# OCEANOGRAPHY IN THE U. S. COAST AND GEODETIC SURVEY

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Oceanographic activities of the Coast and Geodetic Survey were of immediate concern to the new agency of government, *Survey of the Coast,* established by President Jefferson more than 150 years ago. Systematic oceanography in the United States originated with the first surveys by the Coast Survey in 1834-35. The necessity of making oceanographic studies was an initial requirement if the secrets of the restless ocean and the forces affecting its movements were to be revealed. Over the years untold benefits have accrued to industry, science, engineering, and requirements of national defense through the great progress achieved in this branch of the physical sciences.

Strange as it may seem, lack of information concerning the oceans or the science dealing with the earth's water mantle, has been both a hindrance and a motivating force concerning man's relationship with the seas and his desire to conquer them. To the timid or weak man, the unknown facets of oceanography have appeared as barriers to progress or exploration, but to the strong and daring with a desire for knowledge these mysteries of the great water frontiers of the world not only appeared as a challenge to his progress, but also as another facet of nature that must be subdued in the course of exploration.

Benjamin Franklin might be considered the father of oceanography in the United States, or at least one of the first patrons, for his efforts in directing the attention of the scientific world, about the middle of the 18th century, to the existence of the Gulf Stream. The second Superintendent of the Coast Survey, Professor Alexander Dallas Bache, a direct descendant of Franklin, inaugurated the first orderly investigation of the Gulf Stream, undertaken during the summer of 1846. American seamen navigating the historic clipper ships attained world superiority in Atlantic crossings by being the first to discern the existence of the wide river of the sea, which was used effectively on eastern voyages but was to be avoided on the return trips to American ports. Extensive observations of the Gulf Stream by Pillsbury in 1880 brought the discovery of a south-flowing countercurrent beneath the Gulf Stream in the vicinity of southern Florida and the Great Bahama Bank. This interesting oceanic phenomenon was recently *rediscovered.*

Admiral Sigsbee, in his explorations almost 100 years ago, added materially to oceanographic knowledge. He invented and developed many

of the instruments and techniques for gathering and measuring oceanographic data. The improved Sigsbee sounding machine added immeasurably to oceanographic investigations. Another Sigsbee invention was a clam-bucket type of bottom sampler which provided an improved device for obtaining information on bottom materials. Sigsbee also developed a multiple container that provided for simultaneous water temperature and water samples, with an automatic registering device.

## BRANCHES OF OCEANOGRAPHY

Oceanography is a relatively new term in scientific nomenclature. Oceanography, basically inseparable from hydrography, may be divided into four branches — physical, chemical, geological, and biological oceanography. Physical oceanography which deals with the physics of the oceans is the most pertinent to Coast and Geodetic Survey operations. This branch deals with tides, currents and waves, the physical processes in operation, and the distribution of variables such as temperature and density of sea water. Geological oceanography deals with the geology of the continental shelves, structure of the ocean floor, and the deep ocean beyond the continental margins.

Scientific studies in the biology of the oceans have revealed that just as seeds and minute life of the land are windborne and distributed afar, the defenseless embryonic and tiny adult life of the sea is carried from one place to another by ocean currents. The myriad microscopic drifting plants and animals that form the *pastures of the sea* are the sole food of many commercially valuable fishes. In addition, the sponges, pearls, lobsters, cod, tuna, salmon, whale and other marine animals, and some seaweeds, support thriving industries.

The chemistry of sea water is also a facet of the science of oceanography. The evaporation of sea water for commercial extraction of salt is an old and well-known process. Much more modern and less known are plants being operated for the recovery of magnesium and other elements from sea water. The removal of salt by desaltation so that sea water can be made usable at least for irrigation, if not for human consumption, is a problem with which the chemical oceanographers are concerned. Just recently a potential breakthrough was announced whereby *sweet* water can be produced for $1 per thousand gallons.

## PHYSICAL OCEANOGRAPHY

The Coast and Geodetic Survey is a recognized world leader in physical oceanographic work. Oceanography has formed an integral part of the hydrographic surveying and charting work of the Bureau for more than a century and a quarter. In carrying on regular surveying operations, many oceanographic observations and studies have been made, some of which have ultimately led to significant discoveries and uses of far-reaching importance.

