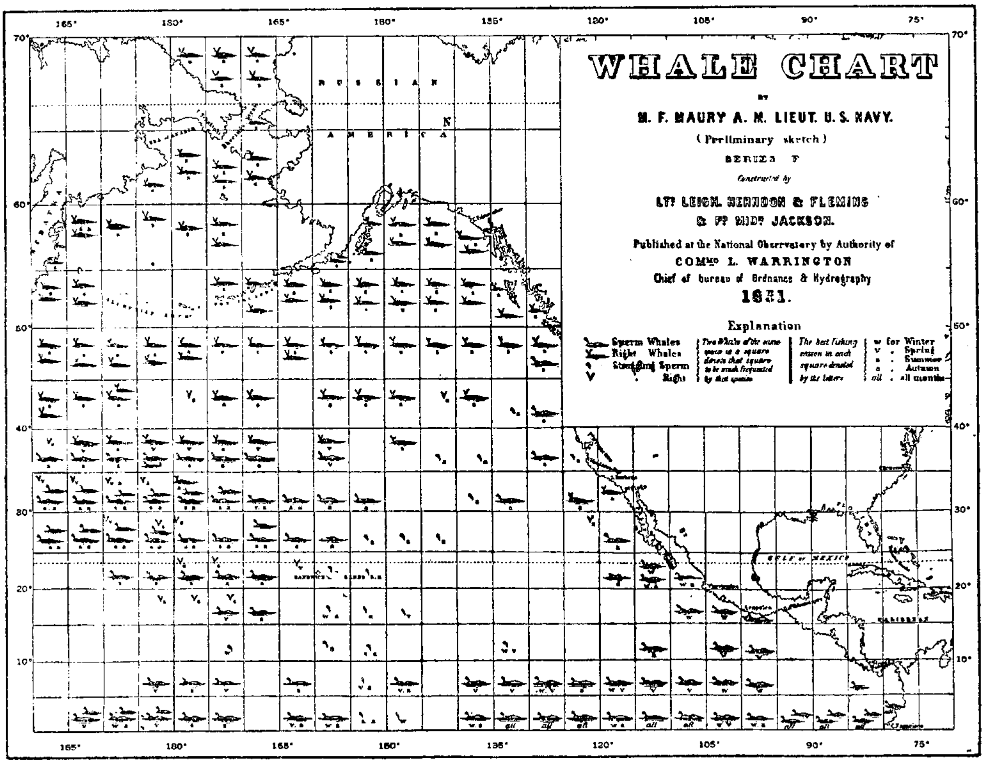

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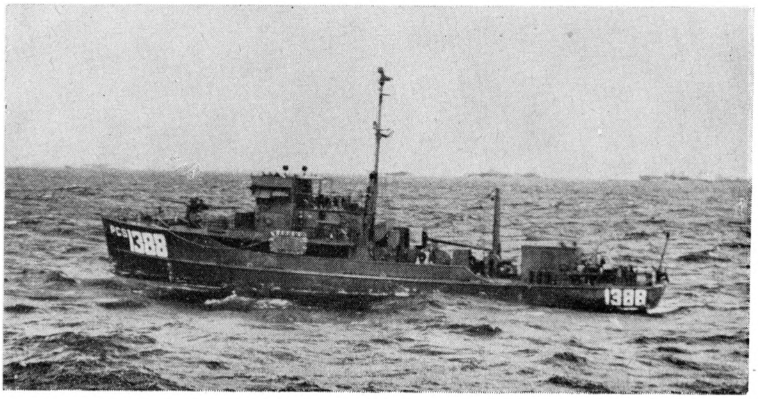
Fig. 1

Portion of Chart Showing World-wide Distribution of Whales

This chart, one of the earliest studies made in the distribution of animal life in the sea, was specifically designed for the Whaling industry.

In thirteen years, Maury was able to launch formally the sciences of oceanography and maritime meteorology by publishing the basic and world-famous *Physical Geography of the Sea.* This book, which went through 22 editions in England alone, contained :—



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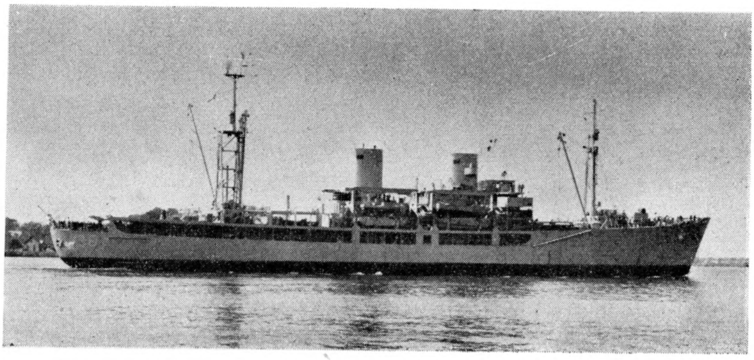
"USS Littlehales".



(Reproduced by courtesy of "The Military Engineer").

"USS Maury"

Survey ships of the Navy named for nautical scientists who played important roles in developing the science of oceanography.

