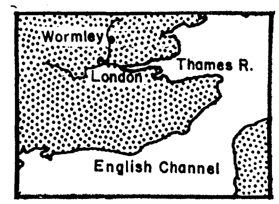


# Britain's National Institute of Oceanography

*Wormley, England.* Exploration of the oceans and of the features underlying them is one of the great opportunities today in science. The major nations have been alert to the challenge and are expanding their activities. Oceanic researchers seek rules to guide the harvesting of fish and more intensive exploitation of minerals in and under the sea. They also seek an increasingly detailed picture of the general circulation of ocean water and new information on the earth's structural history.

For several years these studies have focused on the Indian Ocean, previously little explored. Scientists participating in the international cooperative program in the Indian Ocean have sought biologically productive areas similar to those off the western coasts of Africa and the Americas. They have studied sound echoes, rocks, sediment, gravity, magnetism, and heat flow from the sea floor. These measurements of subocean structures are directly relevant to theories proposing that convection currents in the earth's mantle create mid-ocean ridges and islands and drive continents apart.

One of the world's most active establishments in the Indian Ocean work is the National Institute of Oceanography in Wormley, England, although, with a staff of 35 scientists, it is much smaller than such American laboratories as the Scripps Institution of Oceanography, the Lamont Geological Observatory, and the Woods Hole Oceanographic Institution. Emphasizing basic physical studies of the ocean more than any other British laboratory, NIO works closely with the department of geodesy and geophysics of the University of Cambridge.

The institute is headed by G. E. R. Deacon, a fellow of the Royal Society and a pioneer in tracing the flow of cold, dense antarctic water from the Weddell Sea into the Indian, Pacific, and Atlantic oceans. A particularly well known member of the institute is J. C. Swallow, who invented the neutrally buoyant float used for measuring deep-ocean currents in the International Geophysical Year and since.

### Geophysical Cruise

The institute administers Britain's large new oceanographic vessel, the *Discovery*. The $2.2-million, 2700-ton vessel began work in 1963. Because of the institute's interest in physical studies of the ocean, it was natural last fall that NIO and Cambridge scientists, taking over the ship at the end of a cruise made by another group of scientists to study biological productivity off southeast Arabia, should take the ship for a detailed study of the Carlsberg ridge, seeking evidence on the mantle-convection theory.

The Carlsberg ridge, in the northwest Indian Ocean, is part of the world-wide system of ridges rising from the deep basins of the Atlantic, Pacific, and Indian oceans. Although it runs directly toward a continent, Africa, studies made so far indicate the Carlsberg ridge to be a characteristic deep-ocean rise, with a deep valley in its crest, associated with a concentration of the epicenters of seismic events. The *Discovery* cruise, from 23 August to 4 December, found strong magnetic and gravimetric anomalies corresponding to the peak-valley. Similar anomalies were noted in 1961, when the British Admiralty survey vessel H.M.S. *Owen* twice traversed the ridge.

Likewise, measurements from the *Discovery* showed large magnetic anomalies well away from the ridge, under the abyssal plain. These anomalies appear to originate in the upper mantle, the region immediately below the Mohorovičić discontinuity.

Cruise members paid close attention to the northwest boundary of the Carlsberg ridge, where it comes close to the Horn of Africa (Cape Guardafui). To help them, they had taken along a detailed analysis, by D. H. Matthews of the geodesy and geophysics department at Cambridge (*1*), showing that the ridge has been fractured and that a western chunk has been moved 300 kilometers north.

At approximately 56°E, 10°N, the *Discovery* party examined a sea mount which proved to be nonvolcanic in origin. Material scraped up with great difficulty—two grabs were lost in rough terrain—indicates that the rock was originally laid down in shallow water. The sea mount resembled the island of Socotra nearby and was unlike any feature of the Carlsberg ridge.

It is possible, said A. S. Laughton, one of the cruise members, that the features of the Red Sea, the Gulf of Aden, and the Carlsberg ridge represent a continuum. The Carlsberg ridge may have formed earliest and the Red Sea most recently.

Of possible significance in dating the ridge as a whole and in finding if there is any increase in the age of rock from the ridge center were samples of manganese taken as the *Discovery* traversed the Carlsberg. The coatings increased in thickness with distance from the crest of the ridge. In some places the coatings were as much as 10 centimeters thick.

J. A. Miller of Cambridge is dating the rock samples by means of the potassium-argon method. It is possible that he will be able to determine the ages of the coated rocks, but he is not optimistic. The rocks on which the manganese was laid down are much decayed.

