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OCEANUS

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EDITOR: JAN HAHN

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The Woods Hole Oceanographic Institution

Pushing ahead the frontiers of science.

PUSHING a plow is Dr. Alfred C. Redfield, Senior Oceanographer Emeritus, while working on our experimental clam farm. (See page 3).

The plowing was done to help seed clams dig in. Working fast against the incoming tide not all seedlings could be buried. On the next low tide it turned out that the hard work had not been necessary. The other seed clams which had been left on the flats had buried themselves without human aid.

Editorial

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IT was fitting that the first Bigelow Medal was presented on August 10, 1960, to Dr. Henry Bryant Bigelow, who has been called "The Father of American Oceanography." The medal was established in 1960 by our Board of Trustees and is to be awarded to those "who make significant inquiries into the phenomena of the sea."

Dr. Bigelow, one of the founders of our Institution and its first director (1930-1940) influenced, guided and spurred the staff and encouraged them in boldness, saying that: "An oceanographer, like a turtle, makes progress only by sticking his neck out."

In most scientific disciplines there are relatively few highly coveted gold medals. Oceanography until now has had three such awards. The Alexander Agassiz Medal, the Johannes Schmidt Medal and the Monaco Medal have been awarded to Dr. Bigelow and to but a few other mighty in our field. The next recipient to receive the latest honour may justly be proud to follow H.B.B.

The wide range of Dr. Bigelow's interest in the sea can be gathered by reading his bibliography. To date some 89 scientific contributions have been made by him, singly or in collaboration with others. These papers and books range from "Birds of the Northeastern Coast of Labrador" (1902), through "Oceanographic Cruises of the U.S. Fisheries Schooner **Grampus**" (1913), "Physical Oceanography of the Gulf of Maine" (1927) to the latest publication (with Wm. C. Schroeder) "Four New Rajids from the Gulf of Mexico" (1958).

Dr. A. C. Redfield wrote in the Bigelow Volume, published as a supplement to Deep-Sea Research, Volume 3, 1955:

"The crowning glory of these later years is not, however, the honors which come his way. It is the stream of publications which flowed from his pen, always in association with William C. Schroeder, about fishes. This flow shows no attenuation with time; it reached, in fact, its spate after retirement from academic duty — — —. The handsome monographs on the Fishes of the Northwestern Atlantic show where his heart really lies, for he was free to follow its guidance once he had played his part in putting American Oceanography on its feet."

This interest in *all* aspects of fishes came out at the close of the morning session on August 10, when Dr. Bigelow and his lifelong friend and associate Dr. A. G. Huntsman, animatedly discussed the relative gustatory merits of haddock versus slightly salted cod.

The chimaera identified by Bigelow and Schroeder.

CLAMS

HARRY J. TURNER JR.

The trials and tribulations of scientific research are well illustrated by the difficulties encountered in clam farming.

"THE soft-shell clam, *Mya arenaria* is a commercial mollusk that has played a significant role in the economic and social history of the New England coastal communities and in some instances in other parts of the country. The shells in numerous kitchen middens demonstrate conclusively that the New England Indian tribes depended heavily on this species for food in the relatively barren forest lands of the New England coast. The Plymouth Colony would never have suffered from the disasterous famine of the first winter if the immigrants had known of the clam's existence at the very doorstep of the settlement. Subsequently, other coastal settlements in Maine and Massachusetts managed to survive severe winters by eating clams when the harvest was insufficient. Extensive migrations by inhabitants of inland communities were frequently undertaken in the late winter and early spring to obtain clams to

Hahr

During the clam farming experiments at Barnstable Harbor our biologists became as adept in physical labor as they are in the use of microscopes. From left to right: C. L. Wheeler, H. J. Turner Jr., J. C. Ayers and Dr. Redfield.

alleviate a starvation diet. Because of their abundance and use as an emergency food, clams were held in low esteem and it is reported that the pious Elder Brewster used most unclerical language when on one occasion he complained that he had nothing but clams to eat.

When the economy of the New England States became organized the soft clam declined in use as an article of food. However, its commercial importance soon revived with the hand line trawl fisheries, as the soft clam formed an ideal bait. It opened easily, stayed on the hook well, and its fat body was so enticing that no self-respecting codfish or haddock could resist a nibble. The inhabitants of one small town in Maine practically did nothing else for a number of years but dig, salt, and export clams for bait and also build fishing boats for the larger fishing interests in order to maintain the market for the principal product.

Few attempts were made to regulate the taking of clams until the beginning of the present century. The supply appeared to be infinite and the demand was so moderate that no one worried about a possible shortage. There was one interesting exception in which one of the states bordering the Chesapeake Bay enacted a regulation, sometime before the Civil War, limiting the number of days a week that a slave-holder could feed clams to his slaves. It is unlikely that this was a humanitarian move, but probably a measure to maintain a continuing supply of food to sustain the large slave population.

Not Limitless

Toward the end of the last century it became apparent that the soft clam resources were not limitless, particularly in the New England States. The commercial hook-and-line fishery was at its height using bait in greater quantities and "Clam-Bakes" became increasingly popular at every occasion from a political rally to a fireman's picnic. Improved methods of transportation provided a means of shipping clams to large centers of population where clam chowder became a required item on the menu of fashionable restaurants featuring shore dinners. As a result the demand began to outstrip the supply and such famous clam producing localities as Ipswich and Essex had the unpleasant experience of finding their clams disappearing faster than nature could provide new ones.

At the beginning of the present century, the United States Fish Commission and the appropriate state conservation departments of Rhode Island and Massachusetts each employed biologists to investigate the biology of the soft clam with the aim of establishing methods of restoring the supply to what was supposed to be the former abundant level. These scientists investigated the life history, determined the rate of growth, and unanimously agreed that the only solution to the problem was the establishing of privately owned or leased clam farms. Legislation was enacted in Massachusetts which permitted the selectmen or aldermen of coastal towns and cities to grant tracts of intertidal land to individuals for the purpose of clam culture but the idea was so contrary to the long-established free-fishing tradition that it immediately met with strong opposition. Of the few grants that were made, some failed, and those which turned out to be profitable were soon revoked at the insistence of the independent clam diggers. Discouraged shellfish biologists directed their efforts into other fields, and interest in the soft clam resources went into

See page 6

"THE people of the United States use clams in a variety of culinary preparations, the most popular of which is, undoubtedly, a kind of soup especially esteemed in Boston.

In Rhode Island and Massachusetts clams serve as a pretext for fêtes of a very peculiar kind, called 'Clam-Bakes'. The clambakes which take place every year near Bristol, as well as in several other localities in Rhode Island and Massachusetts, have their origin in an old Indian custom.

The aborigines of these States were accustomed to assemble in great numbers every year for feasts consisting of clams and green corn cooked with sea-weed. — These feasts are delicious beyond description, and it is said that no one is ever made ill by them. In former times the most renowned warrior came from afar to take part in them, and now they are attended by persons of the highest social standing, sometimes to the number of several hundreds."

From a report by Lieut. P. de Broca to the French Government, 1862.

Courtesy, Providence Journal

a decline. Little was done about the situation until after World War II, although the clam kept increasing in popularity and prices soared to record heights.

Interest was revived with the return of servicemen after the war. Enterprising young men living along the coast noting the skyrocketing prices of clams and the general scarcity in the public digging areas, saw an opportunity to enter into a new profitable venture and applied for clam grants under the old law. They were numerous enough to overcome the opposition, and several potential clam farms sprang into being. In addition, the town of Barnstable, Massachusetts, granted a considerable area to the Woods Hole Oceanographic Institution as an experimental farm and the Institution initiated an extensive investigation into the biology of the soft clam.

Now, to operate a successful farm of any kind it is necessary to know how to stock it with the desired species of animal or plant, provide optimal conditions for survival and growth, and harvest the crop in an economical manner. Several difficulties presented themselves immediately to the clam farmers. The soft clam reproduces by spawning either eggs or sperm directly into the water where fertilization takes place. The eggs are microscopic in size and number in the millions per individual spawner. Each fertilized egg develops into a swimming larva that leads a precarious existence for about two weeks, drifting about in the currents. If it survives this period, it settles to the bottom, loses its swimming organs and digs into the substratum. It is still microscopic in size at this time and very susceptible to predations by the the myriads of creatures that inhabit the bottom. It takes more than a month before it grows big enough to be visible to the naked eye.

