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A Rough Life

MILES out to sea, off the Brazilian coast, one may see a man "walking on the water". Coming closer it is seen that a fisherman is standing on a xingada, a raft 3 to 10 meters long. Of a rather complicated construction, the xingada's main logs are of Balsa wood. A small seat, a wicker basket, fish lines, a centerboard, steering paddle, sail, a rack to hang big fish and a gourd with drinking water form the simple equipment. There is no protection against sun, wind and weather, as evidenced by the faces of the fishermen on our cover.

Editorial

VOL. X, No. 1, September 1963

ALTHOUGH oceanography has made great strides in the ability to chart the ocean bottom accurately and in the means to obtain sediment cores, rocks and biological material from the deep ocean, the ill fate of the submarine 'Thresher' pointed out the difficulties of locating a small object only a few hundred feet long in waters over 1½ miles deep.

When one lowers an instrument on a cable where is the device in relation to the surface ship? In one or two miles the various subsurface currents and the drift of the surface vessel are usually unknown or difficult to gauge. As Dr. J. B. Hersey stated: "It is like lowering a ping pong ball into a beer can from the top of a three story building while blindfolded and during a northeaster." The Thresher Search gave rise to a new method using underwater acoustics and a shipboard computing system to locate the position of underwater cameras and other instruments in relation to the ship.

The initial Thresher Search also showed again that the usually available radio-navigation systems generally are not good enough to re-locate a small bottom object. Oceanographers have long been in need of more precise navigation. Two new systems are being developed at our Institution and before long should be able to increase navigation way beyond the point necessary for ordinary ships. Merchant ships want to know where they are, we need to know where we have been and be able to return to the selfsame spot along the shortest route and with the least time spent searching.

As fellow seamen we deeply regret
the loss of the 'Thresher' and her men.

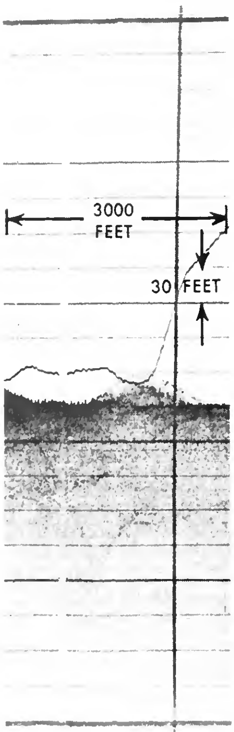
It would be nice if we could have foresight at this time instead of being fully equipped with hindsight.

R.V. 'Atlantis II' departing in July for the Indian Ocean

Dr. HERSEY is Head of the Department of Geophysics at the Institution.

Thresher Search

by J. B. HERSEY



Contact
Delta

AT two o'clock in the morning on April 11, 1963, I was awakened from a sound sleep by the jangling ring of the telephone. It was A. C. Vine who told me that the Navy had decided that the nuclear submarine U.S.S. 'Thresher' (SSN 593) had been lost during a post-repair test dive in the deep water east of Georges Bank. Later that morning we learned of strenuous operations near the last known position of 'Thresher', which were proceeding in hope of finding a disabled submarine. As such hopes disappeared a determination built up to find the 'Thresher' so as to learn the cause of the disaster. The seagoing laboratories engaged in research for the Navy quickly offered their services through a meeting of laboratory directors which happened to be convened that day at the Naval Research Laboratory in Anacostia, D. C. We also happened to have a ship at sea nearest the search area. 'Atlantis II' was just starting her second cruise. N. Corwin was in charge and the program was to collect a series of water samples and biological collections south from Halifax, N. S. Dr. Fye requested Captain Hiller of 'Atlantis II' to break off the program and proceed at once to render all possible assistance in the search.

There followed several days of intensive planning and organizing. Mr. Corwin's group was well able to cope with analyzing water samples for telltale traces of radioactive materials, but they are somewhat allergic to electronic devices such as our special echo sounder, the Precision Graphic Recorder (or PGR), which was an obvious, available search tool. However, they did get a rudimentary system working. Consequently, S. T. Knott, one of the PGR's chief co-designers, with a supporting team from the Geophysics Department were taken aboard the U.S.S. 'Hazelwood' (DD 531) from Newport to join 'Atlantis II.'

In early April the weather east of Georges is not apt to be calm, but when Knott and his team arrived a proper gale was in progress. After two days they were able to board the 'Atlantis II' by high line. Before the 'Hazelwood' sailed a plan had been advanced to bring the bathyscaphe 'Trieste' from the Naval Electronics Laboratory, San Diego to help in the search. The 'Trieste', which descended to the bottom of the Marianas Trench, east of Guam, seemed a logical means of observing directly the hulk of 'Thresher', and the most sanguine hope of determining the cause of the disaster. But the 'Trieste' has little speed (maximum of 1.5 knots) to compete with strong currents. Hence it was immediately important to know the deep currents in this area: were they small, say one or two tenths of a knot, or a knot or more? We didn't know. J. Bruce went out on the 'Hazelwood', staying aboard her long enough to get a reference buoy close to the last known position of 'Thresher'—thereby also judging the strength and direction of the surface currents.

The biologists on 'Atlantis II' took water samples for radioactive determinations, measured temperature and salinity of the water to determine the current pattern and even improvised a coring tool to sample the bottom sediments. With the PGR team on board, 'Atlantis II' participated with three Naval ships in the first systematic bathymetric (echo-sounding) survey of the ten mile square centered about the last known position of 'Thresher'.* After this work, it seemed wise for 'Atlantis II' to return to Woods Hole to be more properly fitted out for the search.

Meanwhile in Washington, the Chief of Naval Operations had requested an ad-hoc group of scientists to serve as the Technical Advisory Committee for the 'Thresher' search (the author is the Institution representative on this committee). A few days later the Secretary of the Navy requested Admiral Stephan, USN (Ret.) until recently the Navy's Oceanographer, to serve as the chairman of a study group to look into the broader problems of search and salvage operations in the deep ocean. Mr. A. C. Vine was requested by Admiral Stephan to serve as a member of this group. The first of these committees had an immediate operational problem: find the

* See "Thresher Search", Vol. IX, No. 4.

'Thresher'. Despite the hard fact that there was left no hope of rescue still almost the same sense of urgency pervaded planning and preparing for the search operations. What could Woods Hole contribute? Our ship schedules are always tight and this spring seemed tighter than usual. 'Chain' was thousands of miles away in tropical Atlantic waters. 'Atlantis II' was closely scheduled for geophysical research north of Puerto Rico. There was the biological cruise that had been broken off when 'Thresher' sank, and, finally, the completion of 'Atlantis II' had been timed to get her to the Indian Ocean in time to observe the after effects of the shift from the dry monsoons to the wet monsoons; a weather phenomenon unique to the Indian Ocean. This shift occurs in mid-June. The ship had to be there as early as possible in July — early August at the latest.

During intense sessions we decided that the biologists would have to wait and complete their work after 'Chain' returned home. This gave us a week when the 'Atlantis II' could search for 'Thresher'. Possibly this might be all the time necessary. We would wait and see, but we doubted 'Atlantis II' could be made available for more time. In any event we prepared by assembling all the experienced seagoing talent that was available at Woods Hole. We also invited assistance from both the Schlumberger Oil Well Surveying Company and Knowles Electric Laboratories, both to assist in radioactive detection measurements. Schlumberger proposed using an electrical self potential measuring detector (SP) which their parent company, a French concern, had used with great success to find sunken metallic objects, including a French submarine. At Woods Hole the PGR's were refurbished, W. Dow prepared a self-contained suspended echo sounder for use as a deep echo-ranging device. A. Johnston prepared our underwater cameras. R. M. Snyder and G. L. Erlanger prepared current meters and buoys for continuing study of the deep currents.

The previous cruise had shown the need for good navigational data. We attempted to make this possible by installing both Loran C and a Decca Navigator, the Sperry Rand Corporation and the Decca Company furnished a specialist each to tend these two instruments and assure their successful operation. Their help proved invaluable.

Knott had found one indication in his previous survey that could be the hulk of 'Thresher' resting on the bottom. All were agreed that 'Atlantis II' should concentrate on evaluating this target. We departed on April 21st and arrived in the search area to find another gale. We did some echo sounding, but otherwise, hanging on was all we could do for the next three days. During the echo sounding we re-discovered the "bump" that Knott had found (by then it was known officially as contact "Delta"). We pushed our navigation systems to the limit and managed to show that Delta was small enough to qualify as a possible 'Thresher'. We planted the current buoys. Between that work and the gale and the time required to learn how to use navigational tools, the week was nearly spent. We had time for a few inspections by the underwater camera in the "Delta" area. These revealed animal tracks in a muddy bottom, sea urchins, starfish, brittle stars, and an occasional fish as the only evidence of life, but did show that good photographs could be made in the area. Hence it seemed worthwhile to develop the photographic or visual search. After returning to Woods Hole the decision was made to extend the participation of 'Atlantis II' in the search, since by rescheduling 'Chain' after her return from the equator she could assume part of the work previously scheduled for our new ship. Preparations were based on the lessons learned during the previous week of operations. S. L. Stillman built a huge framework for mounting not only the lights and cameras but also an echo ranging set converted from Dow's inverted echo sounder. The Schlumberger radioactive detector and the SP gear were added as well. In about five days 'Atlantis II' returned to sea. E. E. Hays led the group for a week, then Dow, and finally Knott. The echo ranging

Please turn to page 6.