The evidence from the manganese coatings themselves is ambiguous, since geochemists have not yet found the mechanism whereby manganese is laid down. The concentration of manganese in sea water is about 10 parts per billion.

Another major aspect of the Carlsberg ridge investigation was a search for increased heat flow over the crest of the ridge. According to M. N. Hill of the Cambridge geophysics group, heat-flow readings are made by a thermistor-like device which is lowered

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in the tail of a corer used to obtain bottom samples. The normal heat flow, Hill says, is something like 1 microcalorie per square centimeter per second. But in some places along the mid-Atlantic rise and the East Pacific rise, American observers have detected heat flows up to six times normal, a finding which suggests that extra heat flows are a characteristic of mid-ocean ridges.

The heat flow is important to theories of the creation of ocean basins and the apparent migration of continents. Theories advanced by the American scientists H. H. Hess and R. S. Deitz propose that these geologic events result from thermal convection in the mantle, and that mid-ocean ridges are cast up by the force of this convection, which also pushes the continents apart.

These convection ideas are part of a very active speculation among geophysicists about continental migration. The subject was hotly debated in London recently in a 2-day meeting (19 and 20 March) concerned with "continental drift," sponsored by the Royal Society.

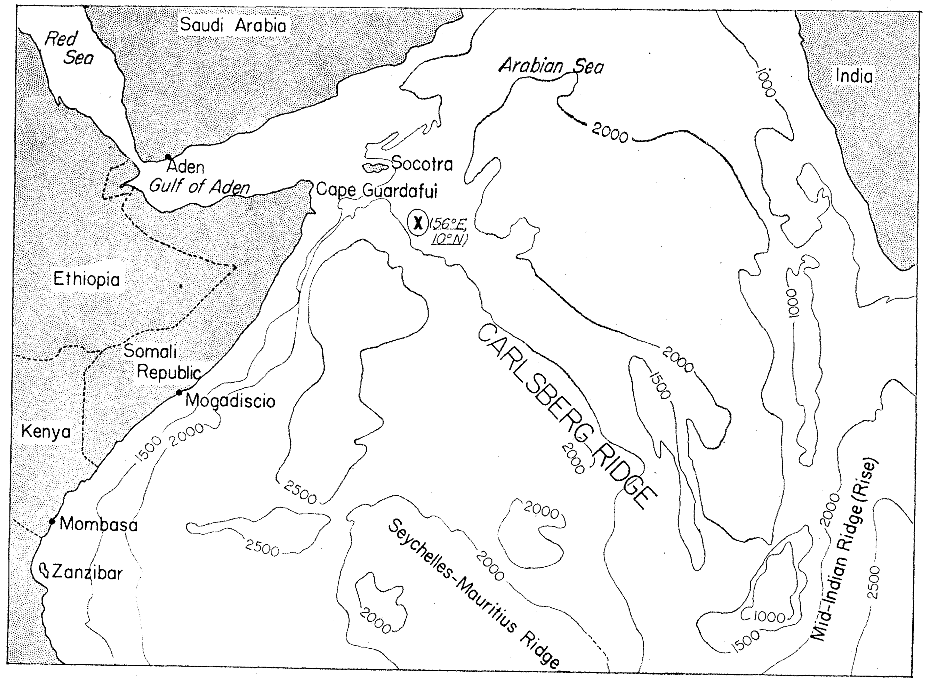
The convection ideas have been supported by observations, such as that of J. Tuzo Wilson, who reports that geologic ages obtained from oceanic islands tend to increase with an island's distance from the mid-ocean ridges.

S. K. Runcorn of the University of Newcastle-on-Tyne has been arguing (2) that the gravity anomalies found in satellite observations can be explained by thermal convection more plausibly than by saying that the mantle is rigid and that its anomalies have been built in since some ancient event, such as a pull-away of the moon.

Sir Edward Bullard, head of the Cambridge geophysics group, has reported that a computer-aided study of available data shows a fit to within 1 degree of the continents around the Atlantic.

Wilson, Runcorn, and Bullard were all participants in the London meeting, as was a chief dissenter, Gordon J. F. MacDonald of the University of California, who asserted that heat flow and gravity observations show that continents extend downward about 500 kilometers and thus place "heavy restrictions on any theory of continental drift."

According to the Hess-Dietz proposal, two convection cells meet at the ridges, rotating in opposite directions, and push up material to form the ridges. Then the cells carry this material away from the ridge center, along the ridge flanks and finally along the sea floor. Moving at a rate of 1 centimeter a year, the material returns to the mantle by sinking below the less dense material of the continents at faults on the margins of ocean basins.