This facet of the clam's history immediately posed the problem — how to stock the farm. The farmer could not simply keep a breeding stock on one corner of his grant and expect any result. For all he knew, the offspring of this stock might wind up many miles away after the two week free-swimming period. On the other hand there was just as much chance that a parent stock in some distant cove might provide the offspring to populate his grant. However, he could not depend on such a fortuitous occurrence but had to find a sure way of stocking his grant. This was the first problem that we of the Institution undertook to solve, under contract with the Massachusetts Division of Marine Fisheries.

We knew from some of our plankton studies that clam larvae are always abundant in the water during the summer, even when adults were relatively scarce because of the enormous numbers of eggs produced by each female. We then made the assumption that the substratum must have some property that either stimulates or discourages settlement at the end of the larval period. This assumption was bolstered by the report of an old fisherman in Barnstable who claimed to have brought about the settlement of large numbers of clams on his grant by resurfacing the area with sediments excavated from a certain marsh bank. We then collected sediments from a wide variety of places and analyzed them for the assortment of grain sizes.

Our preliminary findings indicated that the size assortment of sand grains taken from all places where clams existed in abundance seemed to follow a similar pattern which was measurably different from those taken from places where clams were absent. The materials taken from the marsh bank suggested by the old fisherman fell into this size pattern. We then secured a boat and a scow and transferred materials from other marsh banks where the assortment of grain sizes did not fall into the pattern. The entire operation was done by hand and we became as

A quarter of an acre of clam flats was re-surfaced with marsh grass to help the settling of clam larvae.

adept with a pick and shovel as we were supposed to be with a microscope.

At the end of the summer we surveyed our resurface area and found that they contained clams in what we thought were appreciable numbers, running as high as 300 per square foot, while the surrounding flats remained practically barren. Curiously enough this proved to be the case in all the areas we had resurfaced including the controls. However, the latter plots had become much reduced in size because the strong tidal currents washed the transferred sediments away. The material from the old fisherman's marsh bank had just the right properties to resist erosion so that the entire plot remained practically intact.

We thought that we had solved the problem of establishing a clam farm and waited for our crop to grow. The clams were still there the following spring and showed such growth that we had hopes for the future. Then we were beset by an invasion of predators. Horseshoe crabs wallowed through the area cleaning it out at a rate as high as a square foot per crab per day. Boring snails invaded from all sides each eating as many as three clams per week. To top it all, the green crab population exploded along the New England Coast, appearing in such large numbers that they not only worked over our areas but also migrated northeastward through New Hampshire and Maine inflicting serious damage on extensive natural clam beds as far as the Canadian Maritime Provinces. Before the middle of the summer our experimental farm was entirely cleaned out.

12 million horseshoe crabs

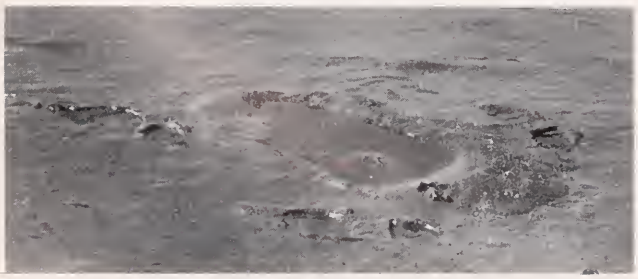
We then expanded our investigation to include studies of the life histories of certain predators which were poorly understood at the time. A complete account of our activities in this direction would be much too long for this article, but the results are of scientific interest. We determined that the horseshoe crab takes at least twelve years to mature. Tagging experiments indicated that the horseshoe crabs of Barnstable Harbor traveled many miles and were part of a motile population in Cape Cod Bay containing over a million adults. When the immature members entered calculation the total population was determined to run well over twelve million individuals. This clearly indicated the futility of killing a few thousand horseshoe crabs in a single locality such as Barnstable Harbor because of the continuous immigration of others from Cape Cod Bay. The life history of the boring snail was worked out, and it was determined that their swimming larvae remained suspended in the water for as much as a

month before settlement. Consequently all efforts to reduce the population in a single locality by attacking the breed-stock would be a futile venture. No practical means of handling the predator problem was discovered, but an extensive investigation of the possibility of using toxic substances is now in progress by the U. S. Fish and Wildlife Service and there are indications of promise.

We also continued our studies of the settlement of clams in an attempt to determine the factors that apparently induced the metamorphosing larvae to choose our resurfaced areas. We were puzzled by the fact that marsh bank materials other than those from the fisherman's favorite bank accomplished this even though their assortment of sediment sizes did not correspond with the pattern found in natural clam beds. Then the studies of one of our colleagues in the U. S. Fish and Wildlife Service gave us a clue.

Dr. Osgood Smith who was working in Newburyport, Massachusetts attempted to determine the rate of settlement of clams by placing trays of sand in the flats for short periods of time and then screening out and counting the newly-settled baby clams. In the course of his experiments he replaced the newly-settled clams in certain trays to determine how fast the population would build up. It so happened that the numbers varied from time to time, sometimes increasing and sometimes diminishing. He suspected predation and attempted to protect an area of flat by staking down a piece of plastic fly-screen. Afer a few weeks, Dr. Smith noticed that the upper surface of the screen became coated with tiny clams with their shells stuck in the openings in such a way that it was clear that they were attempting to burrow down from above. This could only mean one thing. The newly settled clams were not secure in their burrows as had always been supposed, but were continually being washed about by currents and wave action becoming tangled in any suitable material such as experimental screens, clumps of roots or fibrous seaweed. The migrating clams were so small at this stage and generally so few in numbers that they had escaped observation up to that time. Our re-surfaced plots contained a considerable quantity of marsh-grass root fibers which provided ideal places for the entanglement of these migrating clams. Here they became concentrated in the root masses where they grew big enough to take up their final sessile existence.

Marsh grass roots provided a good settling place for young clams.



The "dig" of a horseshoe crab vividly illustrates how a single crab manages to rework a clam flat to find a meal.

The entanglement hypothesis provided a beautiful explanation for the accumulation of clams in the experimental re-surfaced areas but failed to show how dense populations of clams arose under natural conditions. A fortunate circumstance occurred during the month of August one summer when we were making a survey of the soft clam resources of Boston Harbor. We came across an area along the Quincy shore where several acres of low-lying flat were so heavily populated with tiny soft clams that they took up just about all the available space on the surface. They were all approximately ¼ inch long and numbered in tens of thousands per square foot. We surveyed the area carefully and visited it at frequent intervals. By November of the same year the populated area had moved nearer to the shore and the density was reduced to one or more thousands of individuals per square foot. In August of the following year when the clams were a year old and one inch long the population was half-way up the beach and numbered about four hundred per square foot. Three years later when the clams were ready for harvesting, the population occupied essentially the same area but the numbers were reduced to a hundred or so per square foot.

Geology involved

With the help of our colleagues in marine geology we arrived at an explanation involving a hypothesis of "hydrographic concentration" which has been subsequently demonstrated to be correct and also applicable to the formation of concentrations of a number of different marine organisms. Fortunately the geology of the Quincy beach was well understood. The upper beach which consisted of a mixture of coarse sand and pebbles sloped steeply downward nearly to the low tide mark. Here, it leveled off and the sediments graded through decreasing particle sizes from coarse sand to a very fine silt. The mechanics of the formation of such a beach is as follows: waves striking the shore-line rush up the beach with considerable force, carrying particles as big as large pebbles in the uprush. Some of the water soaks into the beach leaving less water to return in the backwash. As a consequence the backwash runs down the beach with reduced force. The reduction of the force of the backwash causes it to leave the coarser and heavier objects behind, so that the upper parts of the beach remains rocky or pebbly. Lighter particles are transported seaward and deposited according to size as the force of the backwash is lessened. The coarser sand grains are dropped first forming a flat sandy beach near the low tide while the finer sands and silts remain suspended until they settle out in the relatively quiet waters beyond the level of the lowest low water. The process is repeated during the rise and fall of each tide sloshing materials up and down the beach, separating the particles according to size and density in much the same way that a winnowing machine separates grain from chaff.

These hydrographic forces act the same way on clams. However, clams differ from inanimate objects in that they grow. When they first settle, the clams are microscopic in size and very light. Any disturbance sufficient to stir up the bottom will bring them into suspension and keep them moving until they arrive at some place where conditions are sufficiently quiet for them to resettle along with the silt particles. This, we believe, is what concentrated the clams in incredible numbers in the finer sediments at the lowest part of the beach.