The Loss of the Thresher

Some environmental factors may have contributed to the loss of the submarine

By C. O'D. ISELIN

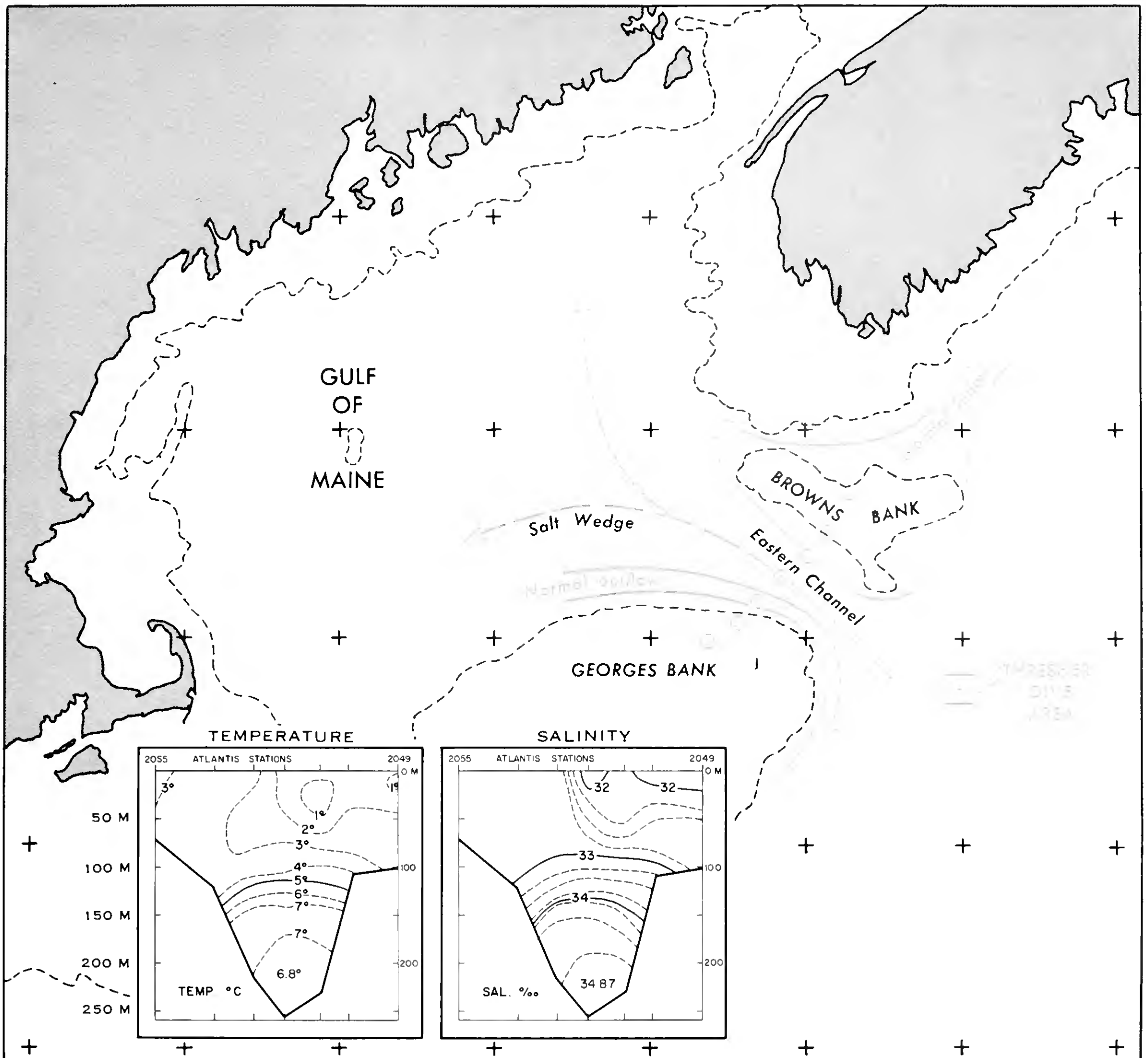
A FEW days before the last dive of the 'Thresher', made directly off the Eastern Channel which is the main entrance to the Gulf of Maine, an intense storm had moved northeastward from the Cape Cod area towards the Annapolis Valley in southwestern Nova Scotia. This storm caused severe southeasterly gales over Georges Bank and Browns Bank, and a marked reduction in barometric pressure over the whole of the Gulf of Maine. As a result much near surface water was driven northward across the banks and also into the Gulf through the relatively deep Eastern Channel.

After the storm center had moved in over Nova Scotia the barometric pressure rose, of course, over the Gulf and the wind shifted to the west and northwest. The excess water in the Gulf of Maine had to come out again and the easiest and most friction free exit is the Eastern Channel.

There is one series of winter observations made by the 'Atlantis' in late March 1934 across the Eastern Channel which shows the normal situation there. From these profiles of temperature and salinity can be seen that wind stirring and convection have resulted in nearly homogeneous water over both banks and down to a depth of about 100 meters near the center of the gully. Below this level both temperature and salinity increase sharply with depth. However, the stability of the water column is dominated by the salinity increase. The relatively warm and salty water at the bottom of the gully is the seaward extension of the salt wedge which at all times of the year enters the deeper parts of the Gulf of Maine. This water can be traced to within a few miles of Cape Cod on the west, and northward to the approaches to the Bay of Fundy, for when sea level was lower than it is today the Gulf of Maine had a Y-shaped drainage system. All land drainage from northern New England then entered the sea by way of the Eastern Channel.

Now that sea level is much higher and the banks are flooded the reverse drainage system prevails. The fresher upper water moves out near the surface, primarily on the Georges Bank side and the most saline water flows inward along the bottom.

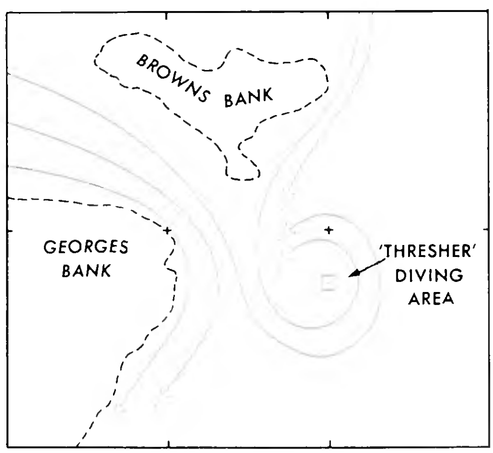
At mid-depths the cross channel trend of density is consistent with the current system indicated in the main part of the first drawing, which also shows the position of the stations plotted in the insert diagram. Water moving southward along the edge of the Nova Scotian continental shelf normally moves into the Gulf on the Browns Bank side. Presumably the outward flow on the opposite side is usually considerably stronger, for it must include the total volume of land drainage as well as that of the salt wedge.



MARCH 1934, PROFILE CROSSING EASTERN CHANNEL

In short, the Eastern Channel can be likened to an inverse Straits of Gibraltar. It is the primary path by which the Gulf of Maine "breathes," that is to say, adjusts itself to exceptional conditions and these had very definitely been occurring for several days before the fatal dive.

The second drawing is my interpretation of the most likely current system prevailing at approximately test depth off the Eastern Channel at the time of the dive. It assumes that the Nova Scotian water had been blocked by a greatly increased outflow and that a strong anti-clockwise eddy surrounded the diving area. In



PRESUMED POST-STORM CURRENTS

such an eddy the most dense water is shallow at the center. At depths where the density is increasing most rapidly in the downward direction less dense water surrounds the eddy at every level. If this picture is correct, no matter in which direction the submarine was headed it would suddenly encounter much less dense water as it neared the limits of the eddy.

Normally this would not be fatal and there would be time to blow some ballast so as to lighten the submarine. Here a second factor may well have come into play. The same storm that disrupted the normal flow through the Eastern Channel was now off the entrance to the Gulf of St. Lawrence and sending out internal waves in all directions. Rather little is known about the amplitudes and periods of internal waves as they approach a funnel-like feature such as the Eastern Channel. Amplitudes of up to three hundred feet can be expected and the period might be as short as 8 minutes.

A submarine approaching such an internal wave at five or six knots would roughly halve the period. Thus, assuming that an exceptionally high internal wave was encountered just as the 'Thresher' reached the edge of the eddy the diving officer could have had his hands full because two causes could be combining to increase his depth at an alarming rate. At this critical point mechanical or electrical failure became the critical factor in regaining the depth control and the submarine continued to sink until collapse depth was reached.

Thresher Search (Cont'd)

set worked well and it seemed to form an effective partnership with the SP gear. Unfortunately we had no magnetometer, but other groups were preparing at least two; thus, this means of searching was not to be neglected.

At the end of this two-week cruise Knott made two long drifting runs with the whole set of detectors mounted on Stillman's framework (the frame and its instruments were soon dubbed the "Beast"). At this time L. Baxter and Knott put into use a means of locating the lowered equipment relative to the ship's position. They then returned to Woods Hole, tidying up the ship as they went.