Carlsberg ridge in the Indian Ocean. Depths in fathoms; 1000 fathoms = about 1850 meters. [Adapted from U.S. Navy Hydrographic Office map]

According to this notion, the continents are being pushed apart, not plowing through the relatively thin basalt crust of the sea floor, as Alfred Wegener suggested in the 1920's. The valleys in the ridge crests are held to be the products of tension, not compression.

Intriguingly enough, none of the successful heat-flow measurements from the Carlsberg ridge showed heat flow much above the normal, Hill reports. A student of his, John Slater, made the measurements. Hill hastens to point out that the absence of extra heat flow does not necessarily invalidate the convection-cell idea. High heat flow has not been found everywhere in the mid-Atlantic ridge. The extra heat flow could stem from recent volcanic activity. Scientists aboard the *Discovery* and others aboard a Scripps vessel have found extra heat flow over the rugged submarine topography of the Gulf of Aden.

The Carlsberg ridge was not the only area of interest during the geophysical cruise. Previous surveys have shown the area between the Seychelles islands, which rest on a granitic block and hence are supposed to be a strayed piece of continent, and Kenya, whose continental shelf appears to have been almost totally obscured by a mass of sediment, to be of interest for students of the Indian Ocean's formation.

Working alone, scientists aboard the *Discovery* obtained short seismic refraction lines, using small charges exploded on the sea bottom and a new bottom recorder built by another of Hill's students, John Shorthouse. The recorder has four cables of varying length attached, each with a hydrophone at the end. For a successful recording, the ship must maneuver so that the cables are spread out to almost their full length on the sea bottom. With echoes from a line of charges stretching out to about 3 kilometers, the recorder should give minute data for the first kilometer of material below the sea bottom.

On longer seismic lines the ship was assisted by the *Owen*, which moved away from an accurately positioned buoy, firing depth charges at half-hour intervals. The distance of the *Owen* was known quite accurately, Hill asserts, because the *Owen* paid out cable from a weight on the sea bottom near the positioned buoy.

The structure indicated by the recordings shows a layer of sediment extending out much farther from Kenya toward the Seychelles than had been expected. At one station near the Seychelles, in 5 kilometers of water, a velocity of 7.8 kilometers per second for the sound waves from the explosion was observed, a value rather close to the 8.1 traditionally assigned to the Mohorovičić discontinuity.

The area is of much interest to Laughton, an old pupil of Hill's, who is one of NIO's principal scientific officers. A student of sedimentation in the abyssal-plain area west of Portugal and of the nonmagnetic sea mounts in the area, Laughton also constructed the precision echo sounder used on a 1961–62 cruise of the *Owen* to prepare for the *Discovery* work in 1963.

Studying soundings made by the *Owen* and the Soviet research ship *Vityaz*, Laughton drew attention to a deep trench near the Seychelles islands, which he called the Amirantes trench. The feature has a gravimetric anomaly comparable to that found in the Aleutian trench.

The Amirantes trench is interesting primarily because it shows how the block from which the Seychelles emerge came to be where it is. The granites of the Seychelles date from the pre-Cambrian, according to a report by B. H. Baker (of the Geological Survey of Kenya) and Miller (of Cambridge) (*3*).

#### Biological Studies

The members of the geophysical cruise took over the *Discovery* from a group of scientists led by R. I. Currie, one of NIO's three senior principal scientific officers. Starting last June, before the fall cruise in search of geophysical data, Currie's group made a cruise in search of biological information, surveying the area of upwelling of deeper, nutrient-laden water off the southeastern coast of Arabia. They found that the region of upwelling extended for hundreds of kilometers, hugging the coast from 55°E to 60°E, and that it was conspicuous near the Kuria Muria islands, where the bird population was large and varied.

Currie's group made extensive use of a new "neuston" net, invented by NIO biologist P. M. David and first tested earlier in 1963 aboard a vessel chartered by the British Antarctic Survey. The nylon net has a mesh of 24 per centimeter. Its open end is mounted on a rectangular frame fixed to a pair of large water skis. The net tapers into a cylindrical trap. Towed from a boom at the side of the ship, usually for 15 minutes at 9 or 10 kilometers per hour, the net collects from the top 10 centimeters of the water. Use of the net resulted in very large catches of what appear to be tuna and sardine larvae, as well as catches of the surface-dwelling marine insect *Halobates*.

The upwelling to which these rich catches are linked was first reported in 1922. The apparent cause of the upwelling is the southwest monsoon, which runs from May to September. The monsoon is created when air masses over the ocean come under the influence of a low-pressure area over Asia. Then the wind blows northeastward along the dry coasts of Somalia and South Arabia.

