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Cover photo: R/V *Thomas Washington,* between ropes, with R/V *Melville* at Nimitz Marine Facility pier, steams across San Diego Bay to fuel dock at the beginning of Indopac Expedition (Indo-Pacific) in the spring of 1976. Photo by Jackie Janke.

Layout and design/Eric Baker.

George L. Hammond (left) and Jack W. McDonald cast off R/V Thomas Washington's *ropes as she leaves Nimitz Marine Facility pier in the spring of 1976 to explore the marginal ocean basins of the western Pacific and Southeast Asia during Indopac Expedition.*

Jackie Janke

made acoustic scattering and high-frequency reverberations studies. ORB spent 51 days off shore and was towed 850 nautical miles.

Anniversary Reunion

The twenty-fifth and twenty-third anniversaries of Scripps's first two major Pacific Expeditions, Mid-Pac and Capricorn, respectively, were celebrated in San Diego on August 17, 1975, with a reunion dinner of expedition participants.

Among the photographs and other memorabilia shared by the former shipmates were relics from America's first thermonuclear tests in the South Pacific, which many of the scientists had observed during Capricorn at the request of the federal government.

Both expeditions required the teamwork of two ships for ocean-floor studies. On Operation Mid-Pac, in 1950, 85 crew members and 30 scientists served on board Scripps's R/V *Horizon,* a 143-ft. converted Navy tug, and the Naval Electronics Laboratory's 220-ft. USS EPCE (R)-857, later named the USS *Marysville,* for a joint UC-U.S. Navy effort.

For Capricorn, in 1952-53, *Horizon* teamed up with Scripps's *Spencer F. Baird,* another 143-ft. converted tug, which was equipped with a new winch and 12,192 m of tapered wire for its primary mission: to explore the Tonga Trench. This deep-sea feature, a chasm in places deeper than seven superposed Grand Canyons, extends for more than 16,600 km in a line between New Zealand and Samoa.

Mid-Pac and Capricorn yielded many discoveries, including the first evidence supporting what now is generally accepted as sea-floor spreading and the more general hypothesis of plate tectonics; the location of an enormous

Operation Mid-Pac participants attending anniversary dinner were (left to right), Dr. Russell W. Raitt, Edward S. Barr, Daniel K. Gibson, Dr. Edwin L. Hamilton, James M. Snodgrass, Dr. H. William Menard, Dr. Roger R. Revelle, Capt. James L. Faughn, Robert P. Huffer, and Jeffery D. Frautschy.

From Capricorn Expedition came these reunion participants (left to right), Edward S. Barr, Dr. Robert L. Fisher, Dr. H. William Menard, Dr. William R. Riedel, Dr. Gustaf Arrhenius, Dr. Walter H. Munk, Daniel K. Gibson, Dr. Edwin L. Hamilton, Dr. Roger R. Revelle, the late Helen Raitt, Dr. Norman J. Holter, Dr. Ronald G. Mason, Dr. Robert B. Livingston, Samuel Scripps, Dr. Theodore R. Folsom, Warren W. Beckwith, and Dr. Russell W. Raitt. Kneeling is Alan Jones.

underwater mountain range in the central Pacific, extensive manganese dioxide deposits near Bikini Atoll, ancient deep-sea bacteria that were later revived, a 1,600-km-long submarine cliff perpendicular to the northern California coast, and explorations of what may be the tallest mountain in the world, Capricorn Guyot, and the deepest point in the Southern Hemisphere, Horizon Deep, which are both in the Tonga Trench area.

Ships Gather Data

Mid-Pac was described as the first large-scale American scientific exploration of the deep Pacific in more than two decades. The two ships traveled a total of 27,000 nautical miles during a three-months expedition that yielded data disproving some long-held ideas about the Pacific and verifying others, according to Dr. Roger R. Revelle, who became

Reminiscing as they read a yellowed newspaper clipping, one of the many memorabilia displayed at joint expedition anniversary dinner of participants in Operation Mid-Pac and Capricorn Expedition, are (from left), Dr. H. William Menard, professor of geophysics; the late Helen Raitt; Dr. Roger R. Revelle, director of Scripps, 1951-64, who led both expeditions; and Dr. Walter H. Munk, professor of geophysics. Mid-Pac took place in 1951; Capricorn in 1952-53. Helen Raitt, who passed away in March 1976, was the only woman aboard Capricorn.

director of Scripps in 1951 and who led both expeditions.

Dr. Revelle is now director emeritus of both Scripps and the Center for Population Studies, Harvard University, Cambridge, Massachusetts. He is a professor recalled to active duty at UC San Diego and continues to teach at Harvard, spending one semester a year at each institution.

The departures of *Horizon* and *Spencer F. Baird* from San Diego for Capricorn were without fanfare, since the trip included participation in the military's Operation Ivy, the first thermonuclear tests at Eniwetok Atoll, in the South Pacific in 1952.