A. Johnston was developing the last set of negatives. He had developed literally thousands of bottom photographs during the two weeks. Although ordinarily an optimist, he was no longer expecting much from those films—"say, what was **that**?" It looked exactly like a crumpled piece of stationery,—and this; surely this has the look of a crumpled sheet of metal. And there are more of the same. "Maybe some of these had better be enlarged before we reach Woods Hole!" The enlargements confirmed Johnston's suspicions, and the whole roll of 500 negatives showed an area nearly one tenth of a mile across strewn with paper, crumpled sheet metal, torn lengths of electrical cable, and many artifacts impossible to identify. Clearly this could be debris dropped by 'Thresher' as she sank—but it could also be refuse thrown over by a passing ship. Knott radioed Woods Hole to make sure that I would meet his ship on her return. Something about the way he asked the question made me call Dr. Fye and E. E. Hays, suggesting that we meet the 'Atlantis II' in Nantucket Sound. With those on board we inspected photographs, shared doubts, and tried to check quick conclusions. In this we were fortunate because, although public interest was high, we were by ourselves and able to think, to doubt, to question, and to examine the logical consequences of the most optimistic guesses without our thoughts going farther than the group on board. Later during the 'Thresher' search such freedom frequently was not to be had. Following an intensive study of the photographs with the Thresher Technical Analysis Group, then stationed at Woods Hole, we concluded that the paper, metal, and other debris were very likely from the 'Thresher'. Now, although we felt the pressure of 'Atlantis II's' schedule, we also were compelled to follow this lead in the hope of bringing the search to a successful conclusion. So yet another week of work was scheduled and again Knott led a group on 'Atlantis II'. They made many camera, echo ranging, and SP sweeps over the search area near the debris (which was found due north and near the Delta contact.) They photographed more debris, and developed possible echo-ranging and SP contact. Although the time was short, other laboratories were now assisting. R.S.Gerard of Lamont Geological Observatory dredged some O-ring gaskets which might well have come from 'Thresher'. Not to be outdone, F. R. Hess on 'Atlantis II' improvised a dredge which recovered large quantities of rock—and a piece from a lead acid battery plate of a type used only on nuclear submarines. At the end of the fifth week of search, (May 21-27), the trail looked hot. But the achievements were by accumulation, not in any one quick, clever thrust. This was our last week of direct participation at sea since the 'Atlantis II' simply had to be released for other commitments. She had played her part well.

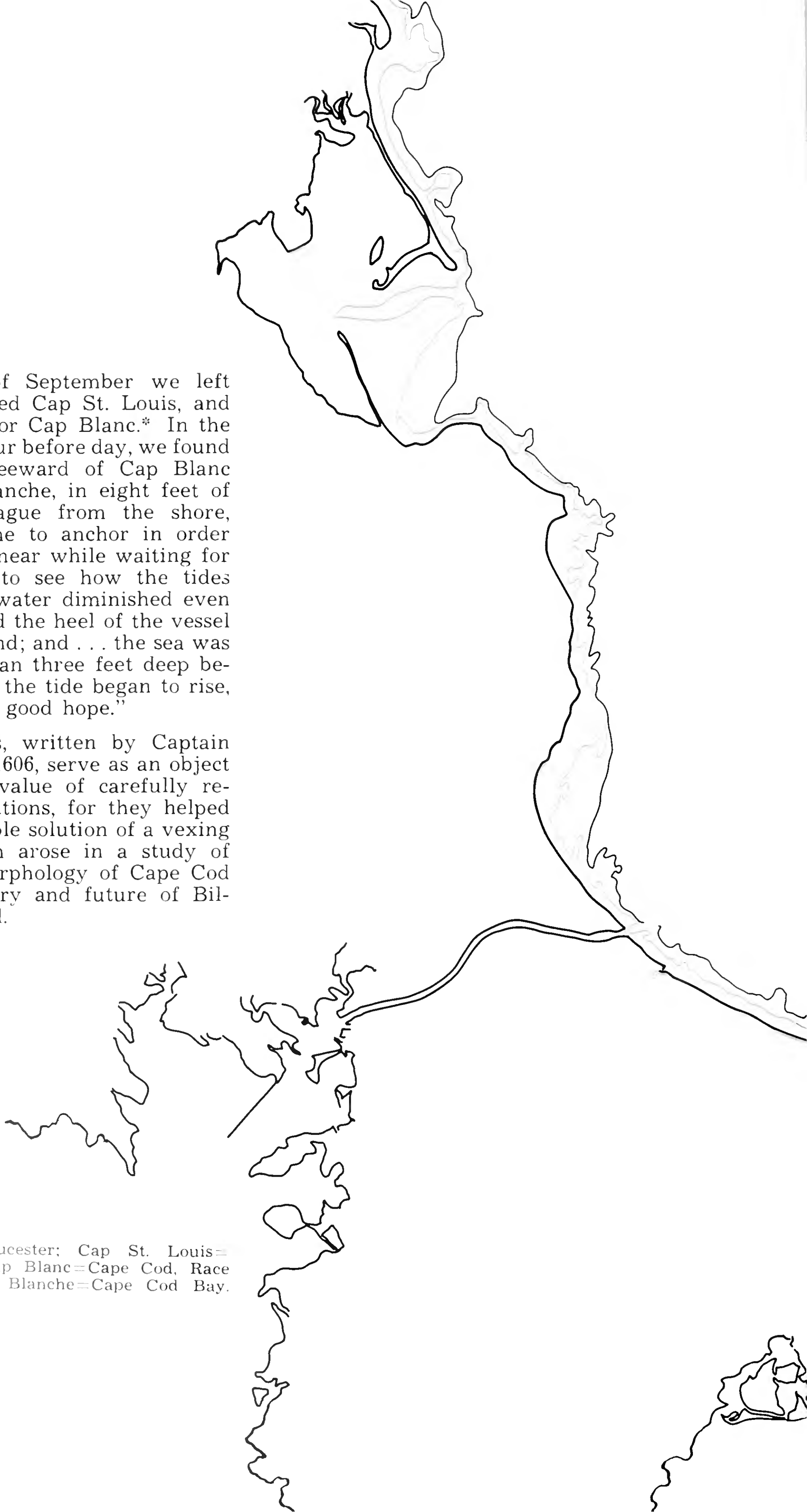
Shortly thereafter the Thresher Analysis Group, which had been our guests since early April, departed for Hudson Laboratories, to continue the analysis of all evidence bearing on the 'Thresher' search. We had defined the area strewn with small debris. The Lamont group and NRL photographed large objects which probably came from 'Thresher'. The bathyscaphe 'Trieste' completed several dives on the scene adding significantly to the mounting evidence. Magnetometer surveys have been made by three laboratories.

Throughout all of this work no need has been more obvious than that for reliable, precise navigational control, both for ships and for instruments or submarine searching near the ocean floor. As this is being written 'Chain' is returning from a ten-day cruise spent testing a navigational aid for the 'Thresher' search. This is an anchored sonobuoy having the hydrophone near the bottom and feeding into a radio sender at the surface over a long cable. Such a system should provide precise positioning. The first test was successful, but improvements need to be made. In addition we extended our previous camera and SP surveys. From our studies we now conclude Contact "Delta" is not 'Thresher' nor any other large metallic object, but we still don't know what it is. Probably a large boulder. We have learned a great deal about how to locate instruments suspended near the bottom by long cables. We have even made schemes operational that give us the position of our camera so quickly (by means of a digital computer on board 'Chain') that we can maneuver the ship to guide the camera where we want it to go and know almost immediately whether it so went. We did photograph some more debris, but not necessarily from 'Thresher'.

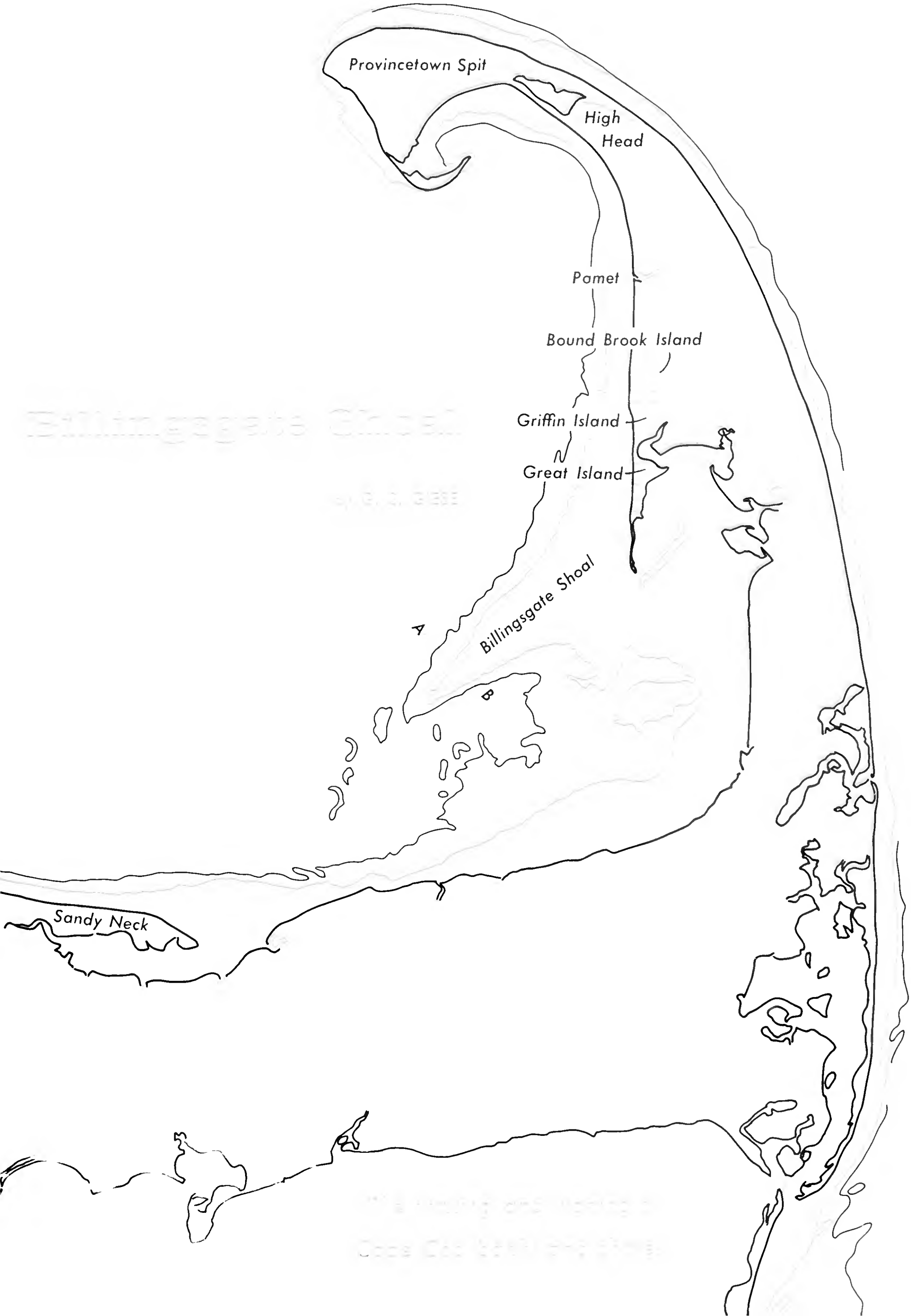
We have learned much about deliberate search in the deep sea, about precise navigating and even controlling the position of suspended instruments. These advances will be most useful in our scientific research, and they will also be particularly useful in advancing deep-sea engineering.

