Slab of sunken ocean floor found deep within Earth

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Deep within Earth, halfway to its center in an area where Earth's core meets its mantle, lies a massive folded slab of rock that once was the ocean floor, reports a team of researchers in the current issue of *Nature*.

The slab, which sank beneath North America some 50 million years ago, holds important clues as to the behavior and composition of the deep interior of Earth and it could help explain how surface features such as volcanos and earthquakes form, the researchers say.

The research team, led by seismologists at the University of California, Santa Cruz, detected the slab by analyzing seismic waves reflected from the deepest layer of the mantle beneath an area off the west coast of Central America. The team includes Edward Garnero of Arizona State University, Alexander Hutko and Thorne Lay of UC-Santa Cruz, and Justin Revenaugh of the University of Minnesota. They describe their discovery in "Seismic detection of folded, subducted lithosphere at the core-mantle boundary," in the May 18 issue of *Nature*.

"In this one location we see quite strong evidence for whole mantle circulation," said Garnero, an ASU seismologist. "Slabs descending deep into the mantle are thought to drive the convective system found within Earth. They are dense and fall into the mantle. But they are connected to the outer shell that includes the oceanic crust."

"It's like a carpet sliding off the dining room table," Garnero added. "If it is more than half way off, it just goes taking everything with it."

The discovery sheds new light on the processes that drive the movement of Earth's tectonic plates. Earth's outermost layer, its lithosphere, is broken into large, rigid plates composed of the crust and the outer layer of the mantle. New plate material is created at mid-oceanic ridges, where the ocean floor spreads apart, and old plate material is consumed in subduction zones, where one plate dives beneath another. But the fate of subducted lithosphere has been uncertain, at least until this slab was detected.

Garnero said there is an on going debate over whether subducted slabs sink all the way down to the base of the mantle or get trapped in the upper mantle. The new evidence favors the presence of subducted slabs in the deep mantle and, if this is the case, then finding this slab could have significant ramifications for our understanding of the inner workings of Earth.

"It is becoming clear that Earth's interior is rich in complexity," Garnero said. "Earthquakes, volcanoes and large pieces of Earth's outermost layer or 'plates,' slowly move, grinding and shifting. All of these point to a dynamical system within the planet, so this discovery could shed light on large scale circulation of rock in Earth's interior, which in turn shifts the tectonic plates, and the nature of the chemistry of material deep in Earth's interior."

Within the mantle, which extends to a depth of about 1,800 miles (2,900 kilometers), cold rock sinks while hot plumes rise toward the surface, and this slow circulation of mantle rock is thought to drive the movement of Earth's tectonic plates. The base of the mantle absorbs heat from the core. The researchers were able to image the buckling and folding of the subducted oceanic slab at the base of the mantle because of the temperature difference between the relatively cool slab and the hotter mantle rock surrounding it.

The researchers used seismic data from earthquakes in South America that were recorded at seismographic stations in the western United States. The researchers analyzed the data with techniques adapted from oil exploration industry to study complex structures in Earth's crust.

"Alex Hutko employed a method that takes hundreds of recordings that all sample the same volume in the deep mantle, and reconstructs an image of reflective surfaces that give rise to the specific bumps and wiggles on the seismograms in a technique called 'migration,'" Garnero said. "This is the most accurate deep mantle imaging effort to date."

Using the method, the researchers found the subducted slab is composed of essentially the same minerals as the surrounding mantle, but its temperature is about 700 degrees Celsius cooler. This temperature difference affects the location of a "phase transition," where the crystal structure of the mantle rock compresses to a more compact form due to increasing pressure and temperature with depth. Seismic energy reflected by this phase transition revealed an abrupt step in the phase boundary about 60 miles (100 kilometers) high.

The researchers also saw evidence of hot plume-like structures at the edge of the slab, indicating possible upwelling of hot material from the base of the mantle as the spreading slab pushes into it.

"Since there is a conservation of mass in the mantle, something must return as the slab sinks into the Earth," Garnero said. "This return flow can include plumes of hot material that gives rise to volcanism."

"We are very excited about employing our migration approach to other regions in the mantle," Garnero added. "This study is just a starting point for bringing once blurry or obscured structures into sharper focus."

Source: Arizona State University

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