The ocean, covering approximately 70 percent of the earth's surface,

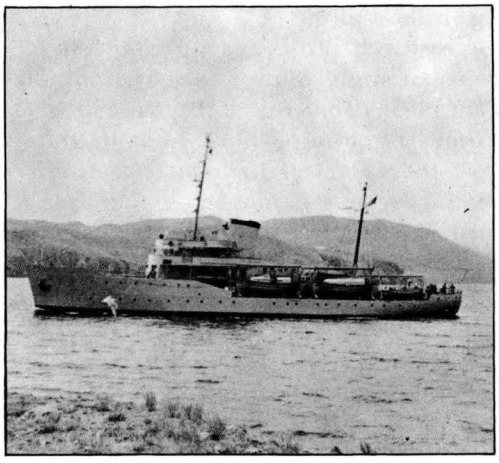

FIG. 1. — USC & GS Ship *Explorer*.

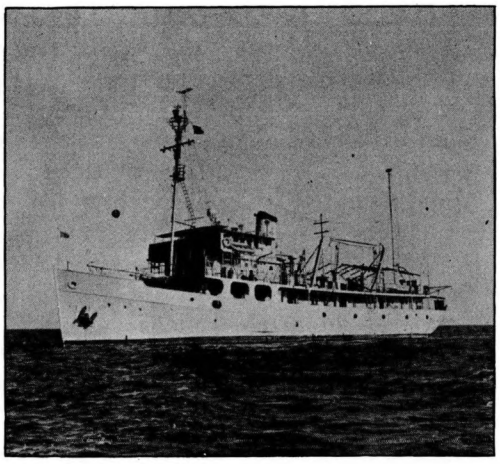

FIG. 2. — USC & GS Ship *Hydrographer*.

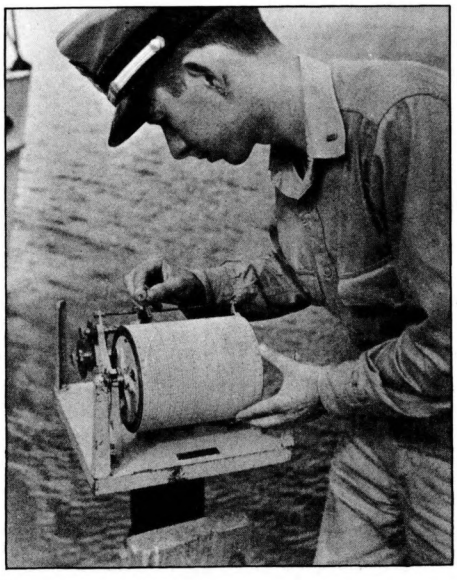

FIG. 3. — Portable Tide Gauge at Port Canaveral, Fla.

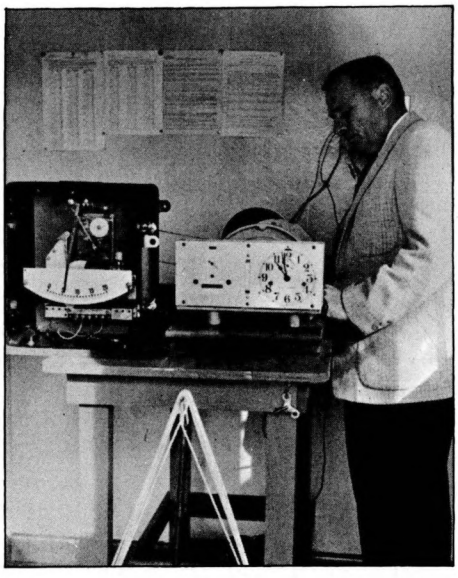

FIG. 4. — Standard Tide Gauge Installation with Remote Recorder.

could hold the key to the future of mankind, if we intelligently seek to understand its mysteries. The vital part played by the oceans in the economy of all maritime nations is just beginning to be realized.

Basic to any oceanographic study or research project is the gathering of the physical data necessary for the projected study. Many types of studies are of necessity repetitious in nature. This means that the ability to collect data at identical locations at different times is all-important. In both the collection of data and the ability to collect these data at the same location, time after time, the Coast and Geodetic Survey has demonstrated unique capability over many decades of sustained effort.

