Roger Revelle: President-Elect, 1973

Roger Revelle, the President-Elect of the American Association for the Advancement of Science, takes on large problems such as the basin of the Pacific Ocean or the human enterprise on the Indian subcontinent. His field of study has been the planet and its dominant species. In three decades, his scientific explorations have covered a remarkable range of activities and have opened up large tracts of scientific terrain for experimenters and theoreticians. To describe concisely the scope of Revelle's interests is difficult, but it will be helpful to quote from Walter Munk's citation of him in 1968, when Revelle was awarded the William Bowie Medal of the American Geophysical Union: "Revelle belongs to a nearly extinct breed of scientists called naturalists. He has pursued the study of the planet Earth with romantic attachment and dogged determination. On problems concerning a balanced judgment of its geology, chemistry, biology, and physics, he is probably without peer."

Revelle was born in Seattle, Washington, on 7 March 1909. In 1929, he received his baccalaureate degree from Pomona College, where he studied under geologist Alfred Woodford, and in 1936 he received his Ph.D. from the University of California. He joined the Scripps Institution of Oceanography as a research assistant in 1931 and in 1948 was appointed professor of oceanography.

Revelle's talents for scientific analysis and leadership matured between 1940 and 1950. This was an exciting decade for oceanographers. Every expedition to sea resulted in unexpected and often important discoveries. In 1946 and 1947, while still on active duty in the Navy, Revelle planned and led the oceanographic and geophysical phases of Operation Crossroads, designed to study the environmental effects of the atom bomb test at Bikini Atoll. The diffusion of radioactive wastes was measured and the environmental impact assessed. The pioneering work of his scientific team confirmed Darwin's theory of coral atolls, which had been the subject of controversy for nearly a century. In the 1947 resurvey of Bikini, the atoll was drilled to a depth of 800 meters. The sediments at the bottom were about 30 million years old, and all of the samples above the bottom were reef limestone that had been laid down in shallow water. This proved Darwin's conjecture correct—that atolls are sunken volcanic islands on which enormous layers of skeletons of reef-building organisms accumulated during the sinking process.

In 1950 Revelle became director of the Scripps Institution. In the next few years, he led a number of expeditions into the deep Pacific that contributed to knowledge of oceanic processes and the geology of the sea floor. This knowledge opened new paths to fundamental understanding of the geological history of the ocean basins. Among his achievements at this time was the development, with Sir Edward Bullard and Arthur Maxwell, of methods to measure heat flow from the earth's interior through the deep-sea floor. Conventional belief had it that heat flow from the sea floor must be much lower than that from continents, since the chief source of heat was radioactivity in the crust and the continental crust was much thicker than the ocean crust. It came as a surprise that the heat flow from under oceans was about the same as that from continents. Revelle and his co-workers concluded that heat sources under oceans must extend down into the mantle and, therefore, that some mechanism more efficient than thermal conduction must operate. They suggested that heat must be transported upward by slow, convective churning of the mantle. The hypothesis was tested experimentally, and the measurements provided important evidence for convection. This work posed some of the fundamental problems that are being resolved today by the theories of sea floor spreading and plate tectonics. In 1963, the National Academy of Sciences gave Revelle its Agassiz Medal for "outstanding achievement in oceanography."

Throughout this period, Revelle became increasingly involved in university and national affairs. As a partner of Waterman, Piore, Conrad, and Rees, he helped to establish the Office of Naval Research and thereby to initiate a new concept for the support of basic research. He was a leading advocate of the International Geophysical Year. And he started the San Diego campus of the University of California.

In the mid-1950's, Revelle became convinced that an isolated oceanographic institution was likely to be shunted away from the mainstream of modern science and, more important, that graduate students in oceanography were handicapped by lack of stimulation from faculty members in other disciplines—physics, chemistry, biology, and engineering. Therefore, he proposed establishing a school of science and engineering, on land near the Scripps Institution, to be supported by public funds. Civic leaders of San Diego vigorously endorsed the idea, and it was accepted by the Regents of the University of California. The city and the federal government contributed land.

The population of California was growing rapidly, and many people concluded that what was needed were three new "general campuses" of the University of California that would provide undergraduate, graduate, and professional training to large numbers of students in many fields. The Regents decided that one of these should be in the San Diego area. Revelle again took the initiative, cajoling, arguing, explaining, and finally gaining approval for an entirely new kind of universtiy. He and his colleagues at Scripps had given much thought to criteria for improving the design of universities; their plan, backed by President Clark Kerr, became the framework for development of the University of California, San Diego.

