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