The Bureau has pioneered in the development of techniques for making oceanographic observations, including depth measurements, temperature, salinity and density measurements, water samples, bottom samples, and the development of special equipment for making these observations.

Knowledge of the nature of the magnetic field over oceans is pertinent to modern oceanographic research. The Coast and Geodetic Survey has collaborated with the U. S. Navy in the development of an induction magnetometer for airborne use over the oceans and for use in magnetic submarine detection work.

## NAVIGATION AND CONTROL

Precision navigation systems and methods have been progressively developed in step with new and improved methods of depth recording. Precision navigation, to be of surveying accuracy, requires a continuous accurate knowledge of the vessel's position at all times while at sea. It is this type of navigation which is employed by the Coast and Geodetic Survey for hydrographic and oceanographic activities.

Radio Acoustic Ranging (RAR) was developed in the 1920's for accurately determining the position of the survey ship when out of sight of land, day or night, in clear or foggy weather. Position of the ship was determined by measuring the time for an explosive underwater sound to travel from the survey ship to underwater hydrophones placed at known locations. RAR gave way to electronic positioning adapting World War II developments such as Shoran to positioning of hydrographic survey ships. Due to the approximate line-of-sight limitation of Shoran, the Bureau developed its own Electronic Position Indicator (EPI) in order to carry accurate positioning to greater distances offshore, up to 500 miles and more. The Bureau is also using a commercially developed navigational system and makes use of Loran.

## CONTINENTAL MARGINS

Every continent rests on a submarine base extending seaward at varying distances from shore. To this submerged extension of the visible continent has been given the name *continental shelf*. More specifically, it may be defined as the submerged margin of a continent, which slopes seaward to a point where a substantial break in grade occurs. Or if we

approach the matter from seaward rather than from landward it would be the first well-defined rise from the ocean floor, which in the majority of instances would be the 1 000-fathom curve.

The continental shelf is not everywhere of uniform width. In the United States it varies from a few miles off parts of California to over 200 miles off Cape Cod. In parts of the Gulf of Mexico it has a width of over 120 miles. The continental shelf comprises an area of more than 300 000 square miles in the continental United States and 550 000 square miles in Alaska. In recent years, the continental shelf has assumed increasing importance with the discovery of oil and gas. A littoral nation's right to explore and exploit the natural resources of the subsoil and seabed of the continental shelf and beyond to its limit of competence, has been given international approval at the recent United Nations Conference on the Law of the Sea.

In the United States, the urgency is recognized for intensive studies of the continental shelves through greatly accelerated hydrographic surveying operations and supporting oceanographic research. Data thus collected are especially essential before effective exploitation of undiscovered natural resources can be undertaken in the great underwater frontiers of the nation. This vast underwater domain presents a great challenge to the modern hydrographer equipped with all the new techniques of this modern technological age.

The Coast and Geodetic Survey has been working in the area of the shelf for many years in furtherance of its statutory responsibility of providing nautical charts and related information for safe navigation. Many by-products have resulted therefrom of interest to the scientist and the engineer, and to the public generally. Detailed surveys of these areas have in the past opened up new fishing banks to commercial exploitation, and have furnished evidence of potential oil reserves in the offshore areas. Additional hydrographic and oceanographic surveys may open up new sources of food supply and bring to light promising areas of other natural resources.

## TIDES AND CURRENTS

The role of the Coast and Geodetic Survey in the study of currents in the oceans and estuaries has traditionally been in the direction of navigational aid to augment the nautical chart. However, as this country turns to the oceans more and more as a source of food and minerals and as a dumping area for radioactive wastes, a knowledge of circulation below the surface becomes mandatory. Similar studies of various harbor estuaries are proposed or already under way because of the increased pollution associated with industrial and population growths.

The continuing development of atomic energy will progressively produce greater amounts of radioactive waste material. Rapidly developing private use of radioactive materials demands adequate control of radioactive waste discharge from nuclear reactors, uranium mills, research laboratories and the like. Since the oceans cover more than 70 percent of the earth and ultimately receive the drainage of the land, they are the

FIG. 5. — Taking sea-water temperatures and salinity on Ship *Hydrographer*.