> A philosophical account of the winds and currents of the sea ; of the circulation of the atmosphere and ocean, of the temperature and depth of the sea; of the wonders that lie hidden in its depths; and of the phenomena that display themselves at its surface. In short....of the economy of the sea and its adaptations—its salts, its waters, its climates, and its inhabitants, and of whatever there may be of general interest in its commercial uses or industrial pursuits.

Actually, much of this information had been incorporated in the 20,000 copies of Sailing Directions and the 200,000 copies of Wind and Current Charts that were issued by 1858 to merchant vessels in exchange for the observations collected by their officers. Oceanographic investigations and writings of Maury came to an end with the outbreak of the Civil War, because he joined the Confederacy at that time.

The two decades during which Maury acquired fame as an oceanographer featured an unparalleled program of survey and exploration by the Navy. In the years 1838 through 1842 our first naval scientific expedition, the United States Exploring Expedition under Lieut. Charles Wilkes, United States Navy, a former officer-in-charge of the Depot of Charts and Instruments, investigated the coasts of lands and the islands of the Atlantic and Pacific Oceans as far south as Antarctica and as far north as Alaska. Such a vast amount of knowledge was gathered by the naval officers and civilian scientists of the expedition that the Congress allotted a total of $359,834 for working up and publishing the material. The final report comprised twenty-four volumes prepared over a thirty-two year period. Surveys and scientific work were also carried on whenever time permitted during the Expedition to Japan (1852-1853), led by Commodore Matthew C. Perry, and during the North Pacific Surveying Expedition (1853-1859), commanded by Comdr. Cadwalader Ringgold, and later by Lieut. John Rodgers. From these and numerous lesser surveys, hydrographic and oceanographic data poured into what was still, according to law, the " Depot of Charts and Instruments " but which was actually called, at various times, the " U.S. Naval Observatory ", the " Hydrographical Office ", the " Depot of Charts ", and the " United States Naval Observatory and Hydrographical Office ".

In 1866, the Congress formally established the Hydrographic Office as an agency separate from the Naval Observatory. With Maury's departure, the Hydrographic Office had turned towards the charting of coastlines and the preparation of coastal descriptions and navigational manuals. Yet, when time permitted, investigations continued to be carried out in oceanographic subjects, particularly those relating to the submarine topography and the bottom deposits of the deep sea. This work, initiated by the Navy at Maury's instigation only a year after Morse's telegraph had been patented, had demonstrated the feasibility of laying submarine cables between the various continents. The work of such vessels as the *USS Tuscarora,* operating under the direction of the Hydrographic Office in the 1870's, was instrumental in outlining the general bathymetry of the Pacific Ocean(1). The continued interest in this work is shown by a manual published in 1892 by the Hydrographic Office entitled *Submarine Cables: Instruments and Implements Employed in Cable Surveys: Theory of Cable Laying, Specifications, and Costs; Submarine Cable Systems of the World.*

By the end of the century, the pioneer cables had been largely completed, and except in fisheries work, new oceanographic developments and applications were slow in appearing. However, mariners continued to forward their logs to the Hydrographic Office where the applicable information was used to increase the accuracy with which the surface currents, sea temperatures, and ice limits were presented on the Pilot Charts which had evolved from Maury's Wind and Current Charts. The Pilot Charts, first published in 1883, provided the mariner with more detailed and complete oceanographic, meteorological, and magnetic data than their predecessors.

In the period 1890 to 1930, George Washington Littlehales, an engineer of the Hydrographic Office who became world-renowned for his innovations in navigation, was particularly prolific in his writings. Several of his articles discussed the salinity of the ocean, the use of oil in calming high seas, measurement of gravity at sea, and the character of various oceanic basins. Littlehales also represented the United States at many international conferences concerned with oceanographic work.

During the early part of the twentieth century, oceanography began to evolve into a full-fledged science dealing with much more than the distribution of the simple properties of

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(1) Scientists are acclaiming a new Hydrographic Office bathymetric chart of the Pacific region. Based on some 250,000 plotted soundings taken largely during World War II, the chart (H.O. No. 5485) accurately shows the detailed bottom topography of the Western Pacific Ocean.

the sea. Development of new instruments and scientific techniques permitted detailed studies to be made into the chemical composition, electrical conductivity, sound transmission, transparency, hydrodynamics, compressibility, and color of sea water, to name only a few. Furthermore, means were developed for studying the subsurface waters. Transmission of sound became of particular importance to the Hydrographic Office when, as a result of work at the Naval Research Laboratory, the first successful echo-sounding devices were installed on two United States destroyers in 1922. These devices sent out a sound signal and measured the time required for the signal to return as an echo from the bottom. Given the velocity of sound at various levels, an accurate measurement of depth could be obtained while the ship was underway, something that had never before been possible on the high seas. Thousands of ships have since been equipped with sonic sounders, for soundings may now be made as simply in deep water as in shallow, permitting three-dimensional navigation to be carried out not only by means of astronomical fixes but also by fixes obtained by noting the irregularities of the sea floor. However, accurate determination of sound velocities involved knowing the salinity and temperature of water at all depths. Therefore, data of this nature gathered largely by expeditions and institutions as a scientific venture had immediate application.

