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Ground Zero

IN OCTOBER 1994 WHOI geochemist Susan Humphris and a cadre of other scientists boarded the research vessel JOIDES Resolution to embark on one of oceanography's most ambitious geological explorations —drilling deep into TAG's active hydrothermal mound.

Susan Humphris

The drilling would remove the first core samples ever taken from a hydrothermal vent, and Humphris had been preparing for this moment for almost two years. As one of the voyage's two chief scientists, she had overseen a five-week cruise on WHOI's RV Knorr that had mapped the site with thirty thousand photographic and sonar images; she had planned where and how deep the drill would go; and she had helped amass an international team to analyze the drill cores on board the ship. Even before the ship set sail, a score of additional scientists were counting on Humphris' success—instruments from the United States, the United Kingdom, and Japan were already anchored on the bottom, waiting to monitor the drilling's impact on the mound's hydrothermal activity.

In the beginning, the work was fruitful. the crew, lowering a hollow, five inch pipe through miles of water, hauled up core samples every few hours, and the scientists kept busy analyzing and cataloguing the material. Then, partway through the two-month voyage, the ocean floor suddenly stopped cooperating. Everything came to a standstill.

As Humphris explains it, much of the TAG mound is not solid rock but an amalgam of tiny pieces of rock cemented together by various minerals including sulfides, sulfates, and quartz. The drilling "broke up the cement and caused the hole to cave in around the drill string," she says. "We kept getting stuck in the bottom."

The crew spent hours wriggling the drill string free of the debris, only to have to punch a new hole nearby. Other times the drill bit wore out, and the drillers, working beneath the ship's twenty-story derrick, would spend an entire afternoon pulling up two and a half miles of pipe a ninety-foot section at a time.

Before long, days had gone by without any new samples. The scientists, tracking the drilling operation on television monitors in their labs, began to grow restless. "At first, everyone's level of excitement was really high, so everything that came up was quite exciting," says University of Michigan research scientist Jeff Alt, who worked on the project. "Then we went through that dry spell, and I think Susan felt lots of pressure. Things were tense for a while. We all wanted the project to be a success."

JOIDES Resolution's derrick towers 202 feet above the waterline. Here riggers are connecting a section of the drill string.

JOIDES *RESOLUTION* IS A converted oil-drilling ship that has been taking scientific seafloor cores since 198S as part of the Ocean Drilling Program (ODP). Competition for ship time is intense, and the process for acceptance and scheduling of scientist's research proposal by the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), an international group of scientists in charge of the drilling, can take several years.

JOIDES *Resolution*'s target must also be worthy of the effort—and the TAG mound qualified in spades. It is one of the largest mineral deposits yet found on the seafloor, and drilling into its active hot springs was sure to benefit a number of oceanographic disciplines. In fact, three months before, a joint WHOI-Japanese team had wired the mound with instruments to measure how the drilling would affect TAG's output of heat and fluids (see below). Three fifty-meter seaweed-shaped temperature arrays, dubbed Giant Kelp, measured the black smoker plumes; the daibutu (Japanese for octopus) hugged the mound with eight arms of temperature recorders; and a video camera kept watch. A month later, a joint British-Russian submersible expedition added still more instruments to measure the mound's flow rates and chemistry.

WITH SO MUCH AT STAKE, Humphris labored feverishly, sometimes staying up twenty-four hours at a stretch, working with the dozens of people behind the ship's operations—the drillers, engineers, and technicians from Texas A&M, the ODP's science operator. Though she had participated in previous drilling voyages, Humphris now realized for the first time the enormous round-the-clock effort involved in moving the project forward, how inordinately complicated it is, for instance, just to keep the ship over the drilling area.

"We were trying to position all of our drilling sites on a piece of seafloor 200 meters across while avoiding all the instruments down there," says Humphris. "The ship is 143 meters long, so by walking from one end to another, you were essentially walking that piece of seafloor." The ship had to maneuver constantly, holding itself steady with its twelve computer-controlled thrusters and an internal 400-ton mechanism that keeps the drill string stable relative to the seafloor.

For Humphris, learning such mechanical intricacies meant mastering the drillers' lingo, one rife with oil-rig acronyms. "They would say, 'Should we use an MDCB?' or 'Are we going to RCB or use such and such a bit?"' says Humphris. "And you're sitting there saying, 'First of all, what is a bit?"'

Jay Miller, ODP staff scientist, says many drilling tools are named after animals. "That's standard, oil field stuff," he says. The doghouse, for instance, is where the head driller stands, and a"Go Devil" and a "Rabbit" are tools that travel down the hole.

