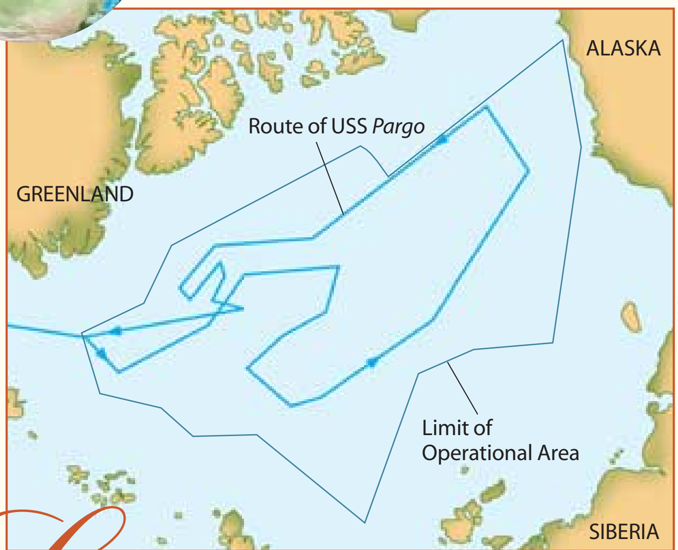
WORLD TOUR

ARCTIC OCEAN: *Forty Days in the Belly of the Beast*



LAURIE GRACE (*map*); WILLIAM F. HAXBY (*globe*)

Or, a marine geologist's account of life on board a U.S. Navy nuclear attack submarine under the Arctic ice

by Bernard J. Coakley

Lying prone on my narrow bunk, I heard the unmistakable sound of water trickling, as though from a faulty faucet. It did not soothe me, as I tried to get some sleep during my first night on a nuclear submarine, cruising below the surface of the sea. Like a camper in a suspect tent on a rainy night, I checked my bunk for damp spots and braced for the inevitable arrival of the drips.

Nestled next to a torpedo tube, I was bathed in dim light. I heard the trickling, the hum of pumps, the click of electrical relays and, from time to time, bits of nearby conversations. Once every hour a navy enlisted man would open an access hatch in the floor near my bunk and climb down into the bilge below. This was to be my life for the next 40 days, a witness to deliberate, continuous action, a confused observer.

"Blind Date" on a Submarine

What was a marine geologist doing on the USS *Pargo,* a Sturgeon-class fast-attack submarine? Heading toward the Arctic Ocean on what had been called a "blind date" between the navy's submarine fleet and the academic research community. I was one of five scientists participating in the first unclassified science cruise, which would exploit the extraordinary mobility of navy submarines to characterize the ocean below the Arctic ice.

As on any blind date, there were surprises for both parties. Many crew members, I discovered, were intensely curious about the science that was taking them to the Arctic. Then, too, life on board a submarine was new and rather strange to me and my four colleagues—Ted DeLaca and Peter C. McRoy of the University of Alaska–Fairbanks, James H. Morison of the University of Washington and Roger Colony, then at the University of Washington. The ship's navy complement consisted of about a dozen officers, 120 enlisted men and two ice pilots, Jeff Gossett and Dan Steele of the navy's Arctic Submarine Laboratory, civilian navy employees specially trained and adept at moving the ship through icy waters.

On a surface ship, you feel connected to the sea, sometimes uncomfortably so. In a submarine, you are both immersed in it and utterly isolated from it. At 100 meters (328 feet) or more deep, doing what submariners call "making a hole in the water," there is little sense of motion and no sensual connection to the world outside. You are in the "people tank." Position is just a pair of numbers. Time is what the clock reads.

We had toured the submarine before the trip but did not fully appreciate how close the quarters were until we were under way. The submarine is a marvel of three-dimensional design, a maze of pipes, cables, wires, struts, bulkheads, walkways, machinery and electronics. The trickling that kept me up during my first night, for example, was the drain in the crew shower, which I later learned was not even one meter from my pillow. Storage on board a sub also suggests impressive resourcefulness: passageways where we once walked upright were now paved with 23-centimeter-high food cans, making it necessary to walk hunched over through the vessel's middle level.

After leaving Groton, Conn., we reached the Arctic Ocean in a few days, cruising north past Iceland, through the Fram Strait, to arrive in the operational area, an approximately three-million-square-kilometer expanse of deep Arctic Ocean within which we would conduct our research.

My attention was devoted to making bathymetric (total water depth) and gravity measurements along the submarine's track. The gravimeter I used is basically an extremely precise scale, measuring minute variations in the gravitational force exerted on a mass. After accounting for the earth's shape and changes in the sub's position relative to the earth's rotational axis, I was left with infinitesimal variations

BERNARD J. COAKLEY

CRAMPED QUARTERS on board a nuclear submarine put privacy at a premium. Here a junior sailor slumbers next to a Mark-48 torpedo in the torpedo room.