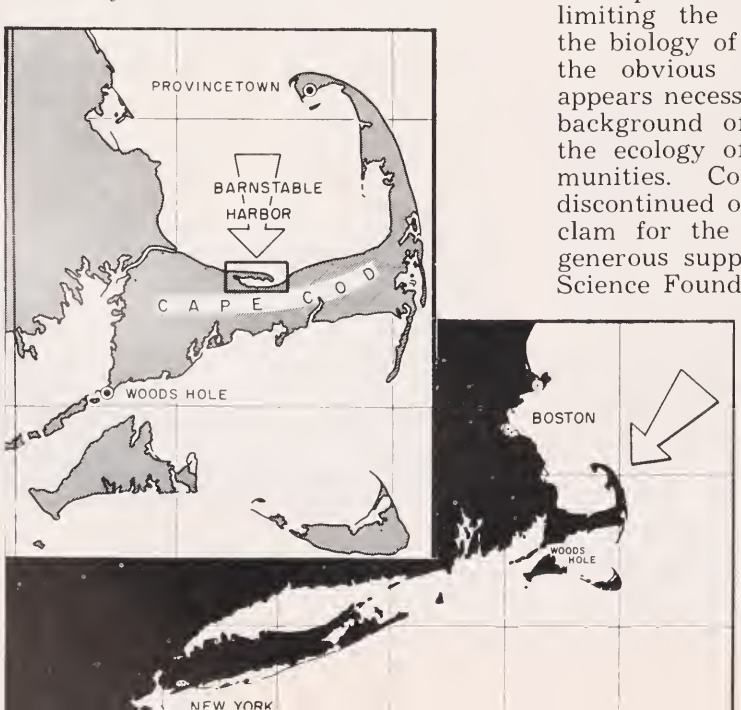
MR. TURNER is a Marine Biologist on our staff and lecturer in Zoology at the University of New Hampshire. He has been with the Institution since 1944 when he came to work on the wave and surf project and subsequently on the anti-fouling program.

The tiny clams sloshed up and down the beach with the rise and fall of the tide and as they grew they became larger and reacted to the forces of the wash, as if they were coarser sand grains. Thus they tended to settle more shorewards where we found them concentrated at low tide in November. As they grew larger they became more like pebbles and became concentrated on the sloping apron of the beach. By this time they had grown so large that they could dig in deep enough to avoid the disturbance of the surface of the substratum by the waves. Here they remained for three years and grew to a size that was acceptable to the commercial market, and providing a period of prosperity for the Quincy clam diggers. A similar occurrence on another beach a few years later was studied in more minute detail by a graduate student at Harvard. His doctoral dissertation confirmed our own findings and proved so many of our assumptions that the principle of "hydrographic concentration" became firmly established as one of the mechanisms of the formation of aggregations of certain bottom animals.

These studies also contributed significantly to an understanding of the enormous magnitude of natural mortality in the marine environment. Biologists concerned with marine fisheries have speculated from time to time as to how many individuals of a generation of any given species survive to maturity, and, for practical purposes have pulled numbers out of a hat ranging from ten to ninety percent. The mortality rate of the clams in the particular generation under study was well over ninety-five per cent during the first year of their lives and by the time they were ready for market only a fraction of one per cent of the original number were still alive. It would be a mistake to claim that these numbers apply to all the creatures that live in the sea but they may well be applicable to the clams and codfish. Each mature female of these species produces one or more million eggs. If all their offspring survived for only a few generations, the ocean level might rise considerably and there would not be room for any other fish!

Further studies

Now after more than ten years of intensive research it has become clear that the problems associated with the development of clam farming are many and complicated. We have come to the conclusion that these problems can not be solved by limiting the investigations just to the biology of the clam and some of the obvious predators. Instead, it appears necessary to build up a large background of basic knowledge on the ecology of marine bottom communities. Consequently we have discontinued our investigation of the clam for the time being and with generous support from the National Science Foundation have undertaken



Barnstable Harbor on Cape Cod, Mass., was the scene of the shellfish investigations.

a study of environmental influences on the reproductive cycle of a variety of bottom-dwelling organisms.

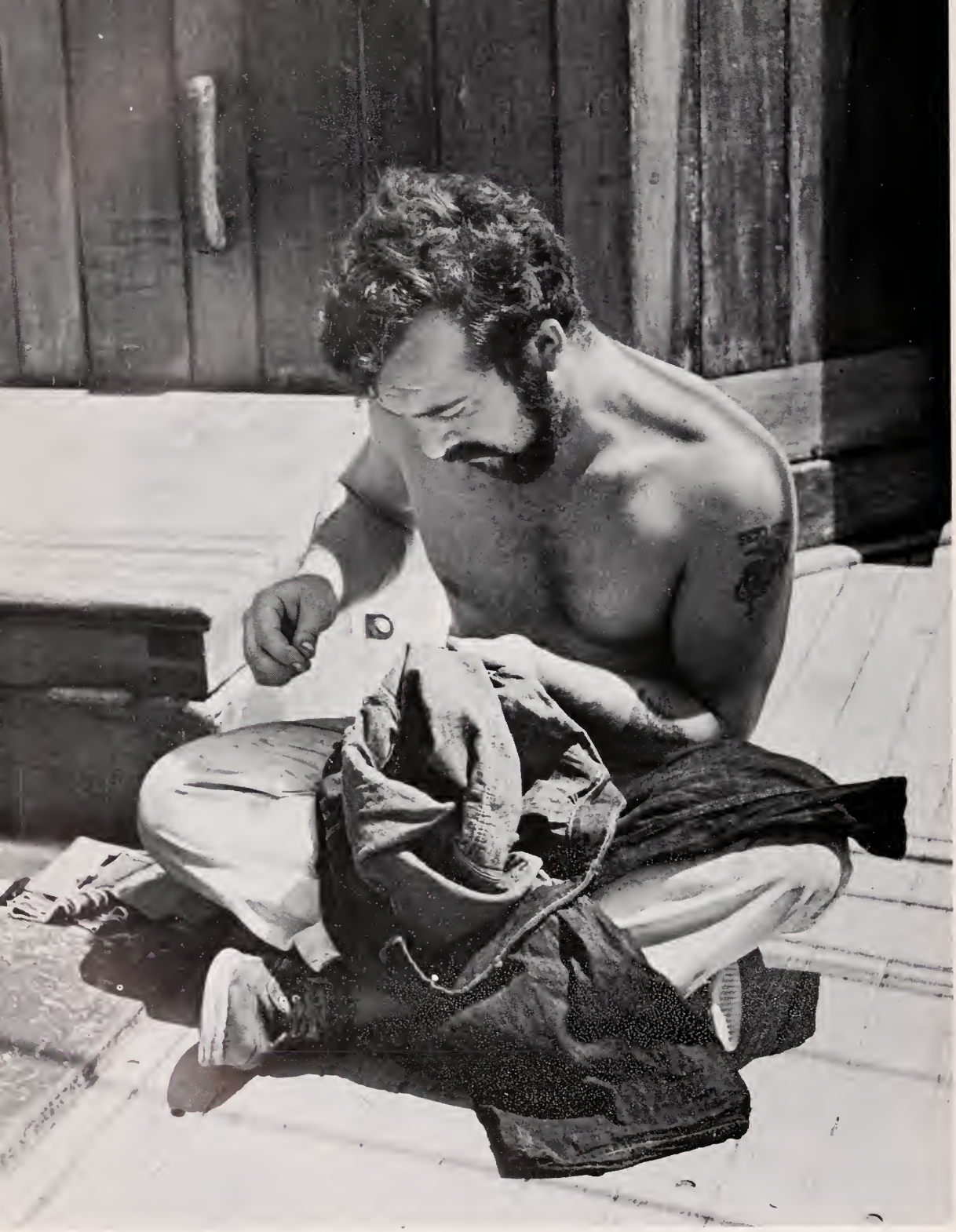
The clam investigation profited greatly from the able guidance of Dr. Alfred C. Redfield whose interest in the out-of-doors is well known to all his associates. In addition, valuable assistance was rendered by Dr. David L. Belding whose investigations of the biology of shellfish at the beginning of the century are known all over the world. Approximately fifteen undergraduate and graduate students took part in the program for various periods of time. Most of these students have gone into marine biology or related fields and a gratifying number of them have received higher degrees.