FIG. 6. — Sea-bottom samples. Ship *Hydrographer*.

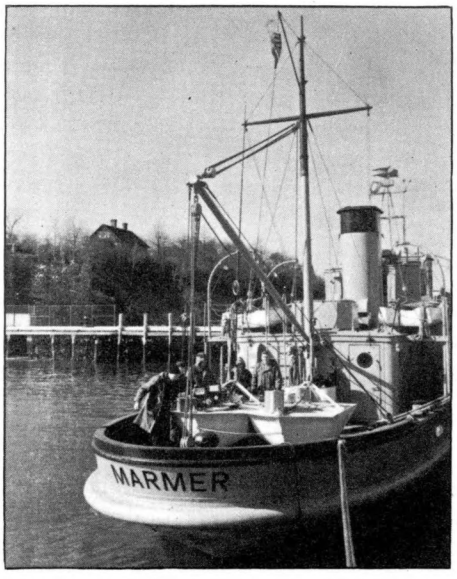


FIG. 7. — Radio current buoys aboard Ship *Marmer*.

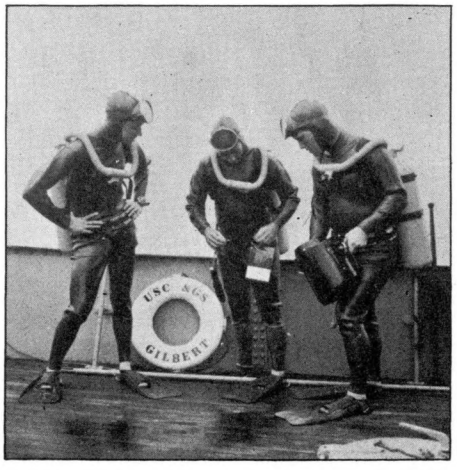


FIG. 8. — Divers preparing to dive from Ship *Gilbert*.

ultimate reservoir where most of radioactive waste will finally accumulate. The only place on earth where the disposal of the wastes can be considered practical is in the oceans. However, the dispersal of radioisotopes in the ocean must proceed very carefully with additional investigations in areas where knowledge is now limited.

Great potential danger is present in the indiscriminate introduction of wastes into coastal waters, especially in the upper layers. This is the habitat of most of the important commercial fishes. The major fishery resources of the world are concentrated near the coasts and could be contaminated. Coast waters enter harbors and bays and could carry waste material with them.

Direct measurements of deep currents are extremely meagre. To date much of these data are obtained by indirect measurements based on precise measurements of temperature, salinity, and density. Last year, actual direct observations were made with current meters by the Bureau's oceanographers at the edge of the continental shelf off the Massachusetts coast. This year in Alaskan waters further investigation will be made by following a number of underwater drogues set at predetermined depths for direct measurement of the velocity and direction of these deep ocean currents.

Variations in the level of the sea attain increasing importance with the development of coastal areas. Data obtained by the Coast and Geodetic Survey at a number of key control tide stations distributed along our coasts provide basic data covering more than half a century for the determination of short-period as well as progressive changes in sea level. Over the past fifty years sea level has been rising along the Atlantic coast at an average rate of eleven one-thousandths of a foot per year, or about one foot per century. There have been ups and downs, but the net change has been an increase in sea level that is probably related to the gradual melting of our polar ice caps. This melting started about 11 000 years ago when the great continental glaciers of the Pleistocene Ice Age started their last retreat from as far south as New Jersey. The rate of rise of sea level has slowed tremendously since the start of that ice retreat, but it is apparently still in progress. On the Pacific coast the rate has been only half of that on the Atlantic. An investigation was conducted in southeast Alaska during the summer of 1959 where the land as measured from sea level appears to have risen as much as 5 feet in 60 years.

As the need for accurate tidal predictions has increased over the years the scope of predictions has expanded from a handful of stations in 1867 on the east and west coasts of the United States, to four volumes containing daily predictions for 5 000 places distributed over the world. The accuracy of predictions has also been increased by improved observations, greater density of station distribution, and improved instrumentation. The prediction process has been changed from the slow, laborious curve and equation method to fast automatic tabulation of tide-predicting-machine computations. Predictions of the ebbing and flooding of the tidal currents are also made by the same automatic equipment. Advance information on currents is not only essential for safeguarding navigation along our coasts, but is also invaluable in many oceanographic activities.

