Age of Electronics (1946-1970)

Toward the Theory of Plate Tectonics
Three Great Tools of the 1960s
Cooperative Efforts in Ocean Research

This photograph shows the C&GS Ship *Pioneer* passing under the Golden Gate Bridge. In August 1955, the *Pioneer* deployed the first towed marine magnetometer, an invention of the Scripps Institution of Oceanography. (NOAA Photo Library). Click image for larger view.

Postwar Developments

Following World War II, the Coast and Geodetic Survey's operations returned to normal. A new type of navigation, known as Shoran, came to replace the older RAR (radio acoustic ranging); and electronic echosounding was the common system in use for delineating the bottom, although the lead line was still used to acquire least depths over possible obstructions to navigation. Tracklines to and from Alaska were still followed. A major development during this period was the Electronic Position Indicator (EPI), a navigation system developed by the Coast and Geodetic Survey that gave accuracies of approximately 100 ft at distances out to 200 mi from shore-based stations. Shoran, by comparison, was only good to 50 to 60 mi under the best of conditions. EPI was first tested and used in surveys in the Gulf of Mexico in 1947. In 1952, EPI was used in the Bering Sea, with the result that the true nature and extent of Bowers Bank, just north of the Aleutian Islands, became known for the first time.

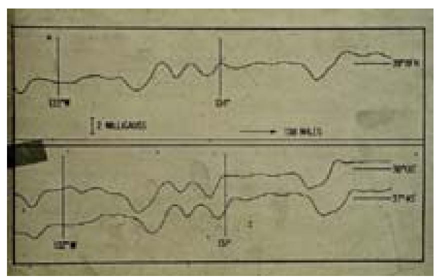
Concurrent with these developments, the academic world was beginning to strike into the deep sea, as Roger Revelle of the Scripps Institution of Oceanography led two significant expeditions in the early 1950s. The first, termed MIDPAC, was a study of the Mid-Pacific Mountains south of the Hawaiian Islands, while the second, Capricorn, involved exploring the far reaches of the South Pacific Ocean. The Northern Holiday and Shellback expeditions of this same era, led by Warren Wooster of Scripps, marked the beginning of academic incursions into the deep sea for physical

This Electronic Position Indicator was used in Bering Sea operations, circa 1951. (NOAA Photo Library). Click image for larger view.

oceanographic studies.

Toward the Theory of Plate Tectonics

Inevitably, EPI and Shoran were replaced by newer commercial navigation systems bearing names such as Raydist and Hi-Fix. EPI had a "last hurrah" in 1955, however, when the Coast and Geodetic Survey Ship *Pioneer* used it to survey the U.S. West Coast from San Diego to Cape Flattery. This was a Navy-funded survey in support of submarine warfare needs. The Navy required accurate bathymetry out to a few hundred miles offshore. Shortly into the project, the Scripps Institution of Oceanography requested that it be allowed to tow a newly developed marine magnetometer from the *Pioneer.* Permission was granted, leading to what the great marine geologist H.W. Menard called "one of the most significant geophysical surveys ever made." The *Pioneer* Survey, as it came to be called, discovered long, linear magnetic "stripes" on the sea floor. Ultimately, this striping led to the ability to date the age of the sea floor, as well as to compare magnetic patterns across fracture zones and from one side of an oceanic ridge to another. Because of these factors, the recognizable magnetic patterns associated with the sea floor were a major element in formulating the Theory of Plate Tectonics.



Early magnetic profiles from *Pioneer* surveys. The top profile, as compared to the bottom two, shows the repeating magnetic "striping" pattern that occurs after crossing over the Mendocino Fracture Zone. (NOAA Photo Library). Click image for larger view.

A third major development of the 1950s was the invention of the Precision Depth Recorder (PDR) at the Lamont Geological Observatory of Columbia University. This machine measured depths with errors of less than 1 percent of total water depth. The PDR discovered abyssal plains -- the flattest places on Earth. The *Pioneer* was equipped with a PDR for its Pacific coast bathymetric survey, and the PDR also helped Bruce Heezen, Marie Tharpe, and Maurice Ewing of Lamont discover the Mid-Atlantic Ridge Rift Valley in 1959. This was, perhaps, the single most significant bathymetric discovery made since the beginning of deep ocean exploration. Like the recognition of sea-floor magnetic striping, and the earlier seismological work of C&GS scientist Nicholas Heck, which established the correlation of many intra-ocean earthquake epicenters with the location of mid-ocean ridges and rises, this discovery of the median rift valley of what we now know are active oceanic ridges was a major stepping-stone on the road to the Theory of Plate Tectonics.