"THE last of September we left Beauport, passed Cap St. Louis, and ran all night for Cap Blanc.* In the morning, an hour before day, we found ourselves to leeward of Cap Blanc in the Bay Blanche, in eight feet of water, one league from the shore, where we came to anchor in order not to get too near while waiting for daylight, and to see how the tides were . . . the water diminished even to five feet, and the heel of the vessel touched the sand; and . . . the sea was . . . not less than three feet deep beneath us when the tide began to rise, which gave us good hope."

These words, written by Captain Champlain in 1606, serve as an object lesson in the value of carefully recorded observations, for they helped lead to a possible solution of a vexing problem which arose in a study of the coastal morphology of Cape Cod Bay: the history and future of Billingsgate Shoal.



*Beauport=Gloucester; Cap St. Louis=Gurnet Point; Cap Blanc=Cape Cod, Race Point area; Bay Blanche=Cape Cod Bay.


Provincetown Spit
High Head
Pamet
Bound Brook Island
Griffin Island
Great Island
Billingsgate Shoal
A
B
Sandy Neck

Billingsgate Shoal is a triangular sand and gravel surfaced bank which extends to the southwest from the eastern shore of Cape Cod Bay. For a distance of four and a half miles from shore, the water over the shoal is seldom more than twelve feet deep at low tide, while thirty to forty feet of water can be found nearby on both sides of the shoal.

Glacial deposits

The land mass of Cape Cod consists of unconsolidated material—boulders, gravel, sand, silt, and clay—resulting from or directly related to glacial advances and, perhaps, the warmer interglacial periods with their accompanying higher stands of sea level. Since the last glacial advance, the sea surrounding Cape Cod has risen hundreds of feet, and much of the glacial deposits have been eroded, while beaches, spits and bars have been built up by waves and currents.

At the onset of our study it was guessed that Billingsgate Shoal was presently being constructed by wave and current action. This guess was built primarily on the form of the shoal which both in plan and section resembles an immense sand bar, with a gradual slope seaward and a steep slope landward.

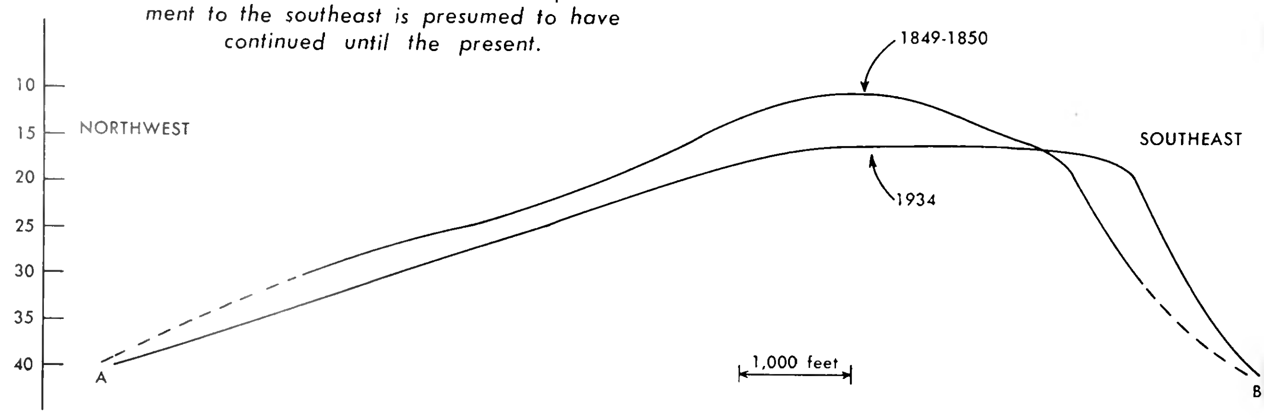
However, Champlain's report of water no deeper (and probably shallower) than that now present over the shoal, and other evidence, such as the line of small submarine mounds southwest of the tip of the shoal, and the rapid erosion of other nearby features (such as Billingsgate Island), suggested that the shoal represented an erosional remnant of a previous land form. A comparison between the U.S.C. & G.S.' survey of 1849-50 and that of 1934 showed that more than ten million cubic yards had been eroded from the shoal during the eighty-five year period, and that the shoal was slowly migrating to the southeast.

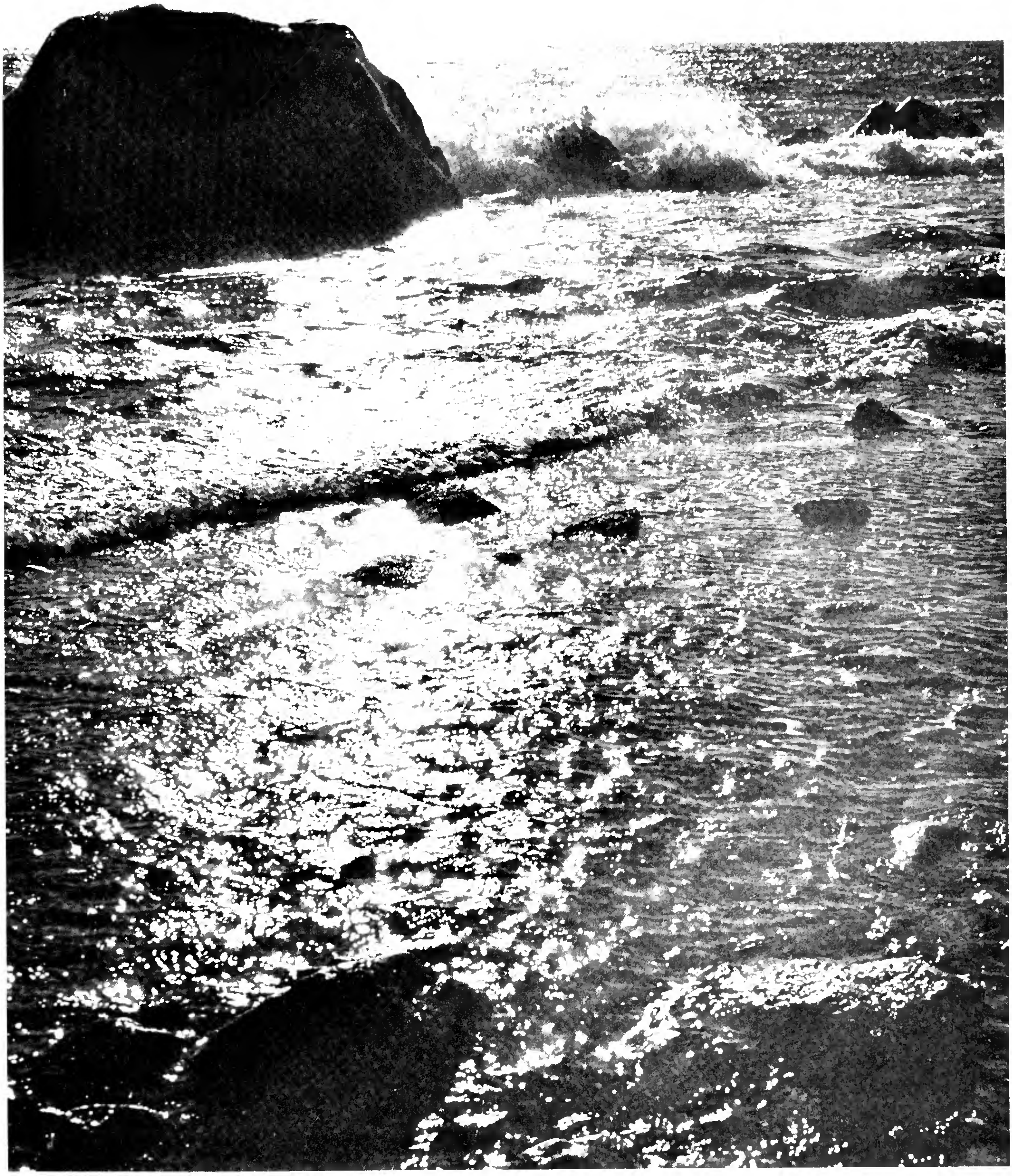
Yet, if Billingsgate was eroding, why did it lack the characteristics typical of the glacial remnants of the area? Where glacial forms are being eroded along the coast of Cape Cod Bay, their surfaces are commonly covered with cobbles and boulders which accumulate as the finer sized constituents of the original deposits are washed away. But on the shoal, the largest material appears to be gravel of a size commonly found on the beaches and spits.

Former Spit

A consideration of the trend of the wave-cut cliffs of High Head in North Truro, and the history of the growth of the Provincetown spit, led to the hypothesis that the shoal was both an accretional and an erosional feature. Billingsgate Shoal is the remnant of a former spit with a history roughly as follows:

These profiles of Billingsgate Shoal made along the lines A-B on the base chart show the changes that have taken place between two surveys made in 1849-50 and 1934. The erosion of the bank and the displacement to the southeast is presumed to have continued until the present.