There are also the operational reports to decipher. "They're all in shorthand," says Humphris. "'POOH at 3 p.m.,' for example, means 'pull out of hole at 3 p.m."'

To everyone's relief, the tension and tedium aboard the ship broke in about a week's time as more core was recovered from a different part of the mound. However, the difficulties were far from over: The drillstring became hopelessly stuck with about forty meters of pipe inside the mound.

Susan Humphris prepares for an ALVIN dive.

Dynamite was twice sent down the hole to blow off the drill bit at the very end of the pipe, but the drillstring still did not come free. The crew feared their only option would be to blow the drillstring apart at a joint above the seafloor, leaving a piece of drill pipe sticking up like a lance. This could potentially have put an end to future operations at the TAG active mound, for "Alvin could have run into it or gotten stuck on it," Alt explains.

Humphris, however, persuaded them to try once more, this time setting the charge to explode a few feet below the seafloor. The pipe came free, and as the drilling crew drew the drill pipe up through the "moon pool," an open shaft seven meters across that extends through the bottom of the ship, Humphris and her shipmates anxiously waited to see how much pipe had been blown off. As the last piece emerged from the water, they saw that the explosion had indeed occurred below the seafloor. Humphris was so happy that she posed for a photograph pointing at the blasted-off piece of pipe. Little did she know that the picture would appear the next day as a screen saver on the ship's computers. "Susan blows up the mound!" the headline said, and there was Humphris grinning broadly.

Though most scientists on board agree there was not a lot of core to go around, what the crew did "catch" was extremely useful. It was the first time anyone had drilled in an active hot spring system where the deposit sat on exposed volcanic rocks, and it was quite an accomplishment. "Usually, you drill through sediment first, which acts as a stabilizer," says Humphris. "This time, we had to pierce sheer rock. "

In the summer before the JOIDES Resolution's cruise, Humphris and her colleagues made detailed studies of the TAG area to guide the drilling project. The ARGO II imaging shed was towed to within a few yards of the mound's surface, and returned still and video images to the ship via a fiber optic cable. Thousands of ARGO II's images were combined to make a photomosaic of the mound.

Humphris says the cores have yielded some important findings. "The mound doesn't form by continuously spewing out minerals that accumulate on the seafloor," she says. "It goes through many cycles." When the vents are active, the vent fluid's minerals precipitate in the cold seawater and fall to the bottom. When venting pauses, the seafloor fissures and breaks up the mineral deposit. "The next phase of hot spring activity then cements the broken fragments together."

ONCE HUMPHRIS AND HER co-chief, Peter Herzig of the Institute of Mineralogy in Germany, had the core samples on board, a different set of challenges arose. The ship's company included petrologists, geophysicists, water chemists, and geochemists, all eager to work on the samples. Due to the shortage, Humphris and Herzig had to dole out the material carefully. "That was hard," says Alt, a geochemist. "There were so many scientists, and sometimes when two of them have a conflict, neither backs down. I've been on cruises when scientists have left with bad feelings."

With so many people wanting a piece of the pie, Miller agrees feathers can get ruffled. "You have people on board for two months working fourteen to sixteen hours a day," he says. "Even the smallest conflict can aggravate."

According to Alt, Humphris and Herzig essentially told their colleagues they had to share. "They said, 'Look, we're going to have to work together,' and I think people came away feeling pretty good," he says.

Drilling Into TAG's Fiery Heart

Drilling takes place twenty-four hours a day from a platform about one meter above the bridge deck in the center of the ship. When the drilling begins, core barrels within the drill string receive and contain the core cut by the bit. The drill can re-enter the hole thanks to a cone, lowered and set on the sea floor; sophisticated sonar equipment and an underwater camera guide the drill string into place.

JOIDES Resolution has recovered more than 115 miles of cores at almost 400 sites in the world's oceans. The scientists on board work twelve-hour shifts, analyzing cores as they are retreived. Cores are stored at four repositories. Atlantic Ocean cores are stored at the Lamont-Doherty Earth Observatory, Palisades, New York, and the University of Bremen, Bremen, Germany; Pacific and Indian Ocean cores are at Texas A&M University, College Station, Texas, and at Scripps Institution of Oceanography, LaJolla, California. TAG cores are in Bremen.

Some scientists believe that heat from the vents drive some ocean currents and influence the earth's climate. To measure the mound's heat output before, during and after the drilling, WHOI geophysicist Richard Von Herzen placed three fifty-meter tall arrays of temperature sensors around the mound's black smokers, Each array, held upright by floats, contained eight temperature sensors that intersected the plume at various heights as the plume moved with the tide.