## SEDIMENTATION

Another phase of the overall oceanographic research program to be considered is the study of sedimentation, particularly as it relates to our coastal areas. Continual changes are occurring in the submerged lands of coastal areas. Areas of sedimentation and shoaling require resurveys for up-to-date charting. But in addition to proper charting of these marginal areas, concurrent studies are desirable to determine causes and methods of correction. In many areas considerable funds are expended each year by the Government in dredging and maintaining navigation in the main shipping channels.

For more intensive study of the bottom sediments, coring devices are used. Studies of core samples disclose a wealth of important scientific data from the submerged surface of the earth which, until recently, has remained hidden from the investigator. The additional fact that the approximate limits of the ocean basins are believed to be unchanged since early geologic times also makes studies of these areas of scientific importance. The sedimentary layers have been deposited in historic sequence. In the middle of the ocean basins they remain undisturbed and have been deposited very slowly, so that a vertical core a few feet long represents a very long period of time.

The geologist obtains important information from the character and thickness of the successive layers. From core samples an idea may be obtained of variations in the depth of the ocean in the past and also of changes in climatic conditions from a study of the fossils of microscopic animals.

Many minute particles of magnetic materials that have settled to the bottom are found in bottom core samples, oriented along the line of magnetic force. A study of these minute particles, with delicate electric apparatus, to determine the shift in orientation through the length of the core, reveals the cyclic change of the lines of magnetic force throughout the period of time represented by the deposits in the core.

## SEAMOUNTS

Continuing surveys are made of ocean waters of the Gulf of Alaska by ships of the survey fleet en route to and from summer survey areas in western Alaska and the Aleutian Islands. The Gulf floor is dotted with immense seamounts which have been discovered over a period of many years. They are grouped or aligned over extensive distances. Large numbers are detached volcanic cones, while others are peaks on extensive ridges. Many of the seamounts rise two miles above the ocean bottom. Discovery of these seamounts and other extensive features in the Gulf of Alaska has created considerable scientific interest in that area.

The operational use of nuclear-powered deep-running submarines of the *Nautilus* type, and the development of counter measures against these, including detection, identification, tracking, and attack, will inevitably require a far greater knowledge of the location and definition of seamounts

as well as other underwater features. The wealth of knowledge accumulated of the Gulf of Alaska and the accurate delineation that is afforded of the underlying sea floor are invaluable in this modern age. All ocean areas should be surveyed with the same degree of thoroughness and accuracy.

## OTHER RECENT DISCOVERIES

The Scripps Institution of Oceanography and the U. S. Fish and Wildlife Service announced the discovery of a great subsurface current equal in flow to a thousand Mississippi Rivers and as swift as the Gulf Stream. This vast hidden river of the sea is reported to be 250 miles wide and 1 000 feet deep. It flows eastward along the Equator in the Pacific Ocean for at least 3 500 miles. This discovery demonstrates the complicated current structure of the oceans. Another but much weaker current was located flowing west beneath the swiftly flowing east current. Both currents lie beneath the South Equatorial Current; thus in a relatively small area of the Pacific are three great currents lying like ribbons, one atop the other, and being pulled in different directions.

More complete knowledge of these currents and other such natural phenomena of the sea might well prove to be important factors in developing the equatorial waters into fertile marine pastures for harvesting fish and other sea life. Certain it is that a better understanding of the location and extent of these currents, the temperatures of the waters involved, the heat and moisture exchange between the ocean surface and the air, will increase our understanding of the weather in all its various phases.

## CONCLUSION

The subject of oceanography is most interesting and one which has many facets; it may be rightly referred to as the last frontier on the globe. Man is exploring outer space, but there is still a tremendous amount of *inner space,* right here on our own globe, about which we know too little. Recognizing the tremendous importance of the ocean, and the scarcity of our knowledge about it, a Committee on Oceanography was formed in 1957 by the National Academy of Sciences of the United States. The first report of this committee, issued in March 1959, outlined in detail the national need for more surveys and more research in oceanography. The National Academy of Sciences program proposed for the next ten years would be an ambitious and far-sighted undertaking.