Drilling discoveries in the Pacific

JOIDES Resolution, the drillship of the international Ocean Drilling Program (ODP), spent the last several months of 1986 cruising around the eastern equatorial Pacific. During Legs 111 and 112, it deepened the ocean's deepest drill hole and retrieved the most continuous sedimentary record ever collected by ODP scientists from a coastal margin. It also helped to erode traditional thinking about water circulation through ocean crust and sediments, as well as scientists' concept of what happens when an oceanic plate plunges beneath a continent.

One of the principal goals of the drilling program has been to unearth the structure of oceanic crust. Over the last few decades, some clues have come from ophiolites, or slices of oceanic crust that have been pushed up onto continents. These suggest that the crust is made of three principal layers: the topmost "pillow basalts," which were formed when extruded lava was cooled by seawater; a "sheeted-dike complex" consisting of a tangled mass of feeders that brought the lava toward the surface; and gabbros, or coarse-textured basalts that crystallized under pressure and were never extruded.

But because ophiolites were probably deformed and altered during their journey onto land, scientists have wanted to sample oceanic crust directly. That is why in 1979 they began to drill Hole 504B into 6-million-year-old crust on the southern flank of the Costa Rica ridge—off the west coast of South America and to the northeast of the Galápagos Islands. On three previous legs, researchers had drilled through sediments and pillow lavas and into the sheeted-dikes layer, to a total depth of 1,350 meters below the seafloor.

Because of technical difficulties during Leg 111, which lasted from mid-August to mid-October, *JOIDES Resolution* drilled only 212 meters deeper into the sheeted-dike complex. But seismic profiles of the crust made from the bottom of the hole reveal reflectors, or boundaries between rock layers, that are 100 and 400 meters down. This suggests that the gabbros layer is within reach of one or two more drilling expeditions.

"The most significant accomplishment in Hole 504B was undoubtedly the well logs [records of measurements taken as instruments are dropped down the hole]," says Russell B. Merrill, a staff scientist on Leg 111. "With this kind of logging, we can see what was missing in the core samples."

So far, says Merrill, the logging and drilling results are consistent with the ophiolite model of the crust.

The most exciting scientific results of Leg 111 came from holes drilled a few kilometers away from 504B, in one of the areas most scrutinized by scientists studying the heat flow and convection of water through the crust and sediments. In recent years, researchers have recognized that the hydrothermal vents at the spreading ridges – where rising lava churns out new seafloor—play an important role in the exchange of chemicals and heat between the oceans and the crust (SN: 12/20&27/86, p.389). As the crust ages and is covered by thick sediment layers, however, this exchange is cut off.

"We know a fair bit about the ridges and about the very old crust, but we don't know much about the area in between," says Leg 111 scientist Michael J. Mottl of the University of Hawaii at Manoa in Honolulu. "We believe the ridge flanks are of equal or perhaps more importance" for exchanging chemicals and heat than are ridge axis vents, he says.

In the mid-1970s the drilling program chose the Costa Rica flank as a site for the study of flank hydrothermal processes. By the time Leg 111 came around, scientists had already discovered that the study area contained two high and two low heat-flow bands aligned parallel to the ridge axis and that calcium and magnesium levels in the pore waters of the topmost sediments change rapidly with depth in high-heat-flow areas. This suggested that in these areas, water from the crust was carrying heat and chemicals up through the sediments.

On Leg 111, scientists drilled through the sediments and to the crust in a high-heat-flow zone and confirmed that water was slowly moving up the sediment column. They also drilled into a heat-flow low and measured changes in the chemical concentrations of the pore water along the hole. These suggested that water was flowing down in this area.

Mottl estimates that the rate of flow is a few millimeters per year through the 275 meters of sediments. That's a surprising result, he says, because previous thinking held that no water escapes from the crust through sediments thicker than 150 meters.

Mottl thinks a small amount of the water circulating through the crust escapes into the sediments and, finally, into the ocean. This water is replaced by seawater that finds its way down through the sediments and into the crust.

"The story we have now is one of the more complete and satisfying stories about thermal process on a midocean ridge flank," he says. "This is the first place we have ever found and verified that [an exchange] is taking place. The next question will be to find whether this is a very unusual situation for a ridge flank or relatively common."

