ROGER REVELLE, OCEANOGRAPHER 1909–1991

By D. James Baker and Walter H. Munk

ROGER RANDALL DOUGAN REVELLE died on July 15th of this year, still active and very much involved in the great global change issues of our day. He will be remembered with fondness and respect by all of us in earth sciences for his deep interest in fundamental science and for his strong desire to apply scientific knowledge toward human good. He was a major figure in fostering international cooperation in ocean science, having founded the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC).

One of his last lectures was a keynote talk to the Second Scientific Meeting of the Oceanography Society on the fundamental importance of technology to the advancement of science. Typically, Roger had brought along several tangible examples of those things that had advanced ocean science, including several strands of wire rope and a diver's regulator valve. He wanted those present to understand how science advanced, and he was successful in making his point.

Roger was born in Seattle on March 7, 1909, and had his early education at Pomona College in California. He earned his PhD at Scripps Institution of Oceanography (SIO), his thesis on "*Marine Bottom Samples Collected in the Pacific Ocean by the Carnegie on Its Seventh Cruise,*" and stayed on as an instructor and assistant professor. After a tour in the Navy, where he was in charge of the Oceanographic Section and then head of the Geophysics Branch of the newly founded Office of Naval Research, he came back to SIO, first as Acting Director and then as Director.

During the decade 1948–1958, Roger transformed SIO into a global seagoing enterprise, helped set the stage for the understanding of plate tectonics and global warming, and played a leading role in raising US support for oceanography by an order of magnitude. During this period, the California Cooperative Oceanic Fishery Investigation planned by Harald Sverdrup was getting underway. This work is still continuing and constitutes an unequaled record of the physical environment and its biological consequences in a large ocean area.

It has long been suggested, beginning with Svante Arrhenius in 1889, that the activity of mankind must be leading to an increase in CO_2. Since the oceans contain ~60 times as much CO_2 as the atmosphere, there was a general belief that CO_2 from fossil fuels would be partitioned in this ratio. Computations by Revelle and Suess in 1956 showed that about half the fossil CO_2 would remain in the air. This led to the measurements (started by Keeling in 1957) showing the increase, one of the few basic facts about global warming. Again in 1957, Roger was among a group that promoted an attempt to drill through the ocean floor to the mantle. This MOHOLE project was ill-fated, but led to the successful Deep-Sea Drilling Project and today's Ocean Drilling Program.

With a clarion call that "the Pacific is our oyster!" Roger led a timid faculty into the blue water of the deep Pacific. The era opened in 1950 with the Mid-Pacific expedition (MIDPAC) into the equatorial waters and to the Marshall Islands in the Central Pacific. This was followed in 1952–1953 by an extended voyage to the South Pacific, which was called the Capricorn expedition. Both expeditions were personally led by Roger. In his words, "they resulted in a set of remarkable discoveries about the ocean floor and what lies beneath it, and were the first of a long series of expeditions, extending farther and farther from San Diego until Scripps' ships literally operated in all oceans throughout the world."

Among the discoveries of MIDPAC and Capricorn were the demonstrations by Russell Raitt that only a thin layer of sediments overlies the solid rock and by Edwin Hamilton that the flat-topped seamounts at a depth of 2,000 meters had been volcanic islands < 100 million years ago. This spoke for great mobility of the "solid" Earth. On MIDPAC Arthur Maxwell found the heat flow through the sea floor to be "normal," suggesting to him, Roger, and Sir Edward Bullard that slow convective movements were occurring in the Earth's mantle. When Roger and his associates tried to core and dredge the Tonga Trench, the instruments came up battered, bent, and empty. If any sediments were present, they were sparse and thin. The observations could best be explained if the rocky sea floor were disappearing into the Earth along the axis of the trench (this is now called subduction). On Capricorn, Ronald Mason towed a magnetometer behind the vessel and recorded a complicated set of wiggles that no one could understand. Later Mason produced a map of the magnetic field under the sea floor, showing stripes of normal and reverse magnetization. On hindsight, the evidence was all there for proclaiming the doctrine of plate tectonics, but it was to be left to others a decade later to fit together the pieces of the puzzle.