Scripps staff designed and built special equipment for making observations during the tests. They later received a formal commendation from Admiral C. M. Bolster, then Chief of Naval Research, for the performance of "difficult and dangerous tasks . . . adding important data to our growing knowledge of weapons effects."

Several of the 45 scientists and many of the 42 crew members who participated in Capricorn had also served on Mid-Pac. *Spencer F. Baird's* 17,400 nautical mile cruise took about four months and *Horizon's* 22,300 nautical mile trip lasted nearly five months.

Dr. Revelle, who had been in charge of the Navy's oceanographic research during World War II, said that before these "voyages of discovery," scientists were more familiar with the North Pole and the jungles of South America than they were with the ocean, which covers more than two-thirds of the earth's surface.

A key factor in this ignorance was inadequate equipment. In 1956 Dr. Revelle said, ". . . until the last few years, the methods for penetrating beneath the sea surface were inadequate to give more than a vague, and in many respects, a quite erroneous, picture."

New Equipment Developed

But, during World War II, the U.S. Government's interest in oceanography and exploration of the Pacific had, of necessity, increased. New equipment for subsurface research that had been developed for submarine warfare would now enable man to study the vast frontier of the Pacific Ocean, about which comparatively little was known.

Armed with then recently developed electronic equipment and the latest scientific gadgets available, members of these expeditions, like their colleagues on the other coasts, launched their assault on the unknown.

Dr. Revelle's comment at the end of Mid-Pac was: "We've got a lot of interesting information on the Pacific Ocean that may turn out to be the richest oceanographic haul ever taken — data that may give us the answers to the origin of the earth itself.

"At any rate, we do know this: the Pacific is a vast, watery frontier and . . . we've only scratched the Pacific's bottom!"

Since Mid-Pac and Capricorn expeditions, Scripps ships, which now number six, have steamed approximately four million nautical miles in oceanographic research. The institution's data files now contain detailed information about much of the ocean's topography, chemistry, and animal life, and thousands of publications have been written.

Expedition Described

On July 27, 1950, *Horizon* and the Navy's USS EPCE (R)-857 departed San Diego. The joint University of California/U.S. Navy expedition was sponsored by UC's Institute of Geophysics, the Office of Naval Research, and the U.S. Navy's Bureau of Ships, and carried out by Scripps and the U.S. Naval Electronics Laboratory at San Diego.

Meteorologists, geologists, chemists, and biologists from Scripps, UC Los Angeles, University of Southern California, Stanford University, the U.S. Geological Survey, and the U.S. Navy served on Mid-Pac. Most of them were from Scripps or were former Scripps graduate students and professors, or underwater experts who had worked on Navy submarine problems during World War II. Some of these persons are currently on Scripps's staff.

Scientists had previously believed that the floor of the Pacific had remained relatively stable for hundreds of millions of years. But the mass of evidence brought back by Mid-Pac scientists showed that it had been evolving for millions of years and there had been changes of up to thousands of meters in depth.

Among the expedition's other findings were:

— a 1,600-km-long underwater mountain range in the central Pacific that is 160 km wide, up to 4.2 km in height, and 1.6 km beneath the sea surface. The submerged mountain range, named "Mid-Pacifc Mountains," stretches all the way from Wake Island to Necker Island near the Hawaiian group. The Pacific Ocean floor was previously thought to be shaped like a large, muddy bowl with little geologic activity. Instead, the vast floor was found to be as rugged as the U.S. continent, with mountains, valleys, plains, buttes, peaks, canyons, and cliffs. Most of the seamounts were flat on top, as if they had been eroded by wave action in shallow water and then sunk below the surface. Extinct reef-building corals and sea-urchin fossils were dredged from atop a seamount that had sunk to the 1,800-m level.

  Scientists believe flat-topped seamounts (termed guyots) in this area sank during Middle Cretaceous to below the zone of coral-reef growth and then finally to their present depth. These seamounts furnished evidence for a deep Cretaceous Pacific Ocean, refuting the hypothesis that animals could have crossed the Pacific on now-submerged, transoceanic continents, but suggesting the possibility of "island stepping stones." These findings also confirmed

Darwin's theory of subsidence with regard to the formation of coral reefs growing on sinking volcanoes. Dr. Revelle said the coral atolls Kwajalein and Bikini are the largest structures ever made by living creatures. He said, "In comparison, the pyramids of Egypt and the Empire State Building are microscopic."

— seismic refraction studies revealed that the central Pacific's sediment layer was only about 100 m thick instead of the previous estimate of 3,000 m, again supporting the concept of a young ocean floor, one of the tenets of the "new" plate tectonics. Such seismic measurements also demonstrated the relative thickness and uniformity of the earth's crust in oceanic areas, features profoundly different from those under the continental areas. Mid-Pac, and later Capricorn, carried these measurements out on a geographic scale seldom approached since that time.

— first use of a heat-flow measuring device, developed at Scripps, revealed that heat flowing through the oceans floor was as great as that under the continents. Dr. Revelle said, "This was an indication that the mantle must be slowly churning."