Shellfish Reports

Ten reports were published on our shellfish investigation between 1948 and 1958. These reports were submitted to the Massachusetts Division of Marine Fisheries and may be obtained from the Division at 15 Ashburton Place, Boston, Massachusetts. Some six other papers were published in the scientific journals.

Spooner

The four Directors of the Woods Hole Oceanographic Institution came together on H. B. Bigelow Day, August 10. From left: Dr. Paul M. Fye, 1958 — present; Dr. Bigelow, 1930-1940; Dr. C. O'D. Iselin, 1940-1950 and 1956-1958; Adm. Ed. H. Smith, 1950-1956.



Hahn

NO TAILORS AT SEA! Once our ships have cast off their lines, both men and equipment are dependent upon supplies brought on board. From needles and spare instrument parts to pencils, someone had to plan a sufficient supply.

Hahn

(Courtesy, American Museum of Natural History.)

SUMMER AT WOODS HOLE. Joan Bricker, a National Science Foundation Fellowship holder collecting small fish in nearby waters. Miss Bricker is working this summer with Dr. Evelyn Shaw of the American Museum of Natural History, who studies the schooling of fish.

"To watch the actions of great schools of fish in which the movement of the individual fishes are lost in the synchronous movements of the whole — like some large, single animal — is to wonder about this pattern of behavior, so different from that of other socially organized, vertebrate groups. In a school all the fish seem to behave alike and each school — whether mackerel, herring, tuna or small shiners — resembles other schools in shape or form."

(From Dr. Shaw in: "Schooling fish", Natural History Magazine, Dec. 1959).

Instruments

and

methods

Spoon

FREE FLOATS

FOR more than 75 years, oceanographers have lowered instruments by winch and cable from shipboard to obtain desired information from the ocean depths. They have not been particularly unhappy about this situation, while—in one instance at least—making it a question of pride. At Woods Hole a small group of people self-complacently explain that they can make a hydrographic station quicker, faster and more accurate than anyone else, anywhere else. Still, the method has some disadvantages. Wires break, instruments are lost, voyages have had to be broken off or were delayed, due to winch or cable failures, while the movement of the ship on the waves rarely keep the instruments at any fixed level.

In the late 1930's, Dr. M. Ewing and Allyn Vine, while developing seismic exploration at sea, dropped series of hydrophones to the bottom with ballasted oil-filled floats. Trigger or salt releases brought the hydrophones back to the surface. Salt block releases employed by the ancient Greeks, also were used in the 1940's to send early deep-sea cameras down. D. Frantz's "pop-up-buoy" (Oceanus, Vol. II, No. 2) has been developed successfully but still is not in general use.

A new free instrument float being developed by Dr. Wm. S. Richardson and P. Stimson has been used repeatedly during the past year. This instrument carrier appears to be well on the way to making some cable lowered instruments obsolete. Made of fiberglas, the six-foot long bombshaped object contains gasoline, for flotation, in the upper half. The lower half has a removable cover to provide room for the desired instrument. This half is not protected against pressure, water flows freely inside the case around pressure-proof instruments. The whole case is dropped, nose first, ballasted by sash weights of 50, 100, or 150 pounds, and also returns to the surface nose first, after dropping the weights.

Successful results have been obtained using the float with a variety of instruments and with different methods. The ballast weights may be released by bottom contact or as in another method by a rope cutter, activated by pressure, severing the weight at pre-selected depths. In

another experiment one buoy was made to sink rapidly while another, fitted with a 30-inch parachute and less weight sank more slowly. Each buoy was fitted with an acoustical noise maker (pinger), so that by listening from the ship with directional hydrophones one could measure the separation of the two floats on the bottom and derive the rate of flow of subsurface currents. The floats also may be used as ocean "weatherballoons". The equipment for such usage is nearing completion.

During some lowerings the buoys were fitted with a strip chart thermistor to measure temperatures. One obtained temperature curve agrees very well with the temperature obtained at the same place on a hydrographic station made by the "Panulirus" of the Bermuda Biolo-ical Station. Oxygen values were measured by J. Kanwisher's oxygen electrode while, on another try, a mechanical current meter was left for hours to record on bottom. Buoys filled with noise makers also have been left on bottom for as long as ten hours to serve as navigation markers.

Three buoys have been used without loss in 63 deep water drops down to 2500 fathoms. This record—rather a remarkable one for new instruments — is due to the noise makers which aid the search for a surfaced buoy. In addition, the floats are painted with fluorescent orange paint so visible that the R. V. CHAIN picked one out by search-light at night in a rough sea at a distance of ½ to ¾ mile. Only those who have stared, vainly for hours trying to locate an object at sea can realize how remarkable this retrieve was.

It is obvious that the technique has many possibilities. Dr. Richardson presently is looking into further methods to be applied. It may also become possible to drop a float from an aircraft, wait for its return to the surface and record its obtained information by radio-telemetering without bothering to retrieve the float. We know some oceanographers who will delight in this type of data gathering.

A Method for Instrumentation —

IN oceanography new instruments often inspire new approaches to research, just as problems in research have suggested the development of new methods. The creation of new instruments and techniques requires a peculiar kind of genius. The main problem is: how should an instrument be designed to extract the maximum amount of information in the most digestible form?

Modern techniques are capable of bringing into the laboratory continuous records of phenomena from which, at present, we are not prepared to extract the fullest meaning. The analysis of continuous or quasi-continuous data remains one of the most puzzling problems in the new age of our science. The challenging fact is that instruments no longer stand alone. They must be directly and flexibly coupled to systems for data processing which extract information appropriate not only to the questions in immediate view but those of the future as well.

Those who work ashore in the development of new instruments and methods are vital to the progress of our science. For where they succeed in providing a continuous purview of the oceans, our ships and sea-going colleagues are freed to examine the oceans for new features and phenomena.

J.H.

The Seismic Profiler

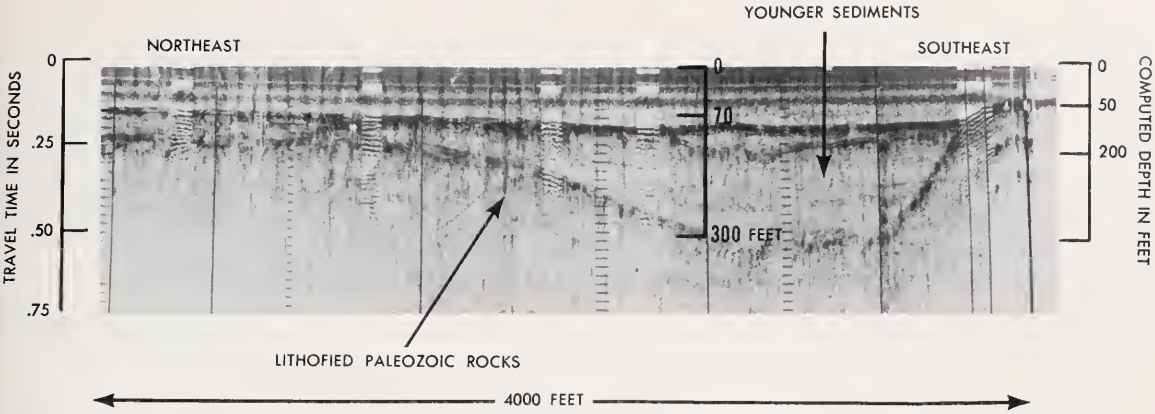
THe location for a projected tunnel under the English Channel was determined recently with the aid of a new technique developed by Dr. J. B. Hersey and Mr. S. T. Knott, Jr. of our Institution. The instrument technique, known as the Seismic Profiler, was developed to obtain geologic information of scientific interest. However, the technique has quickly been adapted for commercial gas and oil explorations. For such purposes the profiler has been used in the Gulf of Mexico, off Venezuela, Japan, the U. S. West Coast, and in the Great Lakes, as well as by the company interested in the Channel tunnel project.