While Leg 111 focused on crust that had been created relatively recently, one purpose of Leg 112 was to study the zones where oceanic crust is destroyed as it plunges into the mantle beneath continents, in a process called subduction. Leg 112 holes were drilled on the continental margin of South America, under which the Nazca plate is subducting. Using the classic model for subduction, scientists expected that sediments carried on the Nazca plate would be added, or accreted, to the South American continent. But seismic and other studies have suggested that this has not always been the case.

Leg 112 confirmed that instead of being built up, the continental margin had experienced a period of subsidence, or sinking. The *JOIDES Resolution* brought up fossils of animals that had lived in very shallow waters as long ago as 40 million years but that are now buried about 4,000 meters beneath the sea surface. ODP researchers suspect that the subsidence of the margin was caused by the movement of the downgoing Nazca plate, which eroded the front and bottom of the South American plate, causing it to sink.

"We've now raised the level of questioning from whether or not massive erosion at the front of the continent takes place to what the mechanism of that erosion is," says co-chief scientist Roland von Huene at the U.S. Geological Survey in Menlo Park, Calif.

Leg 112 researchers also found that starting about 12 million years ago, sediments began to accrete in the classic way after a 2-kilometer-high ridge plunged beneath the margin. But they don't understand what caused this change from subsidence to accretion.

What scientists are beginning to realize, according to von Huene, is that erosion in subduction zones is more common than previously supposed. "We're now finding that there is a real spectrum between accretion and erosion, and that erosion is quite important," he says.

In addition to its significance in tectonics investigations, the South American margin is an important place for studying past oceanic and climatic conditions. In particular, the coasts of Peru and Ecuador are renowned for their upwelling of cold, nutrient-rich waters, which support a rich fishing industry. (El Niños, changes in ocean and wind patterns that disrupt world weather patterns, were named by South American fishermen, whose livelihood is threatened when El Niños suppress this upwelling.)

On Leg 112, scientists collected a nearly continuous record of the sediments and fossils left by plants and animals living at the South American margin over the last 7 million years. The cores "contain a tremendous potential for very detailed studies of the climate and oceanographic history of Peru" with an unprecedented resolution, says co-chief scientist Erwin Suess at Oregon State University at Corvallis.

Suess says some sediment layers are

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laminated, or composed of finer layers. These layers alternate with nonlaminated ones. He believes that contrary to scientists' expectations, the laminated sediments were deposited during glacial periods, when sea levels were low and the winds that blow westward from Peru intensified, displacing surface water and resulting in a period of enhanced upwelling. With more upwelling, algae and diatoms flourished. When these organisms sank to the bottom, they consumed the oxygen that sustains bottom-dwelling animals, which normally churn up laminated sediments. Previously, says Suess, scientists had correlated laminated sediments with high sea level.

The most surprising find of Leg 112 was the discovery of water in the sediments that was twice as salty as normal seawater. Suess suspects that about 10 million years ago the outer shelf was lifted and isolated from the oceans, leaving a salty layer of evaporites — sedimentary rocks that formed when seawater evaporated from a basin — that is now buried deep in the margin. While ODP scientists were able to detect the salt that is now seeping upward from a salt deposit, they did not encounter the salt source itself.

With summer now under way in the Southern Hemisphere, the *JOIDES Resolution*, on Leg 113, is in the Weddell Sea, in the Antarctic, studying the past ocean circulation around Antarctica as well as the tectonic processes that separated Antarctica from Australia and South America millions of years ago.

On future cruises, it's possible that ODP scientists will be joined by their Soviet colleagues. Both the U.S. National Science Foundation (NSF) and the Soviet Union have indicated a desire for the Soviets to pay the $2.5 million annual fee and become ODP's seventh member. But according to an official at NSF in Washington, D.C., there is some opposition in the Reagan administration to Soviet membership. In fact, an NSF delegation's scheduled trip to the Soviet Union to sign the ODP membership agreement has been postponed, he says, apparently because of "administration infighting."

— S. Weisburd

Earth's most abundant mineral

When the earth formed 4.7 billion years ago, it was an unsorted conglomeration of cosmic material. Through heating and chemical differentiation, the compounds making up the planet sorted themselves into three main layers: the core, mantle and crust. By studying the compositions and temperatures of these layers today, scientists can begin to reconstruct the evolution of the earth as it has cooled.