Naval interest in the field of oceanography was further intensified in 1928, when the Hon. Curtis D. Wilbur, Secretary of the Navy, was approached by the National Academy of Sciences concerning the part that the Navy could play in acquiring further knowledge about the oceans. The Secretary appointed a special board with Rear Adm. Frank H. Schofield as Chairman, and Capt. C. S. Kempff and Capt. C. S. Freeman members, to convene with interested scientists and government officials. The findings of the Schofield Board indicated that there were two types of oceanographic work that the Navy might well undertake. The first type included all investigations of the sea that required a specially equipped vessel permanently detailed to the task; the second type consisted of studies that could be carried out by trained observers on the regular voyages of Naval vessels. The Board's recommendation concerning the procurement of a special oceanographic vessel has not been implemented, but the vessels of the Navy and the Hydrographic Office have made notable contributions in developing the contours of oceanic basins and the acquisition of additional data on currents, salinity, and temperatures(2).

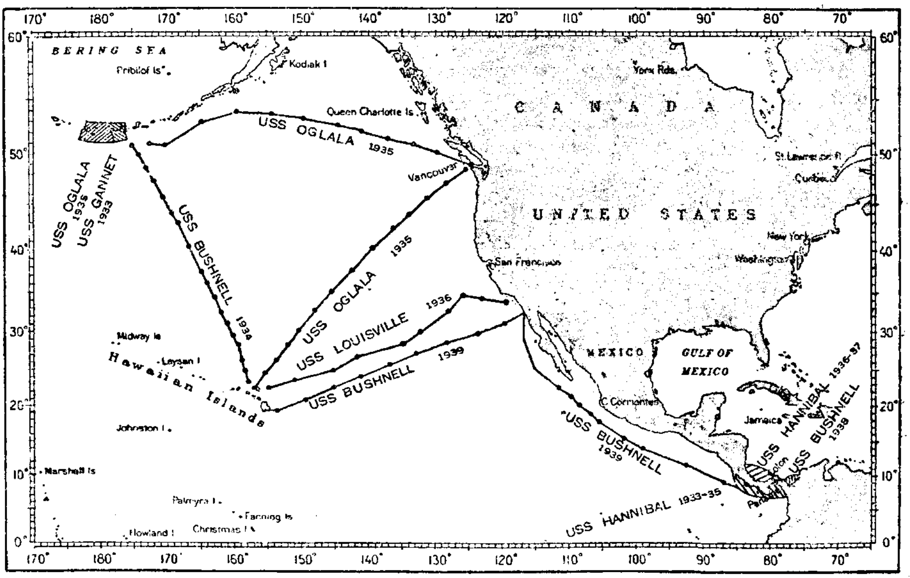

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Fig. 2
Oceanographic Surveys during the years 1933-1939.

(2) It has been roughly estimated that the yearly operating cost of an oceanographic research vessel approaches $ 1,000 per foot of ship's length, that is, a 150-foot vessel costs about $ 150,000 a year to operate when labor, fuel, depreciation, and similar expenses are considered. Because of the fact that the work is so expensive, only governmental activities or heavily endowed private institutions can afford to carry out continuing programs of oceanographic research.

The report of the Schofield Board enabled the Hydrographic Office to purchase a supply of such oceanographic gear as deep-sea reversing thermometers, winches, and wire. Closer association was established with such private institutions as the Scripps Institution of Oceanography of the University of California, the Woods Hole Oceanographic Institution, the Oceanographic Laboratories of the University of Washington, the Bingham Oceanographic Laboratories of Yale University, and the Carnegie Institution of Washington. By 1933, an oceanographic program for the Caribbean Sea and the Gulf of Panama had been initiated as part of the survey work of the *USS Hannibal*. In the first year of work, over a hundred stations were occupied at which the temperature, salinity, and other properties of the water were determined to depths as great as a thousand fathoms. Similar work was carried on for the Hydrographic Office by naval vessels throughout the remainder of the decade (See figure 2) (3). The data and samples acquired from these surveys were studied by the oceanographic institutions and the results published jointly.

During the same period, the Hydrographic Office arranged for gravity measurements to be made in the Atlantic along the West Indies Chain, in the Caribbean, and in the Gulf of Mexico. These measurements were carried out aboard the submarines *USS S-21*, *USS S-48* and the *USS Barracuda (SS-163)* in the years 1928, 1932, and 1936 by Dr. F. A. Vening Meinesz, the famed Dutch geophysicist, in conjunction with several private institutions of learning including the Carnegie Institution of Washington and Princeton University. Geological and geophysical interpretations of the data acquired during the occupation of over a hundred gravity stations were made by Dr. H. H. Hess, Department of Geology, Princeton University, and a detailed report describing the investigations was published by the Hydrographic Office.