In Roger's words, "In those heady days of the 1950s, one could hardly go to sea without making an important, unanticipated discovery. Our small ships didn't cost very much to operate and many SIO expeditions were led by grad-

D.J. Baker, Joint Oceanographic Institutions Inc., 1755 Massachusetts Ave NW, Washington, DC 20036 USA. W.H. Munk, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093 USA.

uate students. John Knauss obtained his PhD on the basis of expeditions to study the equatorial undercurrent in the Pacific."

But by then Roger was deeply involved in the formation of what is now the University of California at San Diego. Henry Charnock quotes Roger that an oceanographic institution not linked to a university would survive only one generation. Therefore his continuing activity as SIO director and his efforts on behalf of the new campus were not in conflict. But many conflicts arose during the creation of the new university; and, when it came time to appoint the first chancellor, Roger was passed over. He moved first to become science advisor to Secretary of the Interior Morris Udall in the Kennedy Administration, then the Richard Saltonstall Professor of Population Study at Harvard University. In 1975 he returned to SIO; among his many activities was the first chairmanship of the SCOR/IOC Committee on Climatic Changes and the Ocean, the group that fostered the development of many large coordinated climate studies in place today.

Throughout his career, when questioned about his profession, Roger would reply, "I am an oceanographer." But this was hardly restrictive; on more than one occasion he was heard to define the profession of oceanography as "whatever anyone at Scripps does." He published over 200 papers and earned most of the awards and medals relevant to his work. Perhaps Henry Charnock said it best: "For an informed view on Earth science, and on its repercussion on the human predicament, he was in a class of his own." We will miss him. ❑

TOMOGRAPHY IN OCEAN MODELS

By Michael S. Foster

THE INSTITUTE FOR NAVAL OCEANOGRAPHY (INO) has conducted a workshop to discuss the applications of tomographic data in ocean models. The workshop was sponsored by the Office of Naval Research (Applied Oceanography and Acoustics Division) and was held at the University of Southern Mississippi Conference Center in Long Beach, Mississippi, from October 10–12, 1990. More than 30 experts, mostly oceanographers, from several disciplines participated in the three-day meeting. Significantly, the workshop allowed valuable interaction between ocean modelers and acoustic tomographers.

The principal objective was development of a "roadmap" for the advancement of acoustic tomography from its current experimental state to a capability for assimilation into ocean models and, ultimately, into future ocean monitoring and prediction systems. In addition, the workshop evaluated present capabilities, highlighted new approaches and techniques, and provided a forum for discussing the problems associated with four-dimensional ocean model data assimilation in general. A Steering Committee (B. Cornuelle, S. Foster, B. Howe, J. Mitchell, R. Passi, P. Rizzoli, D. Thompson, and R. Willems) was established to coordinate recommendations and develop approaches for marshaling scientific talent to achieve an ocean monitoring system, including assimilated tomographic data.

Several recommendations were developed by consensus among the attendees. In the near term, tomographic data from the Applied Tomography Experiment (ATE) 90–92, the Synoptic Ocean Prediction (SYNOP) program, and other data-collection efforts should be incorporated into verification schemes for ocean prediction systems. As a five-year goal, tomographic data–assimilation schemes should be merged with existing schemes. In ten years, a network of transceivers should be deployed in the North Atlantic Ocean and Arctic region.

The "roadmap" developed by the workshop is based on the Data Assimilation Research and Transition (DART) program (Naval Oceanographic and Atmospheric Research Laboratory) and the Optimal Thermal Interpolation System (OTIS) (Fleet Numerical Oceanography Center). It consists of modules as follows: 1) data assimilation (including tomographic data), 2) ocean model, 3) data verification, 4) model verification, 5) system verification, 6) simulation studies, and 7) the future ocean monitoring/prediction system. Closed loops between the various modules allow the feedback and interaction necessary to evaluate modifications within the system. The INO, through its Experimental Center for Mesoscale Ocean Prediction (ECMOP), expects to make a major contribution within the scope of each module by offering facilities for testing and evaluating existing and future ocean models.

A report on the workshop has been published and is available by contacting the Institute for Naval Oceanography, Stennis Space Center, MS 39529-5005, (601) 688-3525. ❑

M.S. Foster, Institute for Naval Oceanography, Stennis Space Center, MS 39529 USA.