As it drives northeast, the monsoon creates currents in the surface water somewhat to the right, or southeast, of the wind direction; the currents carry water away from the coast. To compensate for the lowering of the sea level, water rises from below. Bearing nutrients, it breaks the normal sharp temperature boundary of the tropical seas, the thermocline, which restricts the upward movement of nutrient salts and makes comparative deserts out of some regions of the sea. Off southern Arabia, the *Discovery* survey showed, water temperature is below 20°C at the coast, while it rises to 27° a few hundred kilometers offshore.

It is a principal task of the International Indian Ocean Expedition to look for such areas of upwelling as potential fisheries. Scientists of several nations have sought upwelling off northwest Australia (where a wide, shallow shelf appears to interfere with upwelling), Java, Ceylon, and both coasts of India.

Late this summer, with Swallow as chief scientist, the *Discovery* will join the *Argo*, a Scripps ship, to study the upwelling off Somalia. This will be another cruise combining biological and physical oceanography. Such joint physical-biological work was one of the announced aims of the National Institute of Oceanography when it was created in 1949 from a World War II group of Admiralty physicists at Teddington (Deacon among them) and a group of biologists from the old "Discovery Investigations" of biological productivity in the southern-ocean whale region, made during the late 1920's and 1930's.

The current *Discovery* is the third Royal Research ship to bear the name. The first *Discovery*, a veteran of Robert F. Scott's expeditions to Antarctica, is tied to the embankment in London as a museum. It was replaced in 1929 by *Discovery II*, a vessel built especially for oceanography. Besides making numerous summer cruises, this ship circumnavigated Antarctica twice during winter months, in 1931 and 1951. It carried fuel, stores, and a doctor to Rear Admiral Richard E. Byrd at Little America in 1934, and it picked up Lincoln Ellsworth and his pilot, Hollick-Kenyon, in the Bay of Whales in 1936. During World War II, *Discovery II* was an armed boarding vessel and a lighthouse tender. The ship was scrapped in early 1963.

#### The Institute

Since 1953, the NIO has done its shore work in a building the Admiralty put up at Wormley during World War II on the grounds of a coeducational boarding school, the King Edward School. The site is away from the sea but close to London agencies and libraries.

Next to the NIO building is a long, black metal quonset hut for stores. The hut will be pulled down shortly, to be replaced by a second building about the size of the first, which is expected to be ready in 2 or 3 years. There will be little surplus space in the new building, for plans have already been made for utilizing all its rooms.

The NIO receives about half its budget from the Admiralty and half from a money-granting agency known as the Development Commission. The budget in the year ending 1 March 1964 is $1 million, up from $560,000 only 2 years ago.

In the flurry of reports about the organization of scientific research in Britain there has been debate about the institute's future. A committee on natural resources policy proposed in 1961 that a new Natural Resources Research Council should take over "administrative responsibility" (supervision) of NIO from the Navy as well as the Development Commission's share of the NIO budget. The 1961 committee was headed by Sir William Slater, a former head of the Agricultural Research Council.

But in 1963 there was a new report, this time about Britain's overall scientific organization. The group that issued it, headed by Sir Burke Trend, said, "There are administrative and practical advantages in leaving with the Admiralty administrative and financial responsibility for the National Institute."

Institute members and oceanographers elsewhere appear to prefer the idea of NIO's being directed by an earth sciences or marine sciences division of a new Science Research Council proposed by the Trend group. This

Science Research Council would take over much of the science-support work of the Department of Scientific and Industrial Research, which would be abolished. To some NIO researchers, putting the institution under the Natural Resources council—to be dominated by officials of an agency called the Nature Conservancy—would be like putting Woods Hole under the Bureau of Commercial Fisheries.

### Earlier Work

Although the institute is now committed to Indian Ocean work through this year, its traditional field has been the Atlantic. *Discovery II* took part in joint transatlantic surveys with a Woods Hole vessel during the IGY. Other cruises have studied the area around the Straits of Gibraltar and the abyssal plains to the west. All NIO cruises have been planned to bring the ships home to Plymouth by different tracks, for soundings off the European continental shelf.

A leader in this work has been Swallow, now in the Indian Ocean with the *Discovery*. Swallow's float, which keeps to a roughly constant depth, has been used in many parts of the world to measure deep-water circulation and the equatorial countercurrents that have now been observed in the Pacific, Atlantic, and Indian oceans. The submerged float sends out a sharp sound, received by a ship following the device. During the IGY the float was used to test the prediction by Henry Stommel that there would be a gentle southward "boundary current" on the western side of the Atlantic. A current of 11 kilometers per day was found, at a depth of 3000 meters.