Meanwhile, the important work of preparing accurate current and temperature charts for 1-degree quadrangles of the ocean's surface continued, although progress was comparatively slow because of insufficient personnel. The co-operating observers on merchant and naval vessels were now submitting as many as 200,000 observations per year and such a flood of data required new methods of handling. In 1931, A. B. McManus and W. G. Watt of the Division of Maritime Security worked out a method for placing the oceanographic data on punched cards which permitted machine tabulation and compilation. At the instigation of Dr. T. Wayland Vaughan, then Director of the Scripps Institution of Oceanography, the Works Progress Administration (WPA) in 1935 initiated a project under the Branch Hydrographic Office, San Pedro, California to compile the data gathered in the Pacific during the years 1924-1934. And in 1938, even larger scale WPA projects were set up in New Orleans and Philadelphia to process the 5,000,000 observations received from ships in all oceans during the period 1904-1934. Fulfilment of the long-cherished hope to have this vast amount of data compiled and ready for plotting on charts came in 1941, and much of it found immediate application during the war. The program for the publication of atlases based on those data and showing sea and swell conditions, surface water temperatures, and surface currents is now about 60 per cent complete, while data for the period 1935-1945 are now being compiled.

The century of progress sketched in the preceding section had seen sail give way to steam and motor vessels, and the development of the submarine, aircraft, new naval weapons, and electronics. Oceanography, no less, had developed from a descriptive treatment of the easily observed features of the sea surface to a highly technical science calling into play the skills of physicists, chemists, biologists, geologists—in fact, practically all fields of science.

DURING WORLD WAR II

The impact upon oceanography caused by the entry of the United States into war was tremendous. While there were large numbers of qualified personnel in most sciences that could be called upon to apply their knowledge to warfare, there was only a handful of oceanographers who could assist with the problems that immediately arose in designing and operating new types of vessels and equipment. To carry out successful amphibious landings on little-known beaches according to a rigid time schedule, the subsequent supply of the beachheads, the efficient and expeditious location and rescue of survivors adrift at sea, the planning, maintenance, and destruction of underwater ordnance, and the development of satisfactory evasive, attack, and search procedures for submarines were some of the outstanding

(3) Three of the scientists who participated in this oceanographic work are associated with the Hydrographic Office today; namely, W. G. Watt, Assistant Chief of the Division of Maritime Security, and R. H. Fleming, Chief of the Division of Oceanography, who worked with the « Hannibal », and C. A. Barnes, Assistant Chief of the Division of Oceanography, who was on board the « Gannet ».

problems which required a complete knowledge of the conditions in the sea. The very complexity of the ocean proved helpful to the countries who knew how to evaluate the effect of the marine environment upon military operations. In the invasions of Sicily and Normandy, the Axis forces that had never studied the problem believed weather conditions to be too severe for successful landings, while the Allies, with an exact knowledge of wave and surf conditions and the capabilities of landing craft, knew differently and, by invading according to plan, gained the advantage of surprise. It is well to remember, however, that the Allies were not perfect in their understanding of the marine environment. About seven hundred landing craft were damaged or lost on the Normandy beachhead when steep wind waves averaged but 8 to 10 feet in height; much of the loss has been attributed to the craft having been equipped with too light holding tackle.

To achieve this lead in military oceanography, a number of the Navy's bureaus, plus Army activities and civilian research laboratories operating for the National Defense Research Committee, carried out detailed and widespread research and development programs in applied oceanography. In May 1943, the Joint Meteorological Committee acting for the Joint Chiefs of Staff, recommended that the Oceanographic Section of the Army Air Forces Weather Information Service be transferred to the Hydrographic Office to centralize the program in military oceanography. This transfer was effected in June 1943, and the group of specialists designated as the Oceanographic Unit, Pilot Chart Section, Division of Maritime Security, under the technical supervision of Lieut. Roger Revelle, United States Naval Reserve, a former submarine geologist, and Lieut. Mary Sears, United States Naval Reserve (W), a former marine zoologist. Besides preparing many special studies, this agency assisted in editing for publication by the Hydrographic Office the results of investigations conducted by the contractors.

Throughout the war, the Joint Chiefs of Staff and the various offices, bureaus, and fleet commands of the Navy called upon the Hydrographic Office for basic information on tides, permanent and temporary currents, distribution of sea and river ice, salinity and temperature of sea water at various depths, the frequency of various sea, swell, and surf conditions at specific localities, the color, transparency, and electrical conductivity of sea water, and the distribution of phosphorescence, kelp beds, sound-producing animals, and bottom sediments, all items of importance to some phase of naval operations. Much of this information was disseminated by the numerous reports prepared for the Joint Topographic Sub-Committee, in reports prepared at the request of field activities, by special charts, and by manuals describing the technique of predicting the drift of life rafts and quantitative characteristics of wind waves, swell, breakers, and surf. To aid in providing such vast amounts of information for a global war, the Hydrographic Office assigned some $350,000 for contracts at the Woods Hole Oceanographic Institution, the Scripps Institution of Oceanography, and the Coast and Geodetic Survey.