For many years, geophysicists have been able to detect structures below the ocean bottom by using refraction and reflection techniques with the aid of explosives and the use of two or more ships. A rapid way of obtaining a continuous reflection profile has been made possible by the development of the Seismic Profiler. The device operates somewhat like an echo-sounder but differs by using a broad spectrum pulse originated by shorting a large high-voltage condenser through electrodes towed astern a moving ship. The bottom and sub-bottom echoes from this underwater spark are filtered and recorded on a Precision Graphic Recorder* in the same manner as an echo-sounder. The electric spark emits broad-band sound pulses in the range of 200 to 1000 cycles per second — higher than the deeply penetrating seismic waves, but lower than the frequencies used by echo-sounders which are quickly absorbed by bottom sediments.

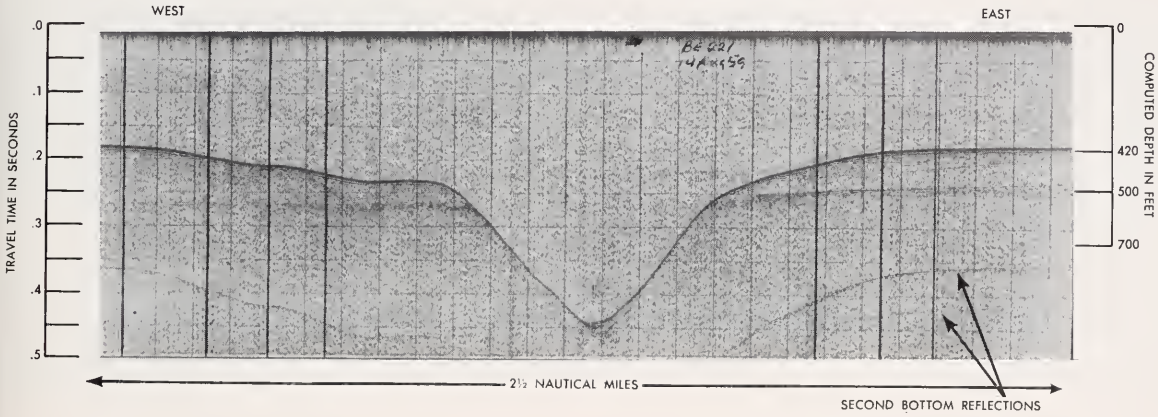
The Seismic Profiler records travel time, not depth below the bottom. The depth of each sub-bottom horizon has to be computed using the acoustic velocities of each layer. The geologic age of the shallow horizons can be determined only by following them until they shoal or outcrop on land or if deep well data exist in the area.

The Profiler has been used successfully in waters from ten to several hundred fathoms deep. Sub-bottom horizons have been recorded from but a few feet to more than a thousand feet below the top of the sediment on the ocean bottom. Until now, our geophysicists have made profiles in the bays and sounds near Woods Hole, on the Continental Shelf and Slope along the U. S. east coast, in the Gulf of Mexico, the Mediterranean Sea and presently, in northern European waters.

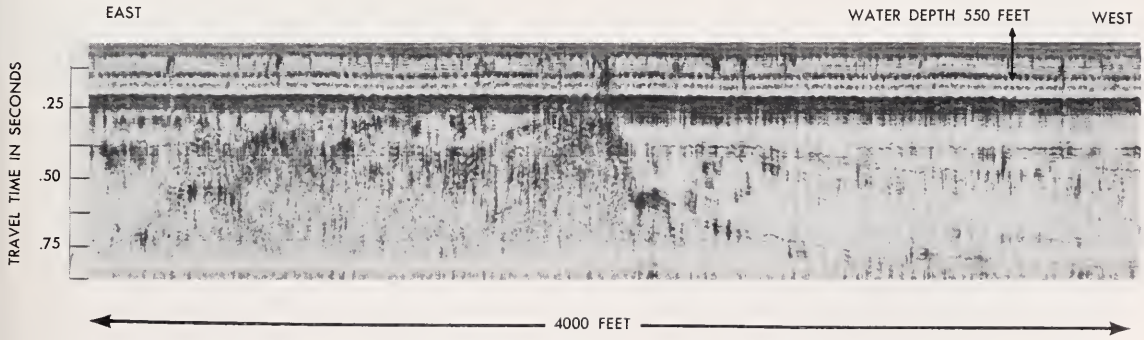
*See: Oceanus, Vol. V, Nos. 1 and 2.



On a traverse of the West Passage of Narragansett Bay, Rhode Island, the Profiler showed that bedrock lies some 230 feet below the bottom of the center of the Passage. The profile shown was made in twenty minutes; a far cry from the many days of drilling formerly necessary to obtain the information, which was needed to aid a hurricane barrier project and to indicate the feasibility of dredging a deep ship-channel.



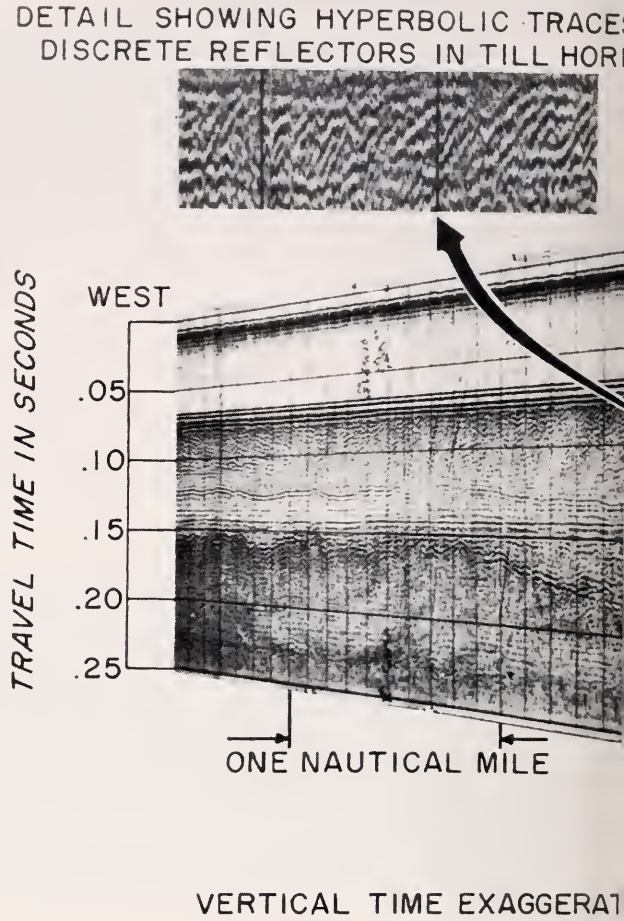
The origin of submarine canyons still is not understood. This profile across Lydonia Canyon, which cuts the continental shelf off New England, shows the erosional nature of a canyon. The continuous sub-bottom horizons at each side appears to indicate that the canyon was scoured into the seabed. The dip of the sub-bottom horizons toward the center of the canyon is not a geologic feature but caused by the fact that sound travels faster in sediment than in water. The arrows point to multiple bottom echoes.