The next step was to test an additional prediction of Stommel's, that well away from the western boundary current in the North Atlantic there should be a weak flow toward the North Pole. Swallow led a joint U.S.-British expedition to the area around Bermuda in 1959–60. The results were very different from the predictions: strong flows instead of weak, going in many directions instead of one, changing rapidly. Following a total of 80 of the fixed-depth floats, Swallow's group found that current speeds averaged 6 centimeters a second 2000 meters below the surface and 12 centimeters at 4000 meters (*4*).

A few of NIO's investigators are not involved in Indian Ocean studies. One of these is M. S. Longuet-Higgins, who was made a fellow of the Royal Society last year. Longuet-Higgins has worked on the statistics of distribution of such wave parameters as heights, slopes, and crest-to-crest distances. He is now attempting to apply some of the mathematical models developed for atmospheric science to the general circulation of the oceans. To help him in his thinking he has had a device built which consists of two concentric plastic globes. The 1.8-centimeter space between is filled with water, and holes at various points make it possible to squirt in colored ink.

Others at NIO not involved in Indian Ocean work are S. Ishiguro, who continues to refine his electronic analog model of the North Sea, and M. A. Johnson, who is studying the fluid mechanics of the turbidity currents which carry sediments across the sea floor, often at great speed.

### Oceanographic Equipment

Besides other grants, NIO has earned $60,000 to $90,000 in recent years by building oceanographic equipment of types which, because of special design or small demand, cannot be manufactured commercially.

Under such men as M. J. Tucker, a principal scientific officer, and N. D. Smith, a senior experimental officer, NIO has developed a series of wave recorders. One of these built at the request of D. E. Cartwright, who is working with geophysicist Walter Munk at Scripps this year, measured wave curvature. This was done with the help of fiberglass floats mounted on universal joints, which were fixed to a triangular frame of tubing. In the center of the frame were a "very sophisticated potentiometer," as Smith calls it, a gyroscope to measure pitch, roll, and vertical acceleration, and a capacitance compass to measure the directions of the waves. Information from this device travels back to the ship through a 90-meter cable.

Besides Swallow floats, NIO also makes its own water-sample bottles out of polypropylene.

According to Tucker, attempts to use a horizontal narrow-beam "Asdic" echo-sounder for detecting schools of fish have not been very successful, but the Asdic has proved to be an excellent geophysical tool. A. H. B. Stride has used it for studies showing that ridges off the continental shelf west of the English Channel are probably made of sand rather than leftovers of bedded rock.

Stride has also used a "thumper" or "boomer" device, first employed for detailed geological investigation of the sea bottom by H. E. Edgerton of Massachusetts Institute of Technology and now made in Boston. In the "boomer," a current discharge into a large copper coil produces very-low-frequency sound waves by slapping a piece of metal into the water. R. Bowers of NIO has improved the methods of using the device, Deacon reports, "so that reflecting layers separated by as little as six feet can now be resolved."

In about a year, Tucker reports, the institute hopes to have a "poor man's thermistor chain" for studies of internal waves in areas near Europe where relationships between temperature and chemical composition are well known. The NIO chain, with 10 to 12 measuring heads set into a cable at intervals, will not have the sophisticated data-display mechanism of chains on American vessels like the research vessel *Chain* of Woods Hole and the U.S.S. *Marysville* of the Naval Electronics Laboratory, and its cost should be about a tenth that of the American chains. A prototype of the NIO chain has been tested at sea.

Like many other oceanographic laboratories, NIO has developed a meter for making determinations of the combined composition of salts in sea-water samples by measuring electrical conductivity. This and other work relating physical to chemical parameters of sea water is done by Roland A. Cox and F. Culkin.

While engaged in its present activities, NIO is also looking toward the future, with a new building for shore work and its new ship freed from Indian Ocean studies after this fall. When he discusses the future, NIO's director thinks of a stronger link between biological and physical studies.

As Deacon put it the other day: "In Britain, not much attention is paid to what would be called 'ocean biology' " as opposed to studies of shallow-water coastal areas. "Physical studies have much to offer to ocean biology. It is clear that there are real territories in the sea, more or less closed physical circulation systems that are biological regions, too."

—VICTOR K. MCELHENY

### References and Notes

1. *Nature* **198**, 950 (1963).
2. S. K. Runcorn, *ibid.* **200**, 628 (1963).
3. B. H. Baker and J. A. Miller, *ibid.* **199**, 346 (1963).
4. The work is summarized by Swallow's wife, Mary, also of the institute, in the June 1962 issue of *Discovery*.