PIETER HAHN

The results of the glacial ages can be seen at Cape Cod where large and small boulders often dot the shores.

Some five thousand years ago, before the beginning of the growth of the Provincetown spit, the glacial deposits forming the eastern shore of Cape Cod were being rapidly eroded by waves from the northwest, the direction of maximum fetch. The resulting strong southward littoral drift deposited this material to form a long spit analogous to Sandy Neck on the south shore of the bay. As the growing Provincetown spit provided protection from the northwesterly waves, the rate of the southerly drift dwindled and the Billingsgate spit began to erode. Finally the protection was so complete that waves from the southwest had a greater effect, and the littoral drift along the northeastern shore reversed its direction. Beach Point began its growth northward, enclosing Pilgrim Lake and protecting the cliffs behind it from further erosion; and the long spit at Billingsgate, lacking an adequate supply of material, diminished to its present form.

Changing Shore

This hypothesis is supported by evidence from several sources. The eastern shore of Cape Cod Bay, south of Pamet, is characterized by deep, marsh-filled embayments and isolated glacial-deposit "islands" all presently connected by an unbroken cordon of sand beaches. However, in the eighteenth century, these "islands" were surrounded by water, and even into the last century some of the embayments were open waterways, thus suggesting that a strong littoral drift along this shore is a recent phenomenon which began only after the wasting away of a barrier to the west. Also, the shoreline southeast of the presently eroding shoal is broken and uneven, indicating little wave action. One would expect that this coast would adopt a smoother outline as the shoal erodes, and this tendency is indeed indicated by a comparison of early and recent surveys. Thus we see in the coastal forms of Cape Cod Bay an interesting series of causes and effects wherein the building of one form (the Provincetown spit) causes the destruction of a second form (the former Billingsgate spit) which results in the remolding of a third form (the shoreline southeast of Billingsgate Shoal.)

It may be that the former Billingsgate spit was built out over a preexisting ridge of glacial deposits. A recent profile run across the shoal by Dr. H. E. Edgerton using his portable, acoustical sub-bottom penetrator showed discontinuous reflections about five feet beneath the surface of the northwestern edge of the shoal. These reflections may indicate boulders. Further investigations must be carried out before the post-glacial history of this coastal area can be described with any certainty.

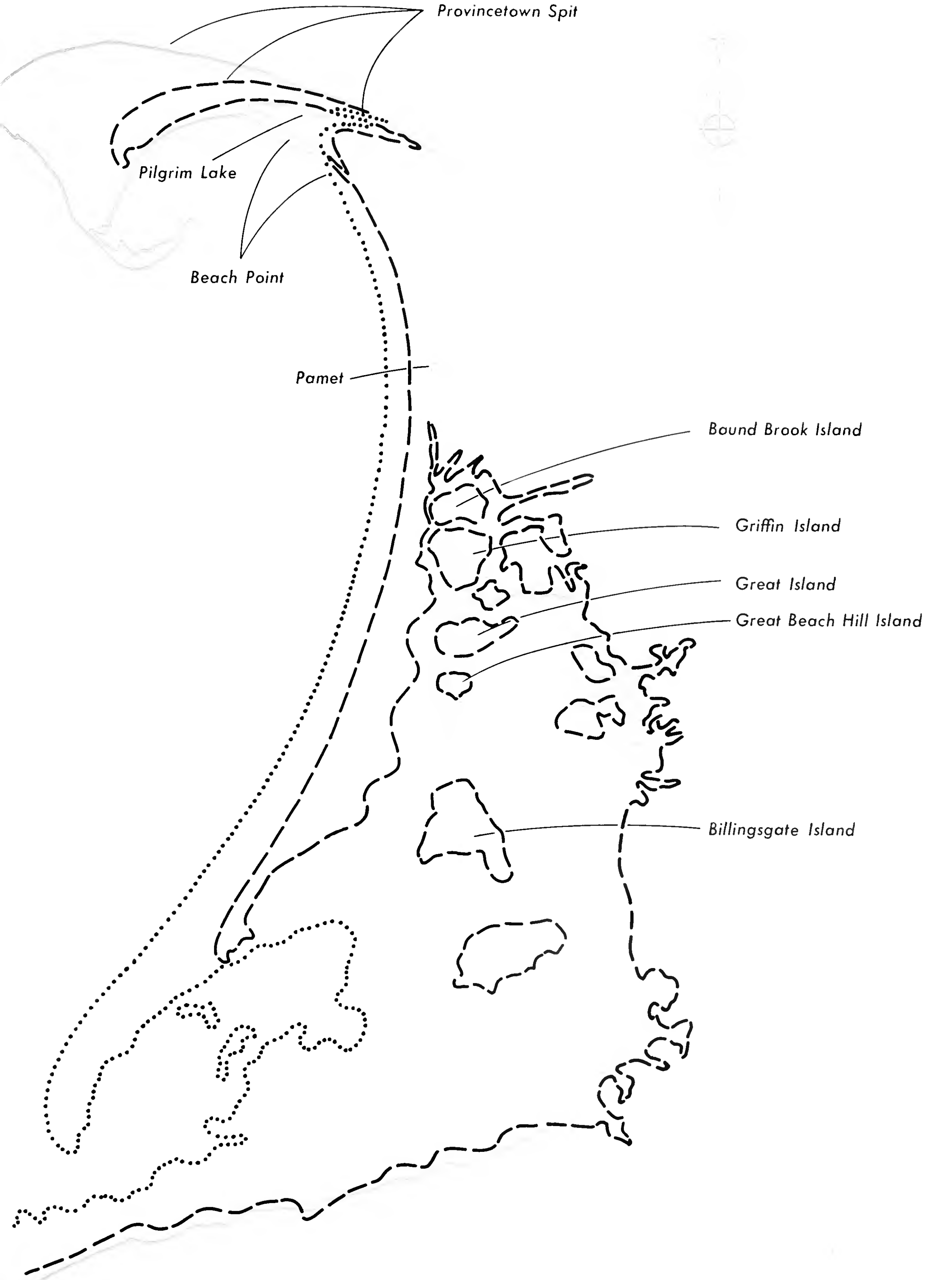
> **Mr. GIESE** joined our staff in 1956 as a research assistant to Dr. J. M. Zeigler. He has been chiefly occupied with coastal and nearshore studies on the outer arm of Cape Cod, Mass. This month Mr. Giese returns to the Graduate School of Oceanography at the University of Rhode Island.

[illegible]ical outlines of the
[illegible] Cape Cod

· · · · · · · · · · · · · · · · · *Outline at the time of beginning of growth of the Provincetown Spit*

— — — — — — — — *Outline at the time of beginning of growth of Beach Point*

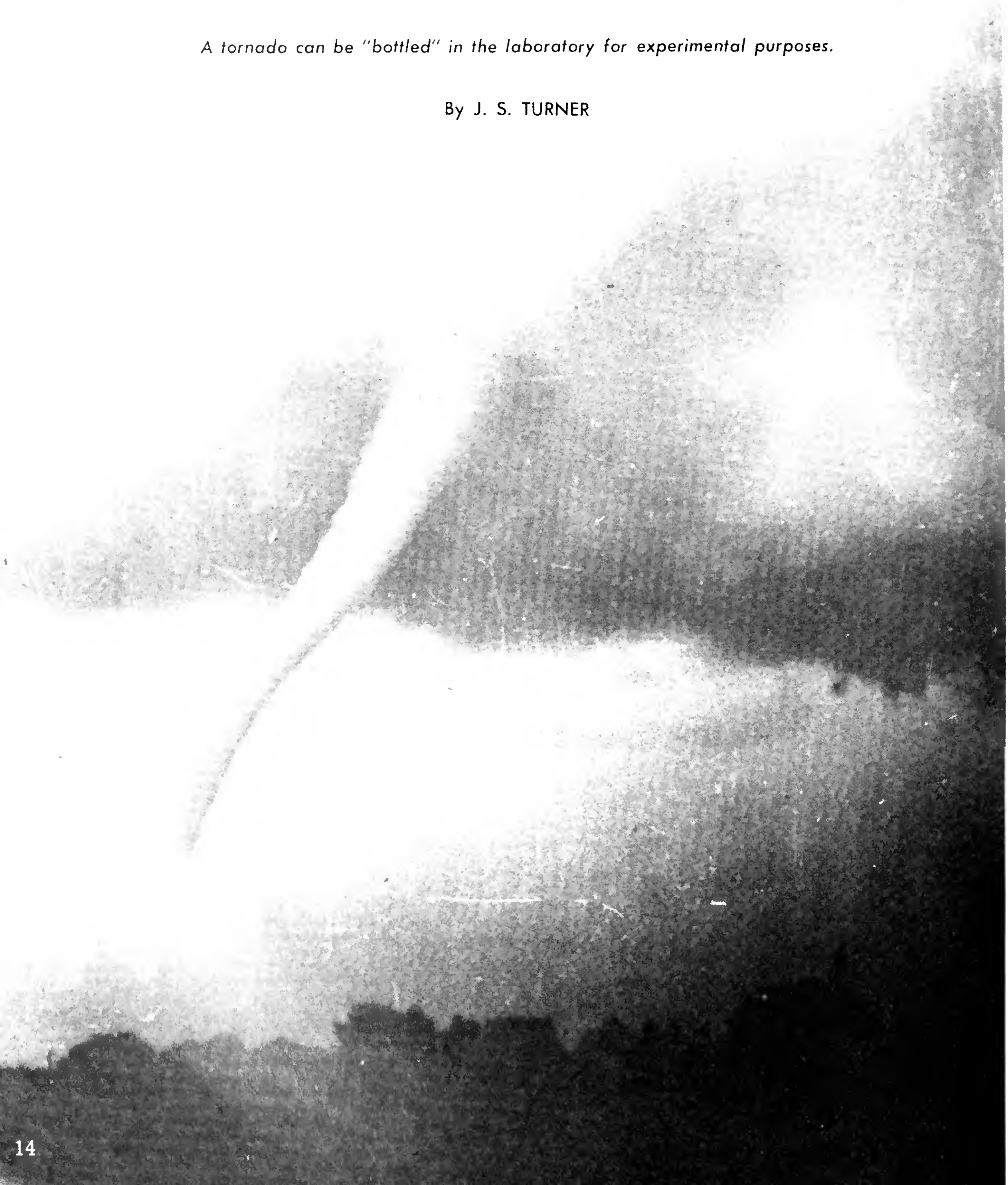
——————— *Present day outline*


Provincetown Spit
Pilgrim Lake
Beach Point
Pamet
Bound Brook Island
Griffin Island
Great Island
Great Beach Hill Island
Billingsgate Island

TORNADO!