It only remained to put the pieces of the puzzle together. Harry Hess, of Princeton University, did this in the early 1960s, when he published his famous "essay in geopoetry," outlining the major elements of sea-floor creation at ridge crests, sea-floor destruction along the oceanic trenches, and the rafting of passive continents over mantle material of the Earth's interior. In the years since he presented this elegant concept, the evidence supporting it has grown at ever increasing rates. This one paper led to a whole new way of looking at the Earth as a unified system, relating the evolution of the sea floor as a key to understanding the distribution and evolution of the continents, the evolution and distribution of life on earth, and the evolution of present-day oceanic current and weather systems. The implications of Hess's theory for economic geology, as related to the distribution of resources, was also enormous. It had become clear that what happened in faraway seas, in far away times, did indeed affect all of us profoundly.

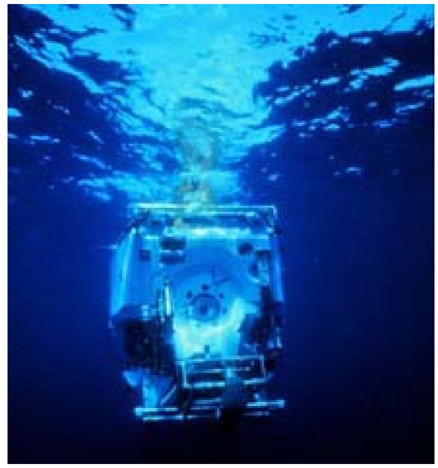
Hess's theory came at an opportune time in the history of ocean exploration. A few years earlier, the Committee on Oceanography of the National Academy of Sciences/National Research Council had issued its 1959 report during the Administration of President Eisenhower; then, President John F. Kennedy had called for a "national effort in the basic and applied research of oceanography." He noted that "Knowledge of the oceans is more than a matter of curiosity. Our very survival may hinge upon it." This statement referred to national defense needs, environmental concerns, and the wise extraction of resources from the sea. In such an atmosphere, oceanography and ocean exploration, like the parallel efforts of the space race, began to thrive.

In 1965, the *Surveyor* used a sidecan sonar system to explore an offshore extension of the San Andreas Fault. (NOAA Photo Library). Click image for larger view.

Three Great Tools of the 1960s

Three great tools of ocean exploration were developed during this period. The first was the Deep Tow instrument system, built and operated by the Scripps Institution of Oceanography. This tethered system was lowered from a surface vessel to just above the sea floor. The system was originally designed to obtain sea-floor slope information in the deep sea. Ultimately, it evolved into a system with multiple sensors for characterizing the deep-sea environment including a downward-looking, narrow-beam sounding system, a sidescan sonar system, television and still-camera systems, and a variety of other sensors and sampling devices. Bottom-mounted acoustic transponder navigation instruments were developed to support the relative navigation of the Deep Tow instrument within a study area. Virtually all deep-towed instrument packages ultimately trace their lineage to the Scripps system.

Multibeam sounding instruments were the second major development of this period. The first multibeam sounding system, known as the Sonar Array Sounding System (SASS), was installed on the U.S. Navy Ship *Compass Island* in 1963. Multibeam sounding systems obtain depths over a swath of bottom perpendicular to the heading of the survey ship, as well as directly below the ship (as in single-beam sounding systems). Such sounding arrays, coupled with accurate navigation, allow the immediate generation of accurate sea-floor maps. Multibeam sounding systems are now the de facto instrument for most

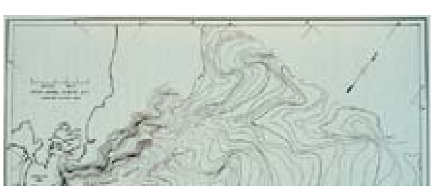


The deep submersibe vehicle *Alvin* is, perhaps, the most active and successful research submersible of our time. (NOAA Photo Library). Click image for larger view.

The third major instrument developed during this period was the manned research submersible. The U.S. Navy acquired the bathyscaph *Trieste* from the Piccard family -- the Swiss engineers who designed and built it -- and used it to dive to the deepest spot in the ocean in 1960. Nevertheless, it was ill-suited to the needs of research scientists. Consequently, the Navy funded Woods Hole Oceanographic Institution to procure a small research submersible. In 1964, the now-famous *Alvin* was launched and began its career of unparalleled oceanic research and exploration. *Alvin* has transported scientists to the edge of creation while studying processes on the ocean ridge systems; its viewing ports have been a window to the unsuspected chemosynthetic communities discovered in the vicinity of hydrothermal activity and cold seeps in many areas of the ocean; and from its interior scientists have observed, for the first time, deep-sea sedimentary and biological processes. Helping to publicize its use as an ocean observation tool was its discovery in 1966 of a hydrogen bomb, lost off Palomares, Spain, from a U.S. Air Force B-52 that had collided with a tanker plane during refueling operations.