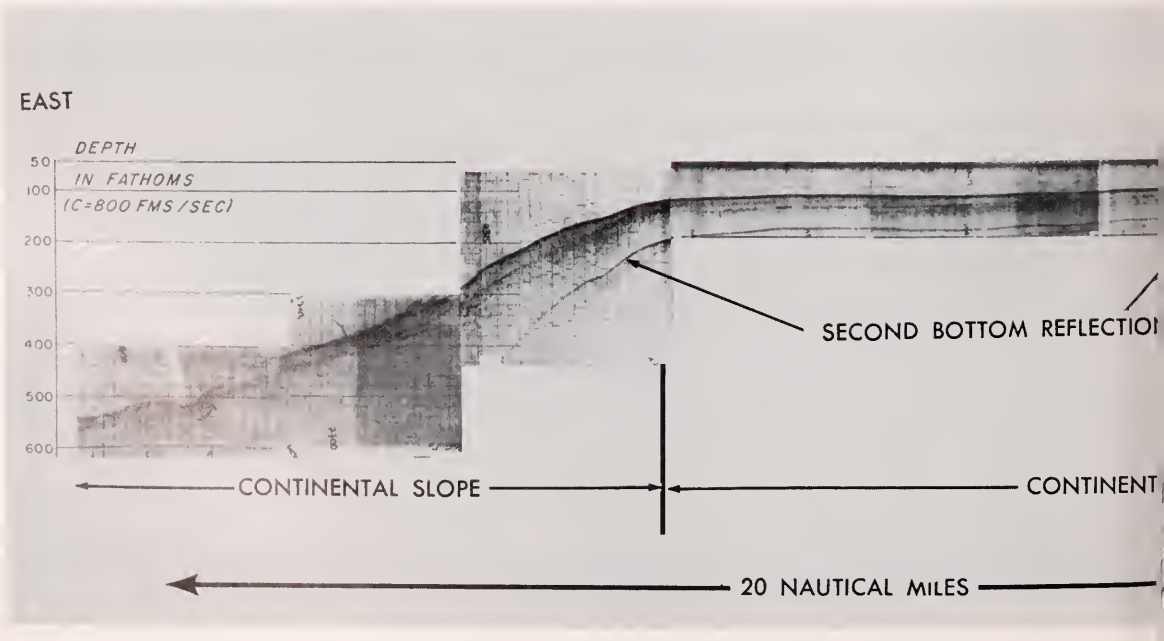


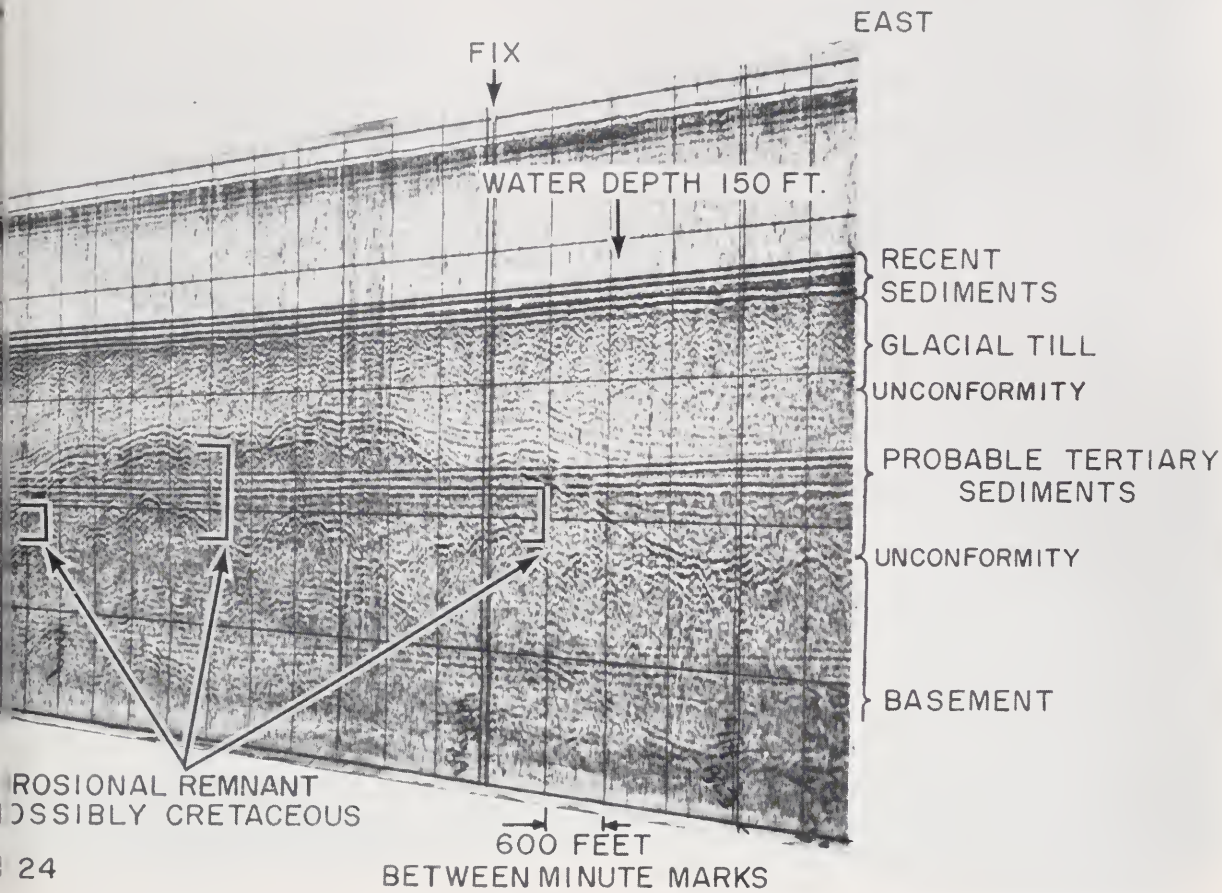
The flank of a salt dome, one of the classic structures for the trapping of petroleum deep below the surface, was found by the Profiler in the Gulf of Mexico. Much of the information needed to construct a geologic cross section is contained in this profile. Other information needed, such as the speed of sound in each of the underlying horizons, can be obtained by seismic refraction "shooting", or by moving the sound receiver away from the "sparker".

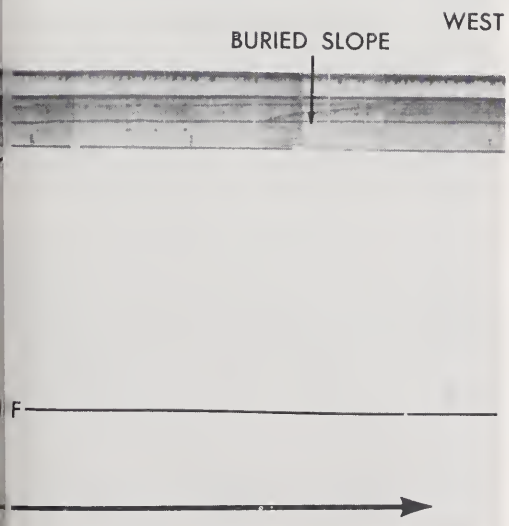
The Seismic Profiler

A long record photographed obliquely shows the stratigraphic sequence below the floor of Cape Cod Bay. Most of the sub-bottom horizons recorded with the Profiler lie below the maximum penetration of sediment cores taken from shipboard. It is, therefore, often difficult to assign the geologic ages of the horizons. Drillings made by our geologists in the Province Lands on Cape Cod made it possible to suggest this stratigraphic sequence.