USS *Pargo* surfaced in August 1993 to put out meteorological buoys and take water samples. The sailor in the conning tower is keeping "polar bear watch."

that could be attributed to the density distribution below the submarine. That was why I needed the bathymetric data, so I could account for the influence of bathymetry and use the gravity anomaly data to examine the distribution of mass below the seafloor. These subseafloor variations reveal much about how the ocean basins formed.

The Arctic Ocean has not been well mapped. The high ridges and plateaus in the basin shape the currents that move water and the contained chemical species and heat, redistributing what enters the basin from the Atlantic and Pacific oceans and the many rivers that drain the northern regions of North America and Eurasia. Predicting this circulation is important for understanding the transportation of contaminants and the formation and persistence of the ice pack. Understanding the present-day circulation will one day provide a better understanding of how the ocean responded to the last ice age. That understanding, in turn, could be an important piece of the puzzle of how the Arctic's unusually sensitive climate system works—and how it may respond to such forces as greenhouse warming in the future.

During 21 days in the operational area, I collected new bathymetric and gravity anomaly data over a track approximately 10,000 kilometers long. We worked below and within the floating pack ice that in the past had so severely constrained oceanographic work in the Arctic Ocean basin. For the first time, we systematically sampled and mapped this remote basin.

Football at the Pole

A highlight of our Arctic itinerary was the obligatory stop at the North Pole. To travel in an isolated environment to a geographic abstraction is a singular experience, but every Arctic cruise that approaches the Pole is drawn to it, like water swirling down a drain. On my 1993 trip, on board the *Pargo,* we surfaced in open water and marked the occasion by venturing out onto the ship's hull. On a later SCICEX cruise, in 1995 on board the USS *Cavalla,* we came up through ice at the Pole. My colleagues and I collected water samples while some crew members played touch football in the perpetual daylight.

Whenever I have sailed for science, I have been very aware of being a guest in the crew's "house." When that house is as cramped and isolated as a submarine, the awareness is unusually acute. I am proud of the data we collected on both the submarine science cruises in which I participated, but what I remember most about each trip is the camaraderie and teamwork we en-

SCIENTIST peers into a hole in the ice (*top*), about a meter thick, for a water-sample bottle coming up from 1,400 meters below the ice. Author Coakley writes software for a workstation in the main passageway through the torpedo room, where the scientists worked.

joyed among ourselves and with the crew and officers who ran the ships.

Although it may sound like a cliché, there is no room for discord on board a submarine. Crew members must be comfortable with one another, having been acclimated by the process that takes them from NUBs ("nonuseful bodies"—the most junior sailors) to fully qualified submariners. To some on this precision team, the other scientists and I must have appeared to be grit in the gears of their fine-tuned machine. But after a brief period of mutual wariness, the scientists and sailors began to understand one another and develop a collective mentality of the cruise, like a small village at sea. With time, we scientists were accepted into the daily round of discussions that marked time in the torpedo room, where we did most of our work.

PHOTOGRAPHS BY BERNARD J. COAKLEY

The first SCICEX cruise was deemed a success by both the academic community and the submarine fleet. In recognition of this fact, in 1994 the U.S. Navy, the National Science Foundation (NSF), the Office of Naval Research, the National Oceanic and Atmospheric Administration and the U.S. Geological Survey agreed to support five more cruises, one each year from 1995 until 1999. The fourth of these cruises is under way as this article goes to press.

In the geophysics program—my primary interest—we have collected approximately 66,000 kilometers of new bathymetric and gravity anomaly profiles during some 130 days in the deep Arctic Ocean. In support of other scientific disciplines, this program has also collected tens of thousands of water samples, hundreds of conductivity, temperature and depth profiles, and voluminous data on the pack ice cover. All this information is improving our understanding of the deep Arctic Ocean basin, which many scientists regard as the canary in the coal mine of global climate change.

We have yet to take full advantage of what submarines offer to scientific research. Although we collected scientific information in places where it had never been collected before, we did so in a manner not much different from the way surface ships did it 30 or 40 years ago—by mapping a point directly below the vessel.

The 1998 and 1999 SCICEX cruises, on board the USS *Hawkbill,* will deploy a sonar system that maps the sea bottom across a 20-kilometer-wide swath. It was specially constructed and adapted with funds from the NSF's Arctic program for use on submarines in Arctic waters. The mission will also make use of a subbottom profiler, which will provide the first ever systematic imaging of the shallow stratigraphy of the Arctic Ocean. The data collected with these two sonars will revolutionize what we know about the history of this ocean basin and the currents that circulate through it.

BERNARD J. COAKLEY is an associate research scientist at the Columbia University Lamont-Doherty Earth Observatory.