Space permits describing in detail but one of the interesting military applications of oceanography—that of the development of a method for quickly locating survivors adrift in rubber life rafts. Although interest was not focused on the problem until the search for Col. Eddie Rickenbacker in 1942, Maury had tackled a similar problem as far back as 1855. In that year, the transport *San Francisco* had been reduced to a drifting hulk by a hurricane 300 miles from Sandy Hook. As there was a regiment of troops aboard, the public demanded that the ship be quickly located, and the Navy turned to the Chief of the Depot of Charts and Instruments for a statement of what might be the most fruitful area in which to search. On the basis of the available oceanographic data, Maury selected an area and, as genius and luck would have it, the transport was found therein. Later studies of the drift of bottles, set and drift of vessels, and pressure patterns computed from data gathered at oceanographic stations, has shown oceanographers that tracking a floating object was far from simple. For example, it was well-known that the schooner *Fred Taylor,* after being run down and cut in two by the steamer *Trave* southeast of Nantucket Island, on June 22, 1892, had its bow and stern portions drift in practically opposite directions. (See figure 3.)

During the early years of the war, applicable pilot charts printed on waterproof cloth were stowed in all life-boats to help meet such emergencies. Detailed tests and studies were made on the drift of rubber rafts by the oceanographic institutions, and by 1944, sufficient data had been accumulated upon which to base the manual, *Methods for Locating Survivors Adrift at Sea in Rubber Rafts.* Once published, the methods were recommended by the Air Sea Rescue Agency as the approved search procedures over oceans, and reports indicate that they were used successfully upon many occasions in the Pacific.

During the war years, the flow of oceanographic information was far from being unidirectional; for example, hundreds of surface ships and submarines equipped with the newly developed bathythermographs sent over 200,000 temperature-depth records to the Hydrographic Office, and the Swell Forecast Section, staffed by American and British oceanographic meteorologists at the British Admiralty, forwarded some 15,000 visual observations of breaker heights made along the eastern and southern coast of England during 1944. As a result of these and similar contributions from many military activities, the Hydrographic Office acquired

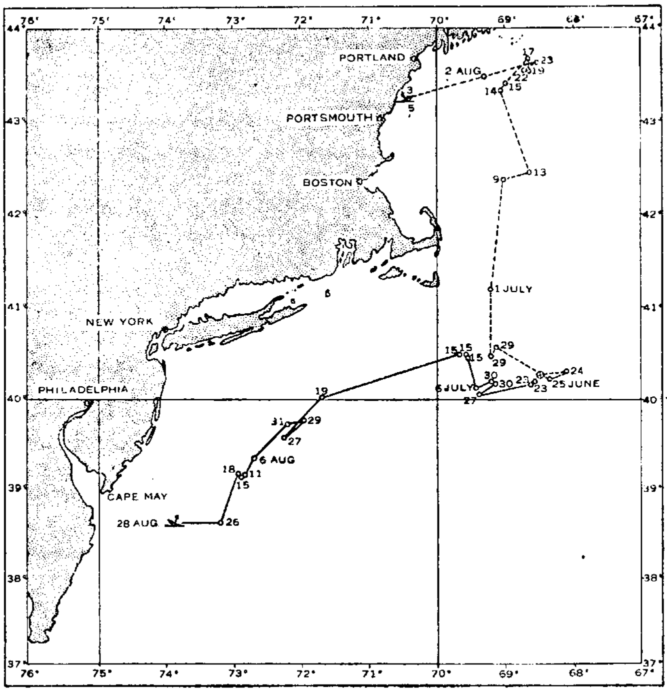

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Fig. 3

Drift of the two portions of the schooner « Fred Taylor »

The encircled cross marks the position of the collision. The stern portion rode high out of the water, while the bow portion was almost entirely submerged.

the greatest store of oceanographic Office information ever assembled by one activity. In addition, a bibliography was started. By the summer of 1945 there were 15,000 entries that covered the theoretical phases of oceanography as well as the information for specific areas. The bibliographic program is being continued on a broader scale. A great many of the wartime publications of the Hydrographic Office dealing with the application of oceanographic data to specific problems of the armed services are still classified but the basic information on file at the Hydrographic Office is available to all.

THE POST-WAR PERIOD

The United States Navy has been quick to realize that modern warfare brought about a new era in the study of the sea. In order to assist in the co-ordination of the research and development program in military oceanography, to provide the basic oceanographic information required by the War and Navy Departments, and to serve as a repository and clearing house for such information, the Secretary of the Navy in 1946 directed the Hydrographic Office to organize a permanent Division of Oceanography. As three of the seven divisions of the Hydrographic Office, namely the Divisions of Chart Construction, Maritime Security, and Navigational Science, already carry on certain phases of work that fall within the scope of applied oceanography, the interests of the Division of Oceanography have been defined to lie in the following fields :

1. Surface and sub-surface currents.
2. Interaction of the sea and atmosphere, including currents due to wind; wind waves, swell, and surf; exchange of heat and water; and conditions which affect radar propagation and the behavior of smoke screens.
3. Distribution of physical properties, such as density, color, transparency, and temperature.
4. Distribution of chemical properties.
5. Distribution of plants and animals in the sea.
6. Characteristics of the sea bottom, including that of beaches.
7. Tides, tidal currents, and tsunamis (tidal waves).
8. Formation, behavior, and properties of sea, glacial, and river ice.