The fundamental idea was to improve communication. Most American university faculties are too large to be able to reach positive conclusions or to agree on experimental innovation in education. Large, amorphous faculties can only react to outside pressures

and have tended to be a negative and largely ineffective force in university governance. Communication among and between faculty and students is far less than optimal. An obvious solution was to create smaller units such as the "Oxbridge Colleges." But these are primarily teaching units, and Revelle and his colleagues believed that university research was an essential element of teaching. They proposed an alternative scheme. This was the creation of "little universities" side by side. Each would contain a sufficient number and breadth of departments to provide liberal education, yet each would have its own distinctive style. There would be as little separation as possible between undergraduates and graduates; the former could participate in research, and the latter would have a continuing opportunity to immerse themselves in a range of intellectual activities.

Revelle's concept was that a university in the modern world should be the equivalent of a cathedral in medieval times, a center of the highest aspirations of human beings and of their noblest actions. The idea was a sharp contrast to the concept of a "multiversity" as a marketplace for the knowledge demanded by the larger society for its current, short-run needs. And the idea was equally far from the concept of an ivory tower of learning in which scholars could shut out the real world. The medieval cathedral was the center of the city and open to all. Similarly, the university should be intimately concerned with the lives of all the people. The cathedral had many chapels, each unique in design. Similarly, the university must embrace complexity and diversity. The cathedral was neither closed nor completed, but built and changed over the centuries; this organic quality should also characterize the university. Revelle's aim was to make San Diego one of the great universities of the world, and to that end it should be built from the top down. He was able to persuade several distinguished scientists to join the enterprise: Keith Bruckner in physics, Harold Urey and James Arnold in chemistry; and David Bonner in biology. In turn, they helped recruit many others. Today the new university includes 28 members or foreign associates of the National Academy of Sciences.

When the first college at San Diego was named in his honor, Revelle said,

Roger Revelle

". . . what would be more appropriate would be a plaque containing about fifteen names. . . . U.C.S.D. was begun by a firm, not by any individual. But I will admit I spent a lot of time on it."

As director of the Scripps Institution, Revelle was in a good position to advance international cooperation. He began by organizing a single-season reconnaissance of the North Pacific Ocean in cooperation with oceanographers from Canada, Japan, and France; 20 research ships participated in the NORPAC expedition. Revelle initiated and led the organizing phase of the International Indian Ocean Expedition, which involved scientists and ships of many nations. He was the United States member of the International Committee on Marine Sciences, which was formed in 1955 by the United Nations Educational, Scientific, and Cultural Organization (Unesco). Later he became president of the Scientific Committee on Oceanic Research organized by the International Council of Scientific Unions. The first International Oceanographic Congress was held at the United Nations in New York in 1959. Revelle was president of this congress, which was sponsored by the AAAS in cooperation with Unesco.

The necessity of ship operations makes oceanography an expensive science. It can be supported on the required scale only by governments. Consequently, cooperation among governments was necessary to enable oceanographers to continue their task of exploring the world's oceans. In 1961, Revelle was one of the founders of the Intergovernmental Oceanographic Commission, organized in Unesco and later sponsored jointly by several U.N. specialized agencies. From 1964 to 1967, he was president of the International Association of Physical Sciences of the Ocean.

Since 1968, Revelle has been a member of the American delegation to the biennial general assemblies of the International Council of Scientific Unions and to the Pugwash conferences on science and world affairs. He was a member of the U.S. delegation to the general conferences of Unesco in 1960 and 1962, and was vice-chairman of the U.S. National Commission for Unesco from 1961 to 1964.

A high point of Revelle's work in international science was his appointment as the first chairman of the U.S. National Committee for the International Biological Program. This program coincided with a rapid growth of public interest in ecology and environmental deterioration, and the U.S. committee was able to organize a series of comprehensive studies of major ecosystems (biomes) and of the interactions between human populations and their environments. Hundreds of American biologists cooperated in the ecosystem studies, which were later used as a model by other countries in the international scientific work of the International Biological Program.