A tornado can be "bottled" in the laboratory for experimental purposes.

By J. S. TURNER



U S. DEPT. OF COMMERCE WEATHER BUREAU H. E. DALE

ATTEMPTS to produce small scale models of atmospheric phenomena have had a long history. Complete realism is hard to achieve because of the many uncontrollable variations in the actual atmosphere, but the necessary simplifications can often be to our advantage, since the more important effects can be isolated for detailed quantitative study. Perhaps the most successful recent experiments have been those on flows in rotating tanks of water, which give information about the circulations in the atmosphere (or ocean), and a variety of convection and mixing experiments. Both of these types have been carried out at Woods Hole over the last few years.*

Tornadoes and waterspouts were among the first atmospheric processes to be modeled in the laboratory. As early as 1780 a very realistic looking "tornado" was produced in water, and since then many suggestions have been made for doing such experiments in water or air. All of these experiments have two things in common: a source of rotational motion, and some means of producing an inflow towards the center of rotation. The flows have been produced mechanically, thermally or by the removal of fluid from a central hole (as in the bathtub vortex). However, little quantitative information was obtained from these early experiments. Nearly the same understanding of the process could have been attained without experiment by using simple arguments about the conservation of angular momentum, and the consequent increase in rotation rate as fluid moves inwards.

Recently, several quantitative experiments have been carried out with the application to tornadoes or waterspouts in mind. These experiments have involved the removal or injection of fluid along the axis of the rotating tank, though a successful model of a "fire devil" was driven instead by the convection current produced by heated air. It seems likely that convection is the main mechanism causing the concentration of angular momentum in tornadoes and waterspouts too, since these are usually associated with large cumulus clouds.

Do It Yourself Experiment

We have found that convection can conveniently be modeled in a liquid

*See: "A Small World", Oceanus, Vol. IV, No. 4, and: "Atmospheric Model Studies", Vol. IX, No. 1.

by using the release of small gas bubbles in soda-water. This process is closely analogous to the release of buoyancy by condensation in the atmosphere, and it has the advantage that no fluid need be added to or extracted from the container. The experiment is simple and spectacular, and anyone with a record player might like to try it for himself as follows:

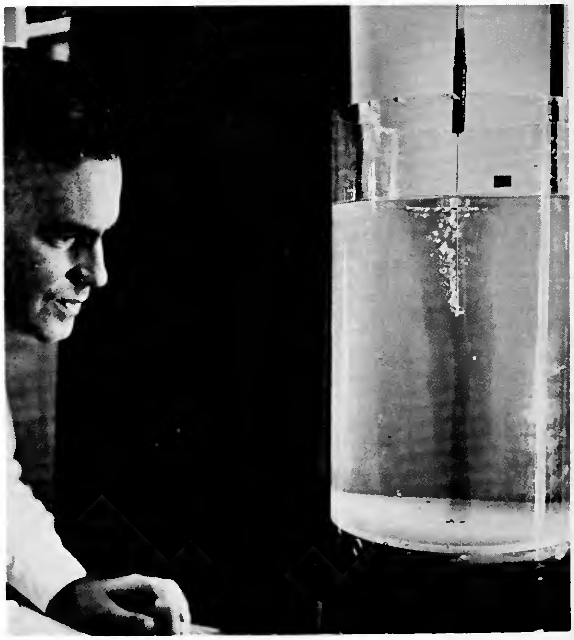
Remove the label from a clear bottle of soda, and pour off the top few inches of liquid, to avoid overflow. Put it on the center of the turntable and rotate at 78 rpm until the soda reaches the same speed. Although there is a large supersaturation of gas in the water very little comes out of solution because of the lack of suitable nuclei on which bubbles can form. Now drop in a pinch of nuclei—almost any solid particles will do, but sugar is best if the soda is to be drinkable afterwards! Bubbles of gas produce an upcurrent and hence an inflow, and a tight vortex will form suddenly.

Quantitative Measurements

I believe that the soda-water vortex reproduces many of the essential properties of a tornado, but it cannot be controlled carefully enough to make convenient quantitative measurements. A vortex can also be obtained by using much the same mechanism, the release of bubbles, if these are injected into the top of a tank of tap water by blowing through a fine tube pushed down under the surface. Such a vortex can be made steady, and it is possible to measure velocities at various points by taking photographs of small particles placed in the water. In this way detailed comparisons can be made between the experiments and various theoretical descriptions of the flow.

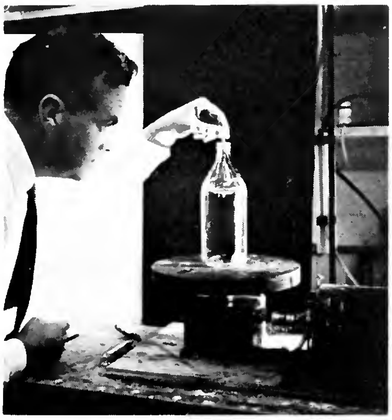
The measurements revealed an interesting pattern of vertical circulation. The region of upward motion at the center is surrounded by a ring in which there is a downward velocity. If dye is put in at the top of the tank, it is drawn down in this annulus; on reaching the bottom it flows very rapidly inwards and then up the center. The dye thus remains within the central region showing that the whole of the vertical motion, and also the increased angular velocities, are contained within this dyed cylinder. It is tempting to compare this picture with those of waterspouts or tornadoes which show cylindrical outlines marked by condensed water or dust, but the nature and extent of the vertical motion in the full scale phenomenon is not well enough known for a proper comparison to be possible.

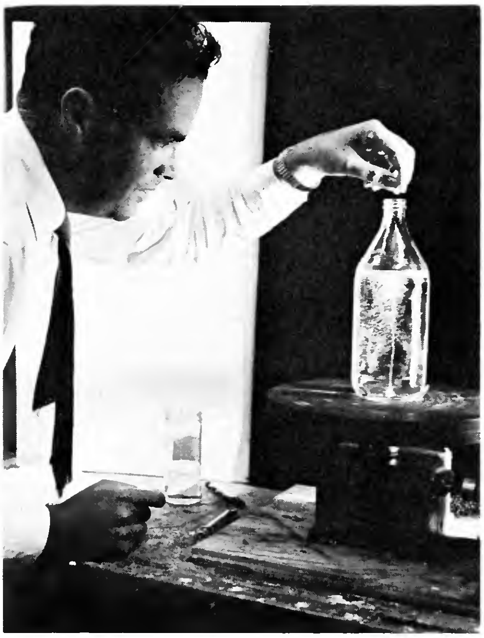
Dr. TURNER, Rossby Fellowship holder at the Institution, is on leave from the Commonwealth Scientific and Industrial Research Organization in Sydney, Australia.



SPOONER

Dye put in at the top of the experimental tank is drawn down by the vertical circulation in the central region round the vortex.





Do-it-yourself tornado

The author here illustrates the soda water vortex.

By rotating a soda bottle at 78 RPM on a record turn table and adding some sugar to the soda, one can reproduce the experiment described in the text.

Report from the East

By C. D. DENSMORE

Before daylight on July 29, 1963, 'Atlantis II' led a fourteen ship convoy into Great Bitter Lake, in the Suez Canal. At 0516 the sun rose.
Thus, without fanfare, started one of the classic chapters in oceanographic history—

The Great Bitter Lake Multiple Ship Survey

By 0600 the first station was underway, an artistic mélange of Nansen bottles, Van Dohrn bottles, a Bodman sampler, a coring rig and an oxygen sonde. This latter was rather remarkable in itself, being a German device, (whose operating manual first had to be translated by Dr. G. Dietrich), with Italian transformers brought out by boat from the NATO lab at La Spezia, Italy, put together by an American and a Frenchman. Three wires were over the side simultaneously in 12.5 meters of water.

It is greatly to the credit of both Science and Crew that a grueling pace could be maintained hour after hour. Station followed station in relentless procession with as many as three Nansen bottles on the wire at once, where depth of water permitted. Surface temperatures topped 31°C.* The sun was warm.

Around 0900 all hands stood cheering at the rail as R/V 'Workboat' cast off on her maiden scientific voyage, under command of 3rd Officer Palmieri and Expedition Leader R. Munns. Dr. Selim Morcos, of the University of Alexandria, was observing. Instrumentation consisted of one Nansen bottle, one Van Dohrn, a surface bucket, two cases of sample bottles and sixty feet of yellow plastic line. The main hydro winch gave trouble at first—his spectacles sweated up—but this minor technical difficulty was soon overcome and a set of stations was run ashore of the mother ship. Temperatures were taken and water samples for salinity, oxygen, nitrate and phosphate determinations.

*87.8°F.