The work to be carried out in these fields falls into four general programs : (1) survey and research; (2) compilation of data; (3) publication of charts, manuals, and reports, and (4) assisting in the training of military and civilian personnel in oceanography. Until a specially equipped oceanographic survey vessel is available, every effort will be made to extend the observational work of the hydrographic survey vessels and other naval craft. To supplement the present small staff and limited facilities and carry out essential oceanographic investigations, the Hydrographic Office and the Office of Naval Research are sponsoring contracts at several of the private oceanographic institutions. Part of this contract work provides field and office experience for graduate students who are now being trained in the many phases of the science of the seas.

In addition to providing the armed services with strategic and tactical intelligence, these programs will supply the merchant marine, civilian agencies of the government, fisheries, airlines, engineering firms, and the general public with valuable information on economic problems and safety at sea. The specific and every-day problems in applied oceanography which arise in connection with safety at sea, such as the drift of ice, derelicts and mines, the preparation of Pilot Charts, and similar subjects, fall within the cognizance of the Division of Maritime Security.

During 1946, the oceanographic activities at the Hydrographic Office were sharply curtailed by demobilization and by practically all oceanographers being required for the atomic bomb tests in Bikini Atoll. However, it was possible to publish the *Ice Atlas of the Northern Hemisphere,* the wartime work of Lieut. (jg) John C. Weaver, United States Naval Reserve. With increased interest in the Arctic regions, this publication is rapidly becoming a basic work. For example, the polar expert, Dr. Lawrence Gould, writes in a recent issue of the *Geographical Review* :

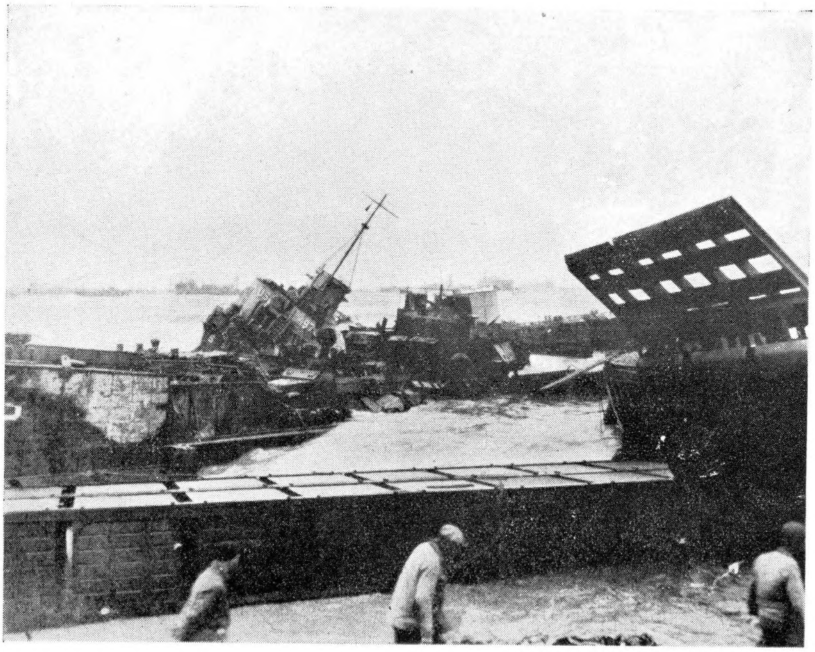
> « Although this great atlas is designed with reference to its usefulness in « navigation, it is much more than simply another tool for the navigator. Any « student of ice conditions in the Arctic, no matter what his approach may be, « will find the atlas, with its superb tables and extensive bibliography, a « necessary part of his equipment. »

Other oceanographic material published include a bibliography on the physical oceanography of the western Pacific Ocean and a technical report by Drs. H. U. Sverdrup and W. H. Munk on the theories used in forecasting wind waves and swell.

Unpublicized work includes a study of SOFAR conditions in the Pacific; arranging for oceanographers and necessary gear to accompany *Task Force Sixty-Eight* to the Arctic in the summer of 1946 and to the Antarctic in the winter of 1946-1947; the preparation of wave refraction diagrams for the breakwater at Guam; examination of a part of the Japanese observations obtained at thousands of locations in the Pacific; and assisting in the outfitting of several fishery research vessels with oceanographic gear.

Work in the future will stress not only the accumulation of additional data on a world-wide basis, but also the interpretation and application of oceanographic observations. During World War II, the existing information about the sea was fully exploited for all areas of strategic importance, but there are vast regions of the sea still virtually unexplored and there are but few locations that have been adequately surveyed. Emphasis will be placed on a thorough study of all data from the military, commercial, and scientific viewpoints, for it is a poor economy that spends large sums for taking observations and does not provide for the full evaluation and use of the information.

Increasing interest in the polar regions has shown the need for special techniques for ice prediction and navigation, and a better understanding of oceanographic conditions in high



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Damaged Landing Craft on Omaha Beach, June 1944.