Relaxing now in her office at WHOI, Humphris, dressed in a T-shirt and baggy pants, still has a cloud of relief about her when discussing her experiences on JOIDES Resolution. "It was not the easiest cruise I've ever been on," she says, sighing.

How Humphris came to be the project's co-chief is a story in itself, particularly for someone who says she used to think the ocean was strictly for "building sand castles and watching the waves come in."

In England, Humphris' father was a dentist, who supported his daughter when she decided to concentrate on science in high school. Humphris moved on to environmental science in college and decided on her true calling in a typically collegiate fashion.

"I was taking a marine chemistry course and learning about scientists who actually went to sea. That sounded like a good idea," says Humphris. "Then I saw some of the boats they went on, and they were sort of nice."

"Sort of nice" landed Humphris in the WHOI/MIT Joint Program, working toward a Ph. D. under the tutelage of Geoff Thompson. Her graduate thesis, done prior to the first actual sighting of a hot spring, was on some rocks in the WHOI collection that had clearly been altered by hot water. Humphris also met her future husband, Pat Lohmann, a WHOI paleoceanographer ("He works on sediments that cover up what I'm working on," says Humphris).

At the time, Humphris already had decided to return to England to do postdoctoral research. "But Pat called me there, and we spent an expensive year and a half conducting a transatlantic relationship." In 1979 Humphris returned to WHOI as a visiting investigator and also became a staff scientist for the Sea Education Association, an independent marine education program in Woods Hole.

She continued working with Thompson, and in the spring of 1986, during the first submersible dives at the TAG site, she made her first Alvin dive and saw the TAG mound up close.

In 1990, Thompson and Humphris made another series of dives, this time accompanied by Meg Tivey. Inspired by what they saw, they immediately began to rewrite an earlier proposal to drill for samples. When that project was approved in December 1992, Humphris was a natural choice for its co-chief. She'd worked on TAG almost as long as anyone.

In March, four months after the JOIDES Resolution voyage, Alvin returned to the TAG site to collect the monitoring instruments on the mound. Humphris feared that the drilling somehow may have changed the activity of the hot springs. After all, they had planned on punching only four holes in the volcanic mass, but wound up with seventeen because of the collapsing rock.

However, the scientists who dove in Alvin put her fears to rest. "The mound was still blasting away," she says, "so I guess we didn't do anything too drastic."

EAST MEETS WEST

For over twenty years, scientists from WHOI and the Japan Marine Science and Technology Center (JAMSTEC) have been sharing information and research. So when the Japanese were planning their first Atlantic Ocean research trip, they asked WHOI to help. In the summer of 1994, the two institutions performed joint experiments at TAG and the Kane Fracture Zone, one hundred kilometers to the south on the Mid-Atlantic Ridge. The work involved three research ships, two submersibles, and a variety of unmanned vehicles.

JAMSTEC's Shinkai 6500 is two meters longer than ALVIN, and carries two pilots and one scientist, rather than one pilot and two scientists.

JAMSTEC is the product of an intense Japanese effort to learn about the ocean and the earthquakes that wrack their island nation. Its research fleet includes the world's deepest diving manned submersible, the five-year-old Shinkai 6500, which can descend to 6,500 meters (WHOl's Alvin can dive just under 5,000 meters).

WHOI and JAMSTEC have had a formal relationship since 1987. Ongoing projects include arctic research, an Earth data and information network, and experiments in physical oceanography, biology, and geochemistry.

''JAMSTEC scientists are the world's experts in the type of deep sea trenches found near Japan," says WHOI geologist Sus Honjo, a Japanese native and American citizen who helps coordinate the JAMSTEC-WHOI research. But they are unfamiliar with spreading ridges such as the Mid-Atlantic Ridge. Although the two institutions have very different histories, habits, and languages, our relationship is very solid and enormously fruitful."

Geophysicist Richard Von Herzen spent three weeks with the Japanese at TAG. "They were very cooperative and their submarine was really first class," says Von Herzen. Although Shinkai 6500 was inspired by Alvin, it boasts a slew of innovations, including a video system that allows scientists on the surface to watch and contribute to the work below.

The scientists left instruments from both countries at TAG to monitor the effect of JOIDES Resolution's drilling. Alvin recovered the equipment in March. "The whole cycle of activities made for the kind of research that normally scientists just dream about," Honjo says.