One significant step toward that end is taken in a Feb. 6 SCIENCE paper by graduate student Elise Knittle and geophysicist Raymond Jeanloz, both at the University of California at Berkeley. With high-pressure experiments, Knittle and Jeanloz have shown that a mineral called magnesium silicate perovskite makes up most of the lower mantle. And since this region accounts for about two-thirds the bulk of the earth, the researchers believe that magnesium silicate perovskite is the "most abundant building block of the whole planet."

Magnesium silicate perovskite was discovered about 10 years ago by L.-G. Liu at the Australian National University in Canberra. He showed that many upper-mantle minerals convert to the perovskite under the pressure of a diamond anvil press and the heating of a laser. But at that time the technology had not advanced far enough for Liu to easily subject the perovskite to the very high pressures found in the lower mantle.

Now Jeanloz and Knittle are able to synthesize the perovskite samples at pressures of the lower mantle: from 240,000 to 1.3 million atmospheres, which is more than four times greater than what had been available to Liu. What's more, Jeanloz and Knittle became the first to study directly the crystal structure of the perovskite using X-ray diffraction while their samples were under these high pressures.

"The guts of our discovery are that once this perovskite is made in the mantle, there's no new high-pressure phase that forms at greater depths [or pressures] as far as we can tell, because we've covered the entire pressure range ... of the mantle," says Jeanloz. In other words, the perovskite retains its composition and structure under mantle pressures.

The researchers characterized some of the mineral's properties — including its density, compressibility and melting temperature — under mantle conditions. "This gives us a real handle for the first time on the long-term behavior of the deep earth," notes Jeanloz.

Since the lower mantle is a solid, the melting temperature of the perovskite gives the researchers an idea of the highest possible temperature of the lower mantle. Jeanloz says they hope to obtain a more exact estimate of the temperature by comparing the seismologically determined densities of the mantle with additional laboratory studies of the perovskite density as a function of pressure and temperature.

Jeanloz says perovskite crystals with the same structure, but with compositions different from the mantle material, have been of intense interest to scientists studying superconductivity (SN: 1/10/87, p.23). Now, in addition to the technological significance of perovskites, he notes, "we're saying they have a geologic importance as well."

— S. Weisburd

Mir: Has full-time occupancy begun?

Permanent human occupancy in space, with crews continually present aboard earth-orbiting stations, is a goal that has been cited in the past by both U.S. and Soviet officials. Now, some Western observers suggest, that process may have begun, with a pair of cosmonauts who boarded the Soviet Mir space station on Feb. 8.

Mir — the name is the Russian word for "peace" — was launched just over a year ago, and was described in Soviet accounts at the time as "a base module for assembling a multipurpose, permanently operating complex" (SN: 3/1/86, p.136). One cosmonaut duo boarded the station the following month and stayed for 50 days, after which they moved to the older Salyut 7 station for 50 more and then came back to Mir for 25, finally returning to earth. But officials had already announced that the mission would be primarily a checkout period, to be followed by a period of unmanned operation. Subsequent crews, it was said, might then take up residence there on a rotating basis.

Now aboard is the first team to arrive since then, cosmonauts Yuri Romanenko, on his third space mission, and rookie Aleksandr Laveikin. They arrived in the latest version of the Soviet Soyuz spacecraft, identified as Soyuz TM-2. According to Soviet space-program specialist James Oberg, an engineer at NASA's Johnson Space Center in Houston, TM-2 is characterized in part by reduced structural weight, enabling 440 pounds of additional cargo to be carried into orbit, and by the ability to dock with Mir without requiring the station to use extra fuel by reorienting itself in space.

According to Oberg, a number of cosmonauts have said in private conversations that full-time occupancy of Mir would begin with this mission. As for the planned length of the present crew's stay, Soviet press accounts have identified it only as "many months." It was reported in January, however, that the duo is to be joined by another in July, and Oberg and others say Romanenko and Laveikin could be there 10 months.

Also due to be docking with Mir in a few months for scientific research will be an "astrophysics module," one of several that are said to be forthcoming. Not that everything is going flawlessly; the astrophysics module was expected early in 1986, Oberg says. Other modules are said to be planned for medical and biological studies, materials processing research and earth observations.

Meanwhile, uncertainties continue about the future of the proposed U.S. space station, permanently occupied or not.

— J. Eberhart