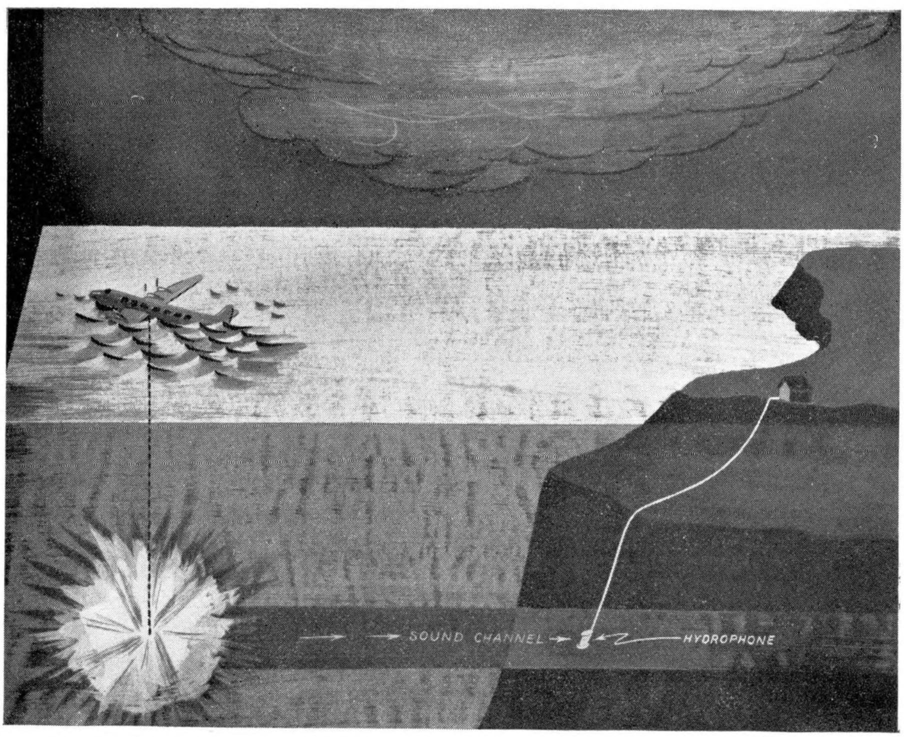

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Fig. 4

Schematic Representation of the SOFAR Technique

A sound signal from a small explosion in the permanent sound channel (layer of minimal sound velocity) of the ocean may be heard by hydrophones located in the channel thousands of miles away. The depth of this channel is of the order of several hundred fathoms and may be determined by using the temperature and salinity data acquired at oceanographic stations.