While the R/V 'Workboat' was relentlessly examining the depths, the R/V 'Atlantis II' proved her versatility by following a station in the deepest part of the Mediterranean, at 5234 meters, with one in Bitter Lake at 7 meters, (this preceded a cast on the Hiller Deep—13.4 meters).

After seven hours of fairly brisk effort, R/V 'Workboat' was hooked to the falls and hoisted aboard the 'Atlantis II' as we steamed to take station at the head of the Suez Canal convoy consisting of towering freighters and tankers which had laid docilely at anchor while we labored.

"In three and one half hours," stated Expedition Leader R. Munns, "we made seven stations. We had a Master, Chief Scientist, Chief Engineer, Doctor, Radioman, Chemist and Winchman, in a brand new ship. We each had a cold beer, and even a swim call during the five minutes the thermometer was equilibrating."

Diffidently, we mentioned the mothership's 7 meter station; but the workboat had made one in 7 feet of water!

What the Egyptian pilot thought of all this is not on record.

Report from the North

By R. M. SNYDER

SOMETIME late last winter, according to radar photography, a portion of the relatively permanent ice foot broke away from the north shore of Ellesmere Island and formed five large ice islands (similar to the now famous T-3, which was used as a drifting oceanographic station). Four of these ice islands began traveling westward with the arctic drift but one—some five by eleven miles in extent and more than 100 feet thick—turned eastward into the Lincoln Sea and down between Ellesmere Island and Greenland where it traveled through Robeson Channel, Hall Basin and Kennedy Channel* and finally lodged (presumably against Franklin Island) forming the key to an ice jam and preventing the further flow of arctic ice southward into Kane Basin.

It was difficult, during months of darkness to tell exactly what had happened and even more difficult, if not impossible to predict intelligently the longevity of the ice jam. In any case it was plain that, for the first time in recorded history, the ice was emptying out of Kane Basin thereby presenting the unique opportunity of making oceanographic measurements beyond the North Water.§

The United States Coast Guard, which conducts the annual iceberg surveillance for the International Ice Patrol normally make a "post season" oceanographic cruise north into Baffin Bay. Arrangements were made in Washington, D. C. between the Office of Naval Research and International Ice Patrol Headquarters for an addendum to the annual post season cruise in which Cdr. C. S. Changaris, CO of the USCGC 'Evergreen' would sail north into Kennedy Channel to observe the ice island and surrounding conditions and conduct oceanographic experiments as practicable.

SNYDER

Responsibility for planning the oceanographic work fell to the Coast Guard Oceanographic Unit attached to the Woods Hole Oceanographic Institution under Capt. J. E. Richey. Standard hydrographic sections were planned across Smith Sound,† Kane Basin and Kennedy Channel. N. Corwin of the Institution furnished the 'Evergreen' with oxygen titration apparatus and chemicals and Corwin and D. A. McGill, also of our Institution, provided freezers and containers for preserving water samples for nutrient determinations. Because of the restricted nature of this area—both in depth (100-300 fathoms) and breadth (25-75 miles) the dynamic calculations for theoretical current flow would be questionable at best and Capt. (Ret.) F. M. Soule and Lt. R. M. O'Hagan of the Ice Patrol expressed to the author the desirability of making direct current measurements. The Office of Naval Research concurred by requesting that I be allowed to load whatever gear was necessary and available

*Named for Capt. W. Kennedy, who sailed north in the 'Prince Albert' in 1851 in search of Sir John Franklin.

§The North Water refers to the relatively ice free water in the extreme northern end of Baffin Bay found early in the 17th century and fished by American Whalers for nearly 200 years.

†More properly Smith Straits

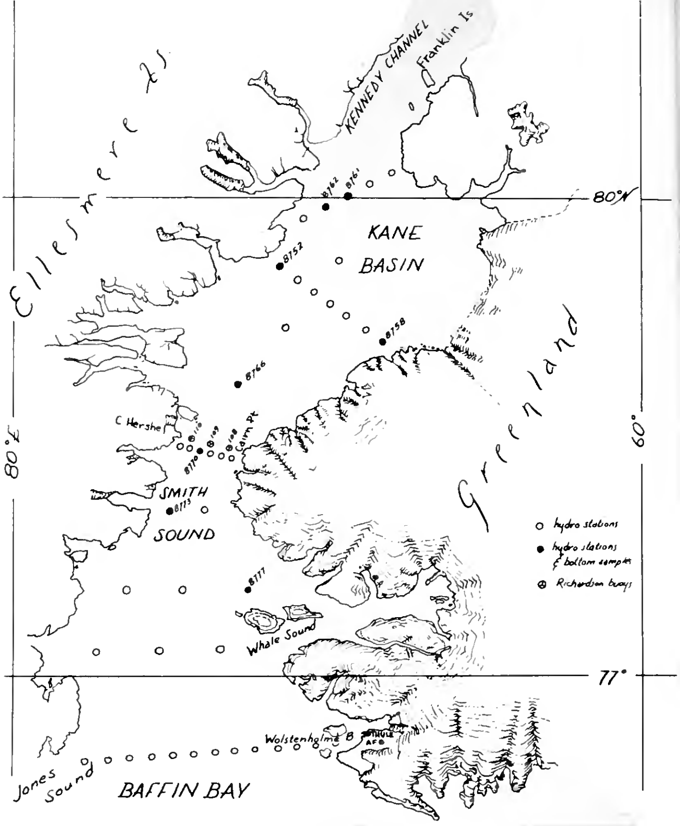
aboard the 'Evergreen' at Boston and to meet the vessel at Thule for the trip northward.

For reasons primarily logistic we had planned to set three doughnut buoys, each equipped with a wind recorder and three or four Richardson current meters, across Smith Sound from Cairn Pt. to Cape Hershel on the way out of Thule to be picked up on the return from Kennedy Channel.

I arrived at the MATS terminal in Thule early in the morning of 26 July —shortly after the 'Evergreen' had docked—to find that the ice island had broken up and started south accompanied by the several thousand megatons of ice it had long delayed from expulsion by the Arctic Ocean.

The ship was due to sail that evening and the day was spent readying the buoys and current meters. The three buoys, Woods Hole Stations 108, 109, and 110 were set between 0413 and 0638 hours EDT on 28 July as planned across Smith Sound. Although the advisability of leaving the buoys under these new circumstances was questioned, I assured the skipper (with concealed reservation) that if the buoys did get involved in an argument with an iceberg either the anchors would drag or the mooring would part at the weak link we had provided above the anchor.

For the next few days the crew was busy around the clock taking some 15 hydrographic stations. As time and conditions permitted, we took bottom samples with the Phleger corer and a discarded Van Veen sampler I rebuilt for the trip. After taking station 8762, we sighted a small piece of the ice island (approximately ¼ mile long) and calculated that the ice was making to the southward at the rate of some 15 miles per day. So far the sea had been glassy calm—the sky bright and clear with very few clouds. As we made south through Kane Basin again, a fresh south wind came up bringing with it grey skies and wisps of wet snow and rain. By the time we had reached our buoys it was



SNYDER

The area north of Baffin Bay where an ice island jammed the flow of ice which usually comes through Kennedy Channel, thus providing an opportunity for oceanographic observations in an area normally too full of ice to break through.

obvious that the wind had impeded the southward flow of the ice and the buoys were not yet in danger. By 1800 hours on 30 July six more hydro stations had been completed across Smith Sound just south of the buoy string and the ice was still a fair distance north. The sky looked ominous, however, and the propitious decision was made to retrieve the buoys. This was accomplished by 2230 that evening. Three more hydrographic sections totaling some 20 stations were made further south, the last duplicating the 1928 Godthaab section from Jones Sound to Wolstenholme Bay. The weather had built up so as to make steaming on some courses uncomfortable and before it abated provided us with the thrilling experience of watching the spume of ocean waves whistling over the tops of icebergs one hundred feet above the surface of the sea. Lest one thinks this big ice no match for an angry sea contemplate a large cube we passed near the entrance to Whale Sound—aground in 100 fathoms of water we estimated its weight to be some 50 million tons and this was small compared to what they make in Antarctica.

Tired of Awe

All things are of interest on a cruise such as this and with 24 hours of daylight one can become tired just standing in awe. On the cliffs facing the northwest corner off Kane Basin we observed long tortured beds of red rock — presumably sandstone — stretching off to the north—fractured in one place to form a series of seven or eight perfect chevrons, one atop the other. The glaciers, brute forcing their way to the sea, are a source of ceaseless wonder — their apparent tranquility disturbed only in the mind's eye by the memory of having walked through a glaciated valley. The sea and sky are of another world —I saw more lenticular clouds in one afternoon than I had previously counted in a lifetime. The wind blowing across the open water from the south is cold and generally brings clear skies—the wind blowing off the ice cap is warm—unearthly.

We saw no polar bears, no narwhales nor belugas, and also no walrus. We did see seals (only the bearded seal was near enough to be identified) dovekeys, fulmars, murres and the long tailed jaeger. From the bottom we brought up worms (Chaetopteridae?), Bryozans (Membranipora?), shells or relatives of our local quahog and scallop and a single skeleton of a coral polyp. Perhaps most interesting of all the animals will turn out to be the goose barnacle (Conchoderma)‡ we found growing on the Savonius rotor on the topmost (50 meters deep) current meter on station #110, after only 3½ days in the water. I am told by my marine biologist friends that there are four ways that a creature of this type and size could have gotten on our current meter and that all four are impossible. A deeper current meter (150 meters) provided a temporary home for over a half dozen members of the barnacle family which I tentatively identified as Balanus amphitrite—undoubtedly a mistake as amphitrite should not have been there either. These specimens grew to better than a quarter inch in diameter in less than three days. The abundance of phytoplankton was evident during the oxygen determination experiments and might it not be that, during periods of prolonged sunlight, the lower animals of the sea, in the presence of high concentrations of nutrients, exhibit phenomenal rates of growth and maturation not unlike their botanical cousins ashore?