Revelle became science adviser to the Secretary of the Interior in 1961 and turned to an entirely new set of problems relating to world population growth and economic transformation. In his newly created post, one of his principal tasks was a study of the problems of salt accumulation and the resulting soil deterioration in the Punjab and Sind regions of West Pakistan. Here the Indus River and its five tributaries of the Punjab flow through a vast, flat plain covered by a network of great irrigation canals, which forms the largest single irrigated area on earth and provides a livelihood for 25 million human beings. For many years this region had been the breadbasket of the subcontinent. In 1961, however, the people of the plain were in serious difficulty. Their farms were not yielding enough food to feed even the rural population. One obvious problem was the high water table and the increasing saltiness of the soil. The canals built by the British were cut through the relatively impermeable layer of the topsoil

into the pervious fine sands of the subsoil that extends thousands of feet to the bottom of the old rift valley. The canals had been leaking for many years. As a result, the water table had risen in much of the Punjab plain to within a few feet of the surface. In many places, new lakes and swamps had appeared. Water evaporating from the high water table left its damaging salts in the root zones of the plants. The situation had become so serious over large areas that farms and even villages had been abandoned. At the direction of President John F. Kennedy and his science adviser, Jerome Wiesner, Revelle organized and led a panel of experts from several disciplines to investigate the problem. Their conclusion was that waterlogging and salinity were symptoms of a more serious disease: poor agricultural practices.

What was needed in the farmlands was more water, not less. The panel proposed that a network of large tube wells be drilled. The water pumped out of the wells would be used for irrigation, at the same time lowering the water table, and the percolation back into the ground would wash the salt below the root zones. Saline soil water would then be removed by a system of drains. It was necessary to introduce fertilizers, new varieties of cereals, pest controls, and better farm management if the potential of the land was to be realized. Revelle and his colleagues estimated that, if these things were done, agricultural production could be increased fourfold within a generation. Following the report of the panel, the government of Pakistan took vigorous action, drilling wells and supporting the farmers in drilling their own wells. In consequence, agricultural production during the last few years has increased about 5 percent per year, with a doubling time of about 14 years.

In appreciation of this work, the President of Pakistan in 1964 decorated Revelle with the order of Sitara-i-Imtiaz for "conspicuously distinguished work in science."

Revelle's concern with the population problem led him to accept the Richard Saltonstall Chair of Population Policy and the directorship of the Harvard Center for Population Studies. For the last 10 years, his primary interest in international scientific cooperation has been in the use of science and technology to assist the less developed countries. Until recently, he was chairman of the board on science and technology for international development of the Office of the Foreign Secretary of the National Academy of Sciences. For several years he has been deputy foreign secretary of the academy, with primary responsibilities in problems of science and technology for the less developed countries. He was a member of the panel on the world food supply of the President's Science Advisory Committee and a member of the research advisory committee of the Agency for International Development. He was recently appointed to the committee on science and technology in development of the International Council of Scientific Unions. He has served as chairman or member of advisory teams of the National Academy of Sciences in the Philippines, Ghana, India, and Korea. From 1964 to 1966, he was a member of the Education Commission of the Government of India.

Revelle's most important work for developing countries has been his participation in studies of the interactions among rapidly growing populations, their resources, and their environment. He was chairman of the study committee of the National Academy of Sciences which in 1971 published *Rapid Population Growth, Some Consequences and Policy Implications.* For the past 5 years, he and his colleagues at the Harvard Center for Population Studies have carried out a major study of land, water, and power resources as related to population growth and potential economic development in Bangladesh.

At the Pugwash Conference on Science and World Affairs in Venice in 1965, Revelle proposed the establishment of an international foundation for science, which would have as its primary purpose the support of research by individuals and by groups of scientists and their graduate students in the universities of the less developed countries, using funds contributed mainly by governments and private organizations in the developed countries. Such a foundation was suggested independently by other scientists, including Robert Marshak and Glenn Seaborg, and it has now been established as a consortium of some 20 national academies of both developed and developing countries.

Roger Revelle's career is one of valiant and selfless service to science and to his fellow human beings. His vision of human potentialities has instilled admiration with a tincture of reverence among many colleagues. In closing, it is pertinent to summarize Revelle's views of the AAAS.

Revelle believes the AAAS should work in three directions: to maintain and improve the health of science in the United States; to foster a spirit of rationality and free and objective inquiry in American life; and to broaden and deepen public understanding of scientific problems and discoveries. To this end, he believes that the scientific community must develop ways to increase the participation of women, blacks, and other minority groups. Revelle has said, "In our times science, technology, and politics are inextricably related. But the AAAS should not act as a lobbyist for any particular position. Instead, it should try to ensure that political issues that have a scientific component are squarely faced and rationally examined in light of all knowledge. Scientists can and should immerse themselves in politics, but they should not claim any peculiar political virtue because they are scientists."

Revelle has long been a proponent of international scientific cooperation. "Science in the United States," he says, "is a vital part of world science, and it is our duty to maintain its viability and to strengthen its international links."

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