Seamap and Other U.S. Initiatives

Other major developments in the 1960s included the U.S. Navy's ocean survey program; the C&GS's building of a fleet of new survey ships, including a number of ocean survey vessels; the building of a research fleet for the university community; and the C&GS's Seamap Project, initiated in 1961. The Seamap Project was started in response to the 1959 National Academy of Sciences report, and was notable because it was the first time that survey ships embarked on the specific mission of systematically mapping large areas of an oceanic basin (the North Pacific). Most tracks were oriented north-south and extended between the Aleutian Islands and the Hawaiian Islands; line spacing was 10 nm (nautical miles) between survey lines. Seamap ships observed an integrated suite of geophysical parameters, including bathymetry, gravity, and magnetics. The ships ran many thousands of miles of trackline before the project ended in the early 1970s. While new technologies and new requirements for accuracy have rendered these first efforts obsolete for most purposes, Seamap was a pioneering effort that proved the importance of such surveys.



Cooperative Efforts in Ocean Research

In spite of the U.S. Government's relatively large investment in survey and research ships during this period,

During the International Indian Ocean Expedition of 1964, the *Pioneer* produced this survey of Trincomalee Canyon in Sri Lanka. 1964. (NOAA Photo Library). Click image for larger view.

it was clear that exploration of the oceans required international cooperation. The Coast and Geodetic Survey participated in its first international cooperative effort in 1963. The project, EQUALANT, was a study of the equatorial Atlantic Ocean between Africa and South America. This was followed by the International Indian Ocean Expedition of 1964, and the C&GS Ship *Oceanographer's* around-the-world cruise of 1967. At the time, the *Oceanographer* was the newest and largest oceanographic ship in the U.S. research fleet.

The trend of international cooperation in ocean science was highlighted by President Lyndon Baines Johnson's 1968 proposal to launch an International Decade of Ocean Exploration in the 1970s. Not coincidentally, President Johnson had spoken at the *Oceanographer's* commissioning ceremony in July 1966, and Vice-President Hubert Humphrey, Chairman of the National Council on Marine Resources and Engineering Development, was the keynote speaker at the inception of its 1967 global cruise for the dual mission of science and goodwill.

Coupled with the move toward international cooperation was a new emphasis on studies of the interaction between the ocean and atmosphere. The first comprehensive study of this nature was the Barbados Oceanographic and Meteorological Experiment (BOMEX), conducted in 1969. Although U.S. agencies conducted all of the scence, this experiment marked the first time that many agencies and organizations cooperated on a large-scale oceanic and atmospheric research project. The U.S. Navy, U.S. Coast Guard, Environmental Sciences Service Administration (ESSA, the forerunner of NOAA), National Science Foundation, academic groups, and the American Meteorological Society all participated in the study.

This meteorological radiosonde balloon was released aboard the *Oceanographer* during its 1967 cruise. (NOAA Photo Library). Click image for larger view.

The Stratton Commission and the Founding of NOAA

Perhaps it was no accident that BOMEX occurred at the same time that President Johnson assembled a group of outstanding men to study the problems our nation faced in managing and protecting the resources of the sea, as well as to determine areas how to best use our scientific and engineering resources to conduct ocean research. That commission, known as the Stratton Commission after its chairman, Julius Stratton, Chairman of the Ford Foundation, produced a report, " *Our Nation and the Sea,"* which served as the blueprint for a new civil agency dedicated to describing and predicting changes in the Earth's environment, and conserving and wisely managing the nation's coastal guiding philosophy for this newly envisioned agency in July 1970:

"The oceans and atmosphere are interacting parts of the total environmental system upon which we depend, not only for the quality of our lives, but for life itself. "We face immediate and compelling needs for better protection of life and property from natural hazards, and for a better understanding of the total environment -- an understanding which will enable us more effectively to monitor and predict its actions, and ultimately, perhaps to exercise some degree of control over them. "We also face a compelling need for exploration and development leading to the intelligent use of our marine resources. We must understand the nature of these resources, and assure their development without either contaminating the marine environment or upsetting its balance. "Establishment of the National Oceanic and Atmospheric Administration -- NOAA -- within the Department of Commerce would enable us to approach these tasks in a coordinated way."

On October 3, 1970, this new agency, NOAA, came into being. A new era of ocean exploration had begun.

(top)