Ocean Drilling Program
Public Information
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Scientists investigate complex formation

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ODP Leg 141: Chile Triple Junction

COLLEGE STATION, Texas -- Scientists recently discovered what happens when two of Earth's greatest undersea geologic features collide. They also drilled through a layer of frozen gases whose release could potentially hasten the greenhouse effect.

Drilling in the deep ocean off the coast of southern Chile, scientists for the internationally funded Ocean Drilling Program obtained cores of sediment and rock near a feature called the Chile Triple Junction. The feature marks the juncture where the Chile Rise joins with the Chile Trench. The Chile Rise makes up part of the chain of undersea volcanic mountains that seams the world like stitching on a baseball. The trench is one of the deep oceanic troughs that outline the Pacific Ocean.

The tectonic plates that make up Earth's surface move apart at mid-ocean spreading ridges like the Chile Rise. Lava quietly erupts from undersea volcanic vents to form new oceanic crust that fills the gap between the separating plates. Ocean trenches, the the ocean floor's deepest depressions, are formed when one plate plunges or subducts beneath the other and is recycled back into Earth's mantle.

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At a point along the southern Chilean coast near the Taitao Peninsula, two oceanic plates that are still spreading apart along the Chile Rise are being forced underneath the South American Plate. The point at which the spreading ridge meets the trench is known as a "triple junction," because three of Earth's mobile, crustal plates meet at this point. The junction creeps northward along the trench at about 6 centimeters a year, imperceptibly slowly in human terms, but quickly as geologic events go. Seafloor spreading and plate subduction create mountains and volcanoes, like those of the Andes, and earthquakes, like that which devastated Chile in 1960.

Oceanic crust carries a thick layer of sediments. When an oceanic plate plunges beneath another plate, these sediments are often scraped off onto the overriding plate, which acts like the blade of a bulldozer.

But scientists thought that as the high and rugged Chile Rise went under, it would tear away, or tectonically erode, the bottom of the overriding plate, dragging scraped-off sediment underneath and causing the front of the continental plate to sink more deeply into the sea.

The scientists drilled 10 holes at five sites in the region to obtain cores of sediment and rock:

--from the overriding plate, including sediments and sedimentary rock scraped off from the down-going plate

--from a 10-mile by 5-mile ridge of volcanic basement, the Taitao Ridge, which was thought possibly to be a fragment of the oceanic crust in the process of being broken off and stuck onto the South American plate.

To complicate the drilling plan, geophysical evidence indicated a layer of gas hydrate within the sedimentary sequence. Gas hydrate is an ice-like mixture of natural gas (methane) and water that forms under the great pressures and low temperatures present in some deep-sea sediments. Like carbon dioxide, methane is a potent greenhouse gas, which can trap the sun's heat in the earth's atmosphere and raise the overall temperature. If marine gas hydrates melted in response to a small increase in the sea's temperature, the released gases could amplify the greenhouse effect.

Although the hydrates in the drill pipe melted away before they could be brought to the surface, they nevertheless left tell-tale chemical evidence of their presence, which will help scientists understand how and where hydrates form. Drilling through the hydrate zone at the locations chosen proved safe; the hydrate did not serve as a seal for a petroleum "trap."

After penetrating the hydrate layer, drilling proceeded through hundreds of meters of silts, clays, sands and gravels, both soft and "lithified" (turned to stone by heat). This material represented the deposition of sediments brought down by glaciers from the Andes mountains during the Pliocene and Pleistocene epochs (about 5 million years ago to the present). The subducting plate has left a welter of sediments and sedimentary rocks that have been fractured, folded and even tilted vertically.

Temperatures measured in the drill hole and chemical studies of the fluids in the sediments indicated that large quantities of heated water flow through the sediments in complex ways and through constricted conduits. This water is squeezed out of the sediments as they are scraped off the downgoing plate. This process is of immense importance to the chemistry of the oceans, and hence to the world's climate because it represents a major re-cycling of many of the chemicals dissolved in sea water.

The scientists found in the water traces of hydrocarbon gases chemically altered to compositions similar to petroleum that were transported into the area from great depths. They had expected that heat from the Chile Rise, as it was subducted under the South American plate, would drive the movement of this water by convection. Surprisingly, at the site where this effect was expected to be strongest, evidence for movement of extremely hot fluids was not found.

Drilling on the Taitao Ridge cored young volcanic rocks. These proved not to be basalts typical of oceanic crust, but to include dacites, more typical of the volcanoes of the Andes mountains. Scientists therefore found the Taitao Ridge had formed more complexly than they had expected; more study of the cores of volcanic rock will be needed before there is a clear answer to how the ridge was formed.

The scientists also found that the subduction of the Chile Rise spreading ridge is indeed causing material to be tectonically eroded from the bottom of the overriding South American plate, Texas A&M University, as science operator, operates and staffs the drill ship and retrieves cores from strategic sites around the world. The science operator also ensures that adequate scientific analyses are performed on the cores. To do this, Texas A&M maintains shipboard scientific labs and provides logistical and technical support for shipboard scientific teams. On shore,in the Texas A&M University Research Park, the science operator manages post-cruise activities, curates the cores and publishes the scientific results.

Lamont-Doherty Geological Observatory of Columbia University is responsible for downhole logging.

Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), an international group of scientists, provides scientific planning and program advice. Joint Oceanographic Institutions (JOI Inc.), a nonprofit consortium of 10 major U.S. oceanographic institutions, manages the program

"This ship ends its three-year exploration of the Pacific Ocean at the end of 1992," said Dr. Philip D. Rabinowitz, director. "We will return to the Atlantic Ocean where our first series of cruises will explore changes in global climate and sea level, the opening of the Arctic gateways and the breakup of continents."

Note: JOIDES institutions are University of California at San Diego; Columbia University; University of Hawaii; University of Miami; Oregon State University; University of Rhode Island; Texas A&M University; University of Texas at Austin; University of Washington; and Woods Hole Oceanographic Institution.

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