— submarine cliff extending more than 1,600 km seaward from the earlier-known Mendocino Escarpment off the northern California coast.

— bacteria from the deep sea that may have "slept" for millions of years were revived in a culture medium. Dr. Revelle had suggested then that these bacteria, which had been buried under 6 m of mud, were in a state of suspended animation in nature's "deep freeze," since little food exists at that depth.

— extensive manganese dioxide deposits, with an estimated 100 million tons on Sylvania Seamount, near Bikini Atoll, and photographs revealing that the seamount surface was rippled and swept by deep currents.

New Tools Aid Ocean Exploration

Many discoveries were made possible by the use of new tools for ocean exploration. Some of these were the recording echo sounder, which traces the bottom configuration of the ocean without stopping a ship; a complex electronic thermometer, for measuring the temperature gradients of deep bottom mud; a new type of dredge for scooping rocks off the ocean floor; a remotely operating, underwater camera, developed at the U.S. Naval Electronics Laboratory, for obtaining flash pictures at oceanic depths; a new technique for pulling long cores of mud from the bottom of the sea; a chemical analytical process for counting bacteria in bottom muds and measuring dissolved chemical substances, and a new method of ocean-floor analysis by seismic refraction.

The seismic refraction technique requires the teamwork of two ships. One ship sets off a high explosive charge and the other detects the seismic waves after they have traveled through the rocks beneath the ocean. During Mid-Pac, the two ships were sometimes as far as 128 km apart when this method was used, and a total of 15,876 kg of TNT — some 1,600 separate shots — were exploded during the voyage.

Mid-Pac scientists also assisted the Navy's air-sea rescue system by regularly exploding four-pound SOFAR (*So*und *F*ixing *a*nd *R*anging) bombs to set a 5,600-km-record of long-range sound propagation. This work was later named "the shot heard 'round the Pacific."

The two ships, which have been described as being not much larger than Magellan's *Trinidada* and *Vittorio,* returned to San Diego in November 1950, with a booty of statistic-filled notebooks, newly drawn charts and graphs, tubes of cored mud from the sea floor, odd pieces of rock, coral, and fossilized shells; hundreds of bottles of seawater and preserved fish, and a variety of bent and battered gear.

Expedition Results Listed

To further the investigation of the Pacific sea floor, Capricorn Expedition, also funded primarily by the Navy, was launched in the fall of 1952. After completion of the thermonuclear tests at Eniwetok Atoll, the ships proceeded to the Tonga area to map the ocean floor.

Research in the Tonga Trench region yielded data later used to develop and buttress the sea-floor-spreading and plate tectonics concepts. Almost no sediment was found at the V-shaped trench, an indication that either the trench was very new or that material was folded into the earth as fast as it was accumulated, said Dr. Revelle.

Exploration of Capricorn Guyot, just offshore of Tonga Trench, showed that its summit was tilted slightly toward the trench, a factor that directly suggests the moving of its foundation toward the trench.

Soundings of the Tonga Trench by *Horizon* were the deepest ever taken in the Southern Hemisphere and established that the trench is second only to the Mariana Trench, near Guam, in depth.

Other evidence of crustal, or mantle, movement was obtained by comparing heat-flow measurements of the sediments in the East Pacific Rise with those on the normal sea floor near the trenches. Temperatures were higher at the rise, and this, Dr. Revelle said, was an indication that the material was rising at the ridge and sinking at the trenches.

Another "first" was the use of aqua-lung divers for the investigation of undersea volcanoes. One of the areas studied was shark-infested Falcon Shoal, a volcanic island in the Tonga group that has been above and below the ocean's surface several times in the last hundred years.

Dr. Revelle said that during the expedition scientists conducted a variety of studies, including electric currents in the atmosphere, with instruments sent nearly 16 km above the sea surface; wave-motion, magnetic profiling, hydrographic casts, and plankton tows. But, he said most of the researchers were marine geologists and geophysicists eager to learn the history of the ocean throughout geologic time.

The track of the expedition was across the Pacific to the Hawaiian Islands, on to the Marshall Islands area, then to the Fiji Islands, over the Tonga Deep to Tahiti in the Society group and the Marquesas Islands, on toward Easter Island and the East Pacific Rise, and north to San Diego.

MAJOR EXPEDITIONS

Eurydice Expedition

When R/V *Thomas Washington* returned to her Nimitz Marine Facility berth in San Diego on July 18, 1975, she concluded an extended cruise into the Pacific and Indian oceans.

The ship left San Diego in September 1974, and logged some 43,000 nautical miles during the 11 legs of the Eurydice Expedition. During the expedition geological, geophysical, biological, and physical oceanographic research was conducted.

Expedition coordinator was Dr. Edward L. Winterer. He also served as chief scientist for two of the 11 legs of the cruise, including the final leg that brought the ship in to port from Majuro, Marshall Islands.

Much of the data obtained during the cruise were based on