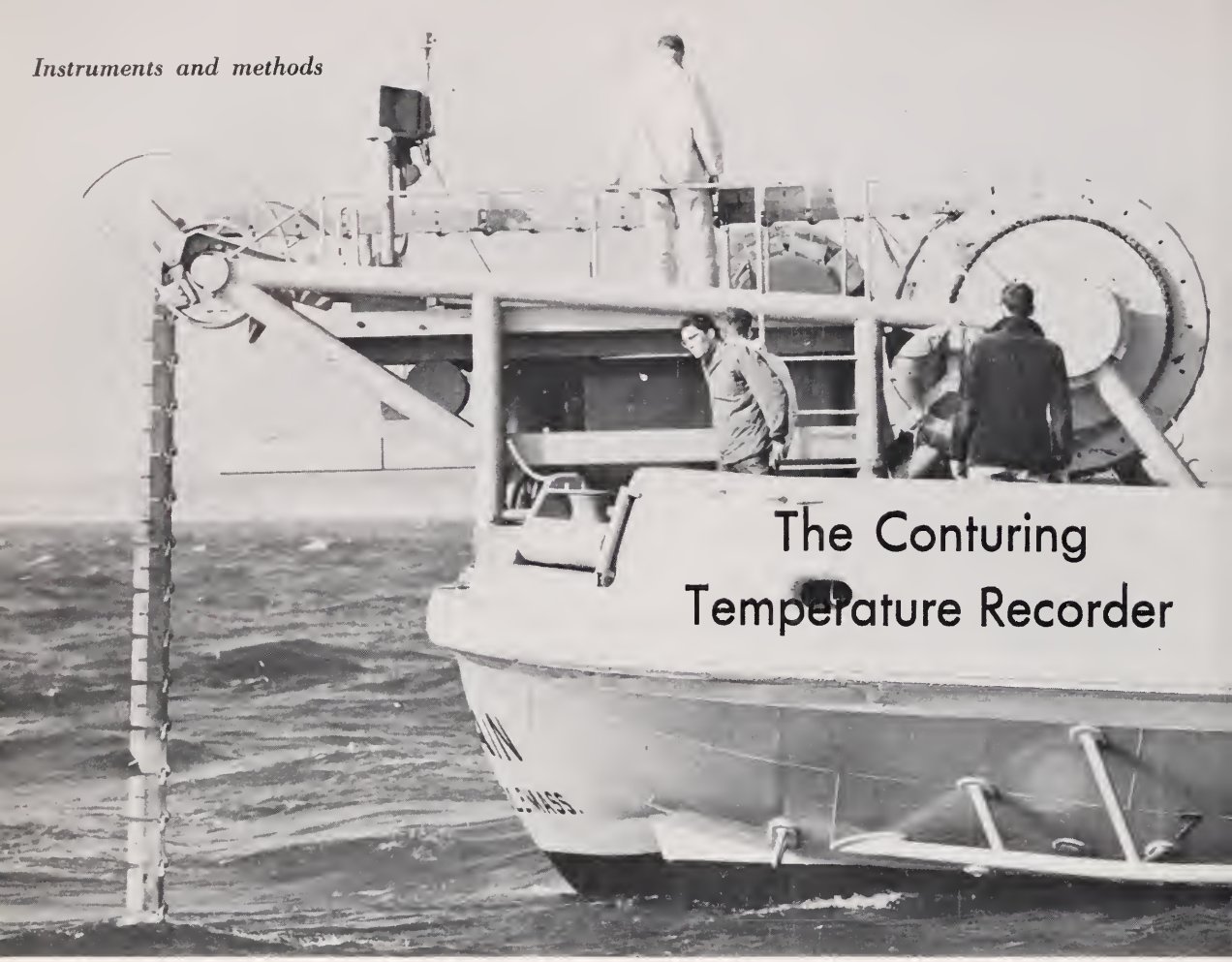








Large scale features can be seen in long sections of record even although the depth of penetration may be limited. This profile across the Continental Slope and Shelf shows an extensive horizon under the Shelf which is finally truncated at the bottom of the Continental Slope (small arrow at left). The arrow at right indicates an old slope representing a buried ancient bottom on the Shelf. Other arrows point to multiple bottom echoes. The water surface acts as an acoustic mirror, so that the train of returning echoes may be recorded several times after the actual bottom reflections.



The Conturing Temperature Recorder

THE upper layers of the ocean vary greatly in temperature, both seasonally and geographically. Here, in the upper thousand feet, the water is stirred by the winds, it cools in winter, heats in summer, exchanges heat and moisture with the atmosphere, mixes by convection and influences such diverse subjects as the living conditions of marine life and the propagation of underwater sound transmission.

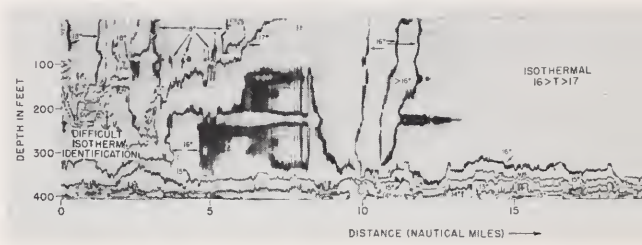
It was not until the advent of the Bathythermograph, developed in the 1940's, that it became possible to obtain a record of the subsurface temperature structure from a ship underway. Since then, hundreds of thousands of BT observations have been made. Lowered once hourly, half-hourly or even sometimes every 15 minutes (during a Gulf Stream survey) the BT observations nevertheless are spot observations spaced miles apart. The contouring of the isotherms (lines of equal temperature) often was uncertain. For sound transmission studies, one or more BT observations taken over a range, often were misleading. A nearly continuous record of the thermal "micro-structure" was needed.

Now, with the contouring temperature recorder it is possible to obtain a BT record every 2 seconds with the aid of an array of 23 thermistors mounted on a nearly vertical articulated chain, towed astern our larger ships. Thermistors, are placed in the towed chain at 25 foot intervals to reach a depth of 600 feet at slow speed. In towing at full speed (10 knots) the chain reaches a depth of 450 feet. The actual towed depth is checked repeatedly by a depth meter attached to the chain. The thermistors are scanned serially by the electronics and plot on a continuous record the vertical distribution of isotherms. The resulting

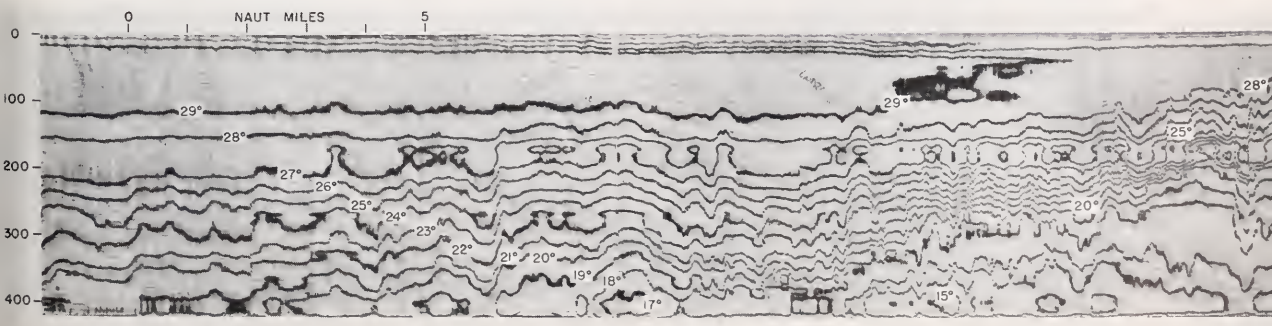
plot may be compared with that of the Seismic Profiler with the difference that a number of isotherms are charted rather than geological horizons. The scanning speed can be adjusted to record each thermistor from once every two seconds to once every twenty seconds. By adjusting the scanning speed in relation to the ship's speed one can make certain that the information is taken from a vertical column in the water. The recorder is capable of contouring each one degree isotherm from -2° C. to 32° C. along with all 0.1 and 0.05 C. between these limits.

The 8 ton winch needed for the fared towing chain is too large to be used on the ATLANTIS or CRAWFORD. It is now placed on the R. V. CHAIN and was also used in 1957 and 1958 on the U. S. C. G. YAMACRAW when that vessel was placed at the disposal of the Institution for work in the North Atlantic and in the Mediterannean Sea. The special towing gear was designed and constructed by Mr. Roy L. Rather, of the Commercial Engineering Company, a member of the Associates of the Institution.

An enormous amount of information has been amassed with this method, revealing in great detail the complicated surface structures between the east coast and Bermuda, in the Gulf Stream area, and the more constant structures in the western part of the Sargasso Sea. Some complete North Atlantic crossings have been obtained as well as many detailed studies in smaller areas. The chain was also towed during the April—July multiple ship Gulf Stream survey.