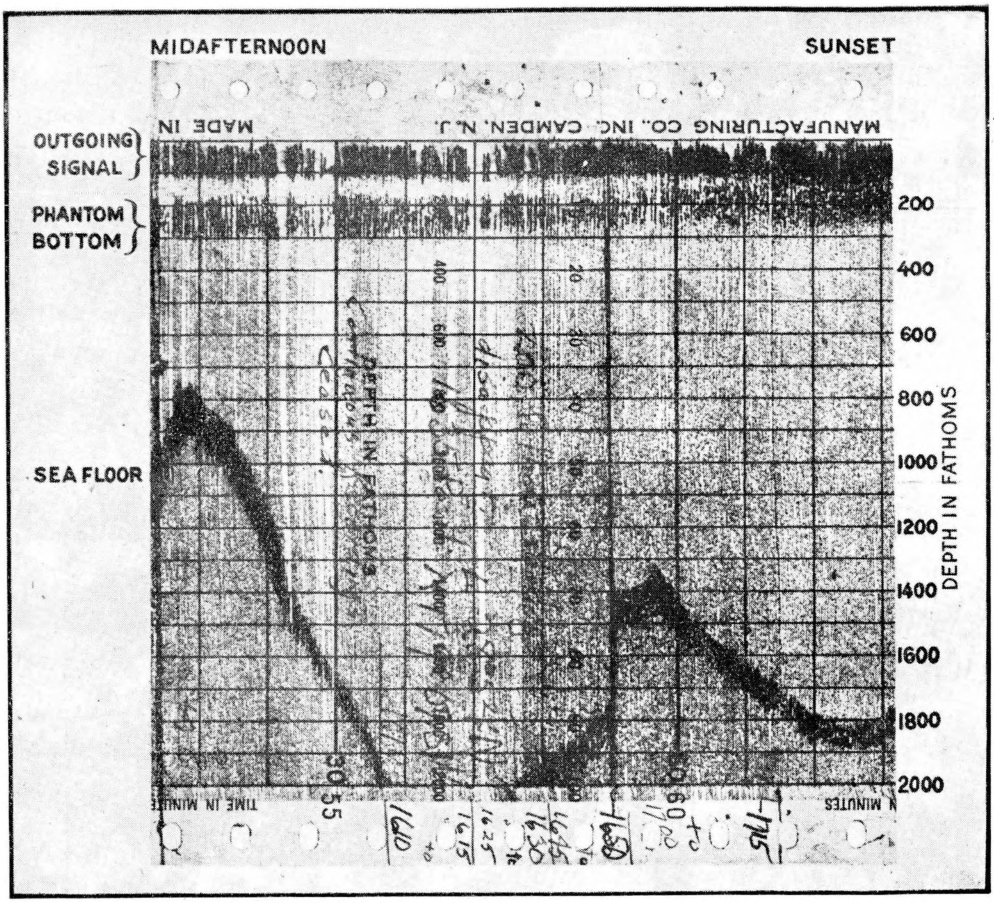

Fig. 5

Sketch of fathogram obtained by the carrier "USS Independence" in the region of Midway Island on December 8, 1945. The landing ship, "USS OZARK", passing four miles to the south of the "Independence" on that day, also reported the phantom bottom.

latitudes. With such information available, specially designed ships might well be able to operate each year for a much longer period than is now considered possible. Another recent development that requires extensive oceanographic information is the method for long-range communication and position finding called SOFAR (Sound Fixing and Ranging) (fig. 4). One of the most important of the several highly useful applications of this technique is that for accurately locating vessels and aircraft in distress. If special signal bombs are dropped, the position of the explosion can be accurately and practically instantaneously determined through triangulation by shore listening stations. The relatively large group of oceanographers assigned to the atomic bomb tests at Bikini Atoll indicates the importance of a full knowledge of circulation and explosively generated waves in future military planning. The most effective use of the " true submarine " now under development, which may operate submerged for weeks at a time, will require preparation of oceanwide charts of currents and other conditions at sub-surface levels.

The ocean is an inexhaustible source of food and other raw materials and the commercial exploitation of the sea offers a fruitful field for research and the application of oceanographic knowledge. During the war, investigations of underwater sound revealed the presence of a " phantom bottom " which can be detected by echo-sounders at depths of two or three hundred fathoms. So far, this phenomenon has only been reported off Southern California, near Midway Island and the Phoenix Islands in the mid-Pacific, and near the Bahamas in the Atlantic. As the phantom bottom changes depth at sunrise and sunset, the echo is probably produced by fish and other animal life. The possible importance of this layer in locating and catching fish of commercial importance has not yet been determined. Simple and remote controlled photographic equipment developed during the war offer great possibilities in engineering problems, salvage operations, and the evaluation of the fish and shell-fish populations in shallow water. This is but one example of new techniques which have not yet been applied either to the scientific study of the sea or to commercial problems.

The increasing amount of oceanographic information will make it possible to prepare synoptic charts showing the distribution and character of the currents, temperature conditions, and other properties believed to be important factors in the control of world climate. The explanation of anomalous climatic conditions such as droughts, unusually cold winters, and excessive storminess must be related in some manner to departures from normal in the oceanographic pattern, and methods of long-range weather forecasting may well be found in the studies of synoptic oceanographic charts.

Results of wartime studies in waves, surf, and nearshore currents are becoming increasingly important to the engineering fraternity. The hydraulic engineer, when designing earth dams that cost a quarter of a million dollars more per foot of height near the crest, must have full information on ride-up and set-up; the petroleum engineer constructing million-dollar drilling platforms miles offshore must be fully acquainted with the potential forces of destruction that the structures may be called upon to withstand; engineers building piers and breakwaters must study the oceanographic conditions that may cause design failure; and sanitation engineers searching for satisfactory oceanic outlets for sewage from coastal cities must be briefed in currents and mixing processes. Other applications evolving from the recent wave investigations include a rigid analysis of potential shipping routes on the basis of fuel consumption, delay, safety, and discomfort to passengers; and a technique for tracking storms by studying forerunners of ocean swell, a method particularly applicable to oceanic storm-generating areas untraversed by shipping or air routes.

Months, and even years of carefully planned observations and measurements are required to permit prompt provision of the basic oceanographic data required by these and many other applications useful to the Armed Services, merchant marine, governmental agencies, fisheries, airlines, engineering firms, and the general public. Even when all necessary data are at hand, the compilation, analysis, and preparation of charts and publications takes several months or more. To keep fully abreast of present developments and future requirements for data, the Hydrographic Office plans to continue the effective wartime liaison with activities outside the Navy. These include the Beach Erosion Board and the Military Intelligence Division of the Army Engineers, the Air Weather Service of the Army Air Forces, the Coast Guard, the Coast and Geodetic Survey, the Geological Survey, the Fish and Wildlife Service, and various civilian institutions and expeditions, both private and foreign, interested in oceanographic investigations. The ultimate goal is to provide full oceanographic coverage on a world-wide basis comparable to that already accomplished by the Hydrographic Office for charts, sailing directions, and other navigational publications. To this end, the Hydrographic Office encourages and will assist all United States agencies in collecting additional data and in compiling all available information including that obtained by exchange from foreign sources. Because of the magnitude of the task, full co-operation will be necessary in order to continue oceanographic investigations on the scale necessary for the national security and the economic development of the United States.

It is hoped that the Hydrographic Office will eventually fulfill the same function for oceanography as it now does for hydrography and the Weather Bureau for meteorology.