‡Goose barnacles are found by the hundreds on our buoy stations in warm waters.

In any case, these points will be pursued — we have the bugs in alcohol, the bottom samples in ice cream containers, the water samples in the freezer and the current vectors on film. The results will be presented in the Coast Guard Bulletin. During the expedition temperatures were read and corrected, salinities and oxygens were determined by Lt. O'Hagan and A. P. Franceschetti and their crew of aerographers and the results turned over to Dr. D. C. Nutt of Dartmouth and the Arctic Institute and Dr. L. K. Coachman of the University of Washington who also boarded the 'Evergreen' at Thule.

Acknowledgments

During the entire trip I was impressed by the energy and dispatch with which the Coast Cuard personnel carried out their oceanographic duties while upholding the high standards set for them over forty years ago during the first expeditions for the International Ice Patrol, so ably lead for years by our former Director, the late Adm. Ed. H. Smith. And they certainly deserve their reputation as expert buoy handlers. I would like to express here my appreciation to Captain Richey, Commander Changaris and Lieutenant O'Hagan as well as the crew of the 'Evergreen' and the personnel of the C.G. Oceanographic Unit for the opportunity of participating in this most interesting and rewarding expedition.

A Stable Buoy

by E. B. KRAUS

WE have constructed a buoy which is not significantly affected by the heaving of the sea surface. The tip of the instrument mast which is an integral part of this buoy reaches to a height of 50 feet above the sea surface. The design called for extreme stability; for example, we required movements of less than one degree at the mast tip in waves of ten feet height. The sea around Woods Hole is not rough enough at this time of year to know whether or not these specifications have in fact been met. However, we are confident from preliminary tests that they will be at least approached.

Why do we need such a gadget? There are two basic ways of measuring the transfer of properties such as heat, moisture or momentum between the air and the sea. The most direct way is to record simultaneously vertical velocities associated with eddies in the air and the instantaneous value of the property whose transfer we wish to measure. For example, if we record vertical velocity and temperature at the same time and if we find that on the average the upward moving air is warmer than the downward moving air parcels, we will conclude that there is an upward transfer of sensible heat. The horizontal stress on the sea surface, or the transfers of moisture can be determined in a similar way by measuring simultaneously vertical and horizontal velocity or vertical velocity and water vapor pressure. Vertical velocities near the surface always are very small. It would not be possible to measure them if our sensors moved at the same time. It is therefore necessary that the structure which carries these sensors is fixed and does not move.

In the second method we measure mean values of heat or horizontal momentum or moisture at a number of different heights. A knowledge of the resulting temperature or wind or moisture profiles enables us again to estimate the transfer of heat or the stress or evaporation. To establish these profiles we have to know the distance of our sensors from the mean sea surface. As before, we cannot tolerate movement in their support. For both these reason a stable structure is again required.

In the first instance we wanted measurements in the tradewind region at a depth where the waves do not "feel bottom." That meant that we have to go to a depth of a hundred fathoms or so. It would be quite uneconomical to erect a tower from the sea bottom at such a depth. The problem is being solved with a buoy that can be floated at the surface to the observation site. There it is to be moored and the main flotation of the buoy is then cranked down to a mean depth of about 14 feet below the sea surface. The resulting 5000 pounds of excess buoyancy make for an extremely light mooring under high tension. Only a skeleton structure and the mast itself reach above the sea surface.

The original laboratory model of the buoy was constructed out of three beer cans by Dan Clark on a dark and dull winter evening. A larger model was also constructed by him at his own initiative: it was tested out in Great Harbor last year and now collects rust in the Eel Pond. The full scale buoy was designed by Ocean Research Equipment who subcontracted the actual construction to Dan Clark.

Reminiscent of FLIP, but far less expensive, a stable buoy was developed for measurements of air-sea interactions.

SPOONER

Preliminary tests indeed were successful. The buoy was tested in 100 fathoms off Provincetown. A two to three feet high sea was running with occasional five foot waves. R. Heinmiller was standing on the platform on one leg without support for his hands, pretending to play the accordion while a shark fin was observed circling the strange structure. It was not possible to discern any movement of the horizontal members of the buoy against the horizon by naked eye. When the buoy was pulled over with the boat, it returned to the upright position without oscillation within about 15 seconds.

There are some teething troubles and minor modifications will have to be made. It seems however that the buoy could easily provide a cheap means of obtaining observations with instruments that require a reasonably rigid support. That means it could be used to measure rain or wind anywhere on the continental shelf. We foresee no difficulty with moorings down to a depth of 200 fathoms. This means that the buoy may well be found useful not only for our present purpose but also for synoptic data gathering.

Dr. KRAUS, meteorologist on our staff, formerly was with the Snowy Mountains Authority in Australia. He first came to the Institution on a Fellowship.

Book Review

"Ideas and observations on progress in the study of the seas."
Edited by Dr. M. N. Hill. Vol. 2, Interscience Publishers, New York, 1963
$25.00

IT IS difficult to review a book objectively when in theory you are one of its editors. Actually, I did almost no work at all after the planning stage. I am as surprised as anyone to see how well it turned out.

Volume 2 of "The Sea" has five sections: the first on new advances in chemistry, the second on new advances in understanding of the fertility of the oceans, a third and perhaps too short section on currents, a fourth on biological oceanography in general and a catch-all section of miscellaneous subjects. The original purpose of all this work has clearly been accomplished, namely to bring oceanography up to date since the publication in 1942 of "The Oceans" by Sverdrup, Johnson and Fleming. So rapidly has the subject expanded, especially during the last ten years, that it seemed hopeless to try to select one author or even a small group of authors to cover the entire field.

Volume 2 has 29 contributors of which seven were in one way or another closely identified with Woods Hole at the time the articles were originally prepared. All but one still are.

Interscience Publishers has done a magnificent job of printing and editing. It is only to be regretted that the price could not be kept within bounds. Page proof for Volume 3 on "The Earth Beneath The Sea" is beginning to arrive at my desk. The three volumes together, which are of somewhat different lengths, involving at least 2,000 pages of expertly prepared text, will sell for about $65. The spark plug and work horse of the enterprise is Dr. M. N. Hill of Cambridge University, England. All marine scientists owe him a great debt of gratitude. If you want to find out where oceanography is going, this is it!

C. O'D. I.

Automatic Oxygen Measurements

by J. KANWISHER

BEFORE an oceanographer has spent much time at sea he begins to realize how big the oceans are. At any given time he looks around him at roughly a five mile circle of water. When this is plotted to scale on a chart it becomes an insignificant dot. After months of steaming he finds that he has looked only at a small fraction of the seas. Yet it is his profession to compose a reasonable picture of the whole. To extrapolate from what little he has seen (or measured) requires considerable faith in the basic regularity of the ocean system. In his attempt to get a synoptic picture he is always frustrated by the slowness of research vessels and by time consuming measuring techniques.

New vessels are not noticeably faster. But radical improvements in instrumentation are appearing. The thermistor chain* gives an embarassingly complete picture of the temperature structure of the upper water layers. In-situ salinometers are available which give a complete profile of salinity and temperature. It is now possible to do the same for oxygen, the third most sought after parameter. A small electrode mechanism attached to the end of the hydro wire can indicate continuously oxygen tension in the ship's laboratory as the wire is payed out. The electrode can also be used to measure the oxygen in a water sample brought on deck in a Nansen bottle.

The electrode is nothing more than a small button of platinum and a surrounding ring of silver. These are covered by a thin film of polyethylene. A drop of alkali is contained behind the film. The drop is the liquid medium in which the electrochemical action of the polarographic measurement takes place. The device depends entirely on a fortuitous property of the plastic film. It allows oxygen to pass through but excludes the salts of sea water. Thus the platinum polarograph can operate behind the polyethylene without the usual interference from these salts. A small battery, which supplies a polarizing potential, completes the apparatus. A current is generated which is directly proportional to the oxygen tension the platinum 'sees' through the oxygen permeable plastic film. One can read this current on a meter or have it continuously traced on a recorder.

The chief interest in developing this electrode (in cooperation with Dr. D. E. Carritt of the Institution) was to make our physiological experiments less tedious. It has done this well. We have applied it to such tasks as monitoring the oxygen in a whale's breath and to measuring photosynthesis in sea weeds under the Arctic ice. Reliable time curves of oxygen allow one to spend more time thinking about the meaning of the experiment rather than worrying whether one's messy Winkler chemistry (the old way) is to be trusted. I have demonstrated its usefulness as a seagoing hydrographic method. Its further use will depend on those concerned with such measurements to learn to apply it properly.

*See: Instruments and Methods, Vol. VII, No. 1, Sept. 1960.

The article by P. L. Sachs: "St. Peter and St. Paul Rocks", in the June 1963 issue is being reprinted in 20 languages by UNESCO.

Associates' News

AMONG our Corporate Associates there are many who receive only one copy of Oceanus, addressed to the President of the organization or its industrial representative. Many such corporations have reference libraries; some already are on the mailing list. We shall be glad to hear from Corporate Associates' libraries who do not receive Oceanus, so that we can "spread the word" among the scientists, technicians and other employees of our supporters.

THE ASSOCIATES of the Woods Hole Oceanographic Institution are a group of individuals, corporations and other organizations who, because of their love for the sea and interest in science and education, support and encourage the research and related activities of the Institution.

Membership dues in the Associates are as follows:

Member	$50
Contributing Member	$100
Patron	$500
Life Member	$1,000
Corporate Member	$1,000
Sustaining Corporate Member	$5,000 or more.

All contributions and dues are tax deductible to the extent provided by law.

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