Contouring from Bathythermograph observations on board the Atlantis



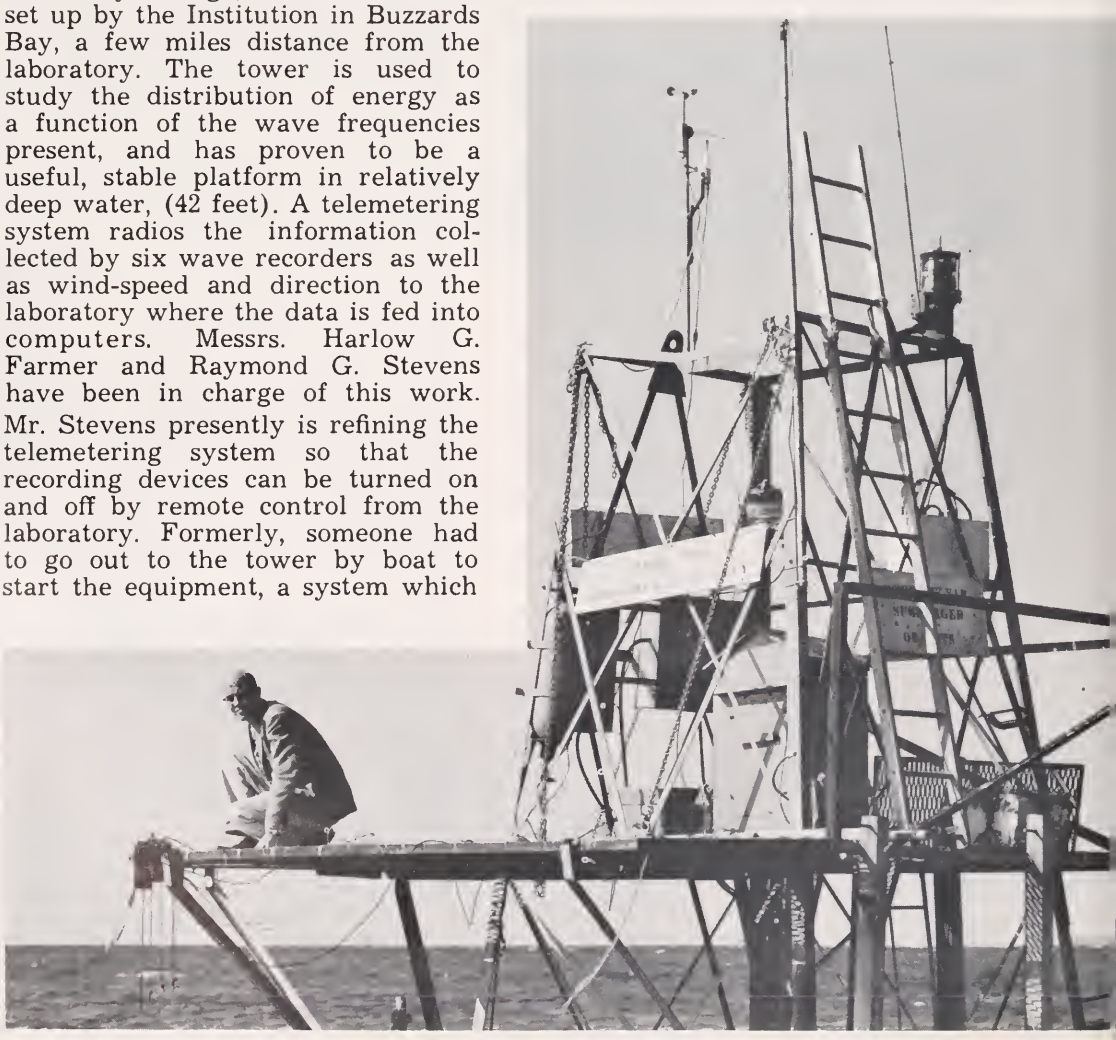
GULF STREAM EAST OF JACKSONVILLE, FLORIDA
OCTOBER 5, 1958

Wave towers

A KNOWLEDGE of surface waves became of vital importance for amphibious landings during World War II. Since then, the study of ocean waves has advanced rapidly and is resulting in the design of seaworthy, faster and lighter ships, better shore protections, establishing the heights of offshore towers, as well as many other practical applications. Safer and faster passages across the North Atlantic Ocean are provided by a radio "wave condition" report. Ships can circumvent areas of high waves and, although taking a longer path, arrive earlier in port without damage to ship or cargo.

Three years ago, a wave tower was set up by the Institution in Buzzards Bay, a few miles distance from the laboratory. The tower is used to study the distribution of energy as a function of the wave frequencies present, and has proven to be a useful, stable platform in relatively deep water, (42 feet). A telemetering system radios the information collected by six wave recorders as well as wind-speed and direction to the laboratory where the data is fed into computers. Messrs. Harlow G. Farmer and Raymond G. Stevens have been in charge of this work. Mr. Stevens presently is refining the telemetering system so that the recording devices can be turned on and off by remote control from the laboratory. Formerly, someone had to go out to the tower by boat to start the equipment, a system which did not always provide information on desired conditions of waves and wind.

Dr. John M. Zeigler and Mr. David M. Owen are on, or better, off a wave tower several thousand miles away. They are studying the motion and particle sizes of bottom sediments in shallow water under known wave conditions. The wave tower is situated off the Dutch coast near the Hague. The two investigators do not appear to have too good a time in their aqualung gear, as the water is cold, flows fast and apparently is so turbid that visibility is limited to but a few feet.



The wave tower in Buzzards Bay standing in 42 feet of water. The wave recorders consist of a series of fine wires whose electrical resistance is changed by the passage of waves.

Recent Books

Frontiers of the Sea
by Robert C. Cowen
Introduced by Roger R. Revelle
Doubleday & Company, Inc.
Garden City, New York $4.95

MR. COWEN, a science writer for the Christian Science Monitor, recently completed a popular account of the past, present and future of oceans and oceanography. The book is attractively illustrated, both with photographs and with many simple but effective line drawings by Mrs. Cowen, who also helped in the library research. Mr. Cowen is by training a meteorologist, but through diligent reading has managed to master a good deal of oceanography.

The scope of the book can be summarized as follows: Three chapters deal very effectively with the geology and geophysics of the ocean basins. These are followed by a chapter on waves and another on currents. He then takes up the interaction between the oceans and the atmosphere. The remaining four chapters deal broadly with the biology and with the fisheries situation. Finally there are brief accounts of some of the special problems of the future.

Mr. Cowen is a skillful reporter. It is evident that in preparing to write this book he has interviewed many oceanographers and has studied carefully the recent reports of the National Academy of Sciences' Committee on Oceanography.

C.O'D.I.

The Biology of Marine Animals
by J. A. Colin Nicol
Interscience Publishers, Inc.
New York and London, 1960. $14.00

With the current popular interest in marine science and oceanography, increasingly large numbers of young people with scientific inclinations will be directed to research with marine organisms. The publication of J. A. Colin Nicol's book would seem well timed, for as he states in his preface: "It is for these young men and women and for undergraduates specializing in marine zoology that this book has been written..." However, it should not be interpreted that this is merely a text book in a rather specialized field of biological science, but rather, it should be considered a "source" book or series of carefully integrated review articles. Not only the beginners in science but also the more experienced investigators whose interests occasionally lead him outside his field of specialization should find this a useful summary.

The book is abundantly illustrated with line drawings, graphs, etc. Perhaps even more important are numerous summary tables presenting comparative data in a useful and accessible form.

With a book of wide scope, it has been necessary for the author to make some selection of the material to be included. Perhaps, here and there, it may seem to some readers that important references have been omitted or significant detail left out. In an effort to make the text read smoothly, the distractions of names and dates has been largely eliminated and alternatively the reference numbers included at the end of each paragraph or section. Although the continuity of the subject being discussed is thus preserved, it frequently becomes difficult to determine the exact source of a specific bit of information should the reader wish to follow up a subject in more detail. The same criticism might also be leveled at certain tables which include the legend only "data from various sources". However, the bibliography at the end of each chapter is extensive with emphasis on the work of the past twenty or thirty years. No reference more recent than 1957 would seem to be included.

Clearly, no single reference work by a single author can completely meet the requirements of every worker in the field. Yet, this is a commendable work, and for the purpose for which it was intended, it has no equal. Few workers interested in marine organisms, no matter what their personal bias, can afford to be without it.

R.J.C.

Currents and Tides

Henry Stommel, has been appointed Professor of Oceanography at Harvard University, where he will join Columbus O'D. Iselin in teaching Physical Oceanography. Mr. Stommel has been on the Institution's staff since 1944 and received worldwide attention for his theoretical studies of ocean currents.

"The marine Science and Research Act of 1960" (S. 2692), passed the U. S. Senate on June 23 without a dissenting vote. Senator Magnuson (Wash.) opened the floor remarks and was followed by Senators Butler of Maryland, Keating of New York, Case of New Jersey, Hart of Michigan and Thurmond of South Carolina, Other Senators offered to do so if additional support appeared to be needed.

The Act calls for a comprehensive ten year program of oceanographic research.

With the R. V. CHAIN in Northwestern European waters, the meetings of the International Union of Geodesy and Geophysics held at Helsinki, a Cloud Physics meeting in Italy and the International Geological Congress in Copenhagen, and several independent trips, it was possible for staff members to stumble over one another in European capitals.

The names of renowned research vessels are perpetuated on the Institution's "Challenger House" property. A newly erected building has been named after the famed U. S. Coast and Geodetic survey steamer "Blake". Other ships remembered are: "Meteor", "Fram", and "l'Hirondelle".

So many unattended oceanographic instruments have been used in recent years that we receive many inquiries regarding ownership of objects recovered or sighted at sea.

Buoys, instrument cases, and bottom recorders of various types have a habit of getting lost or are expendable. A card file now is kept to aid in identification of reported objects.

"A combination of applying Woods Hole recommendations, a seat-of-the pants feeling for the ocean, and prayer", were credited by Carleton Mitchell as his basic techniques for winning the Newport-Bermuda ocean race for the third time in a row. The Institution's advice on the Gulf Stream, provided since 1954, was "of great aid" to the participants. See: "The Secret of Bermuda" by Carleton Mitchell, Sports Illustrated, July 25, 1960, and the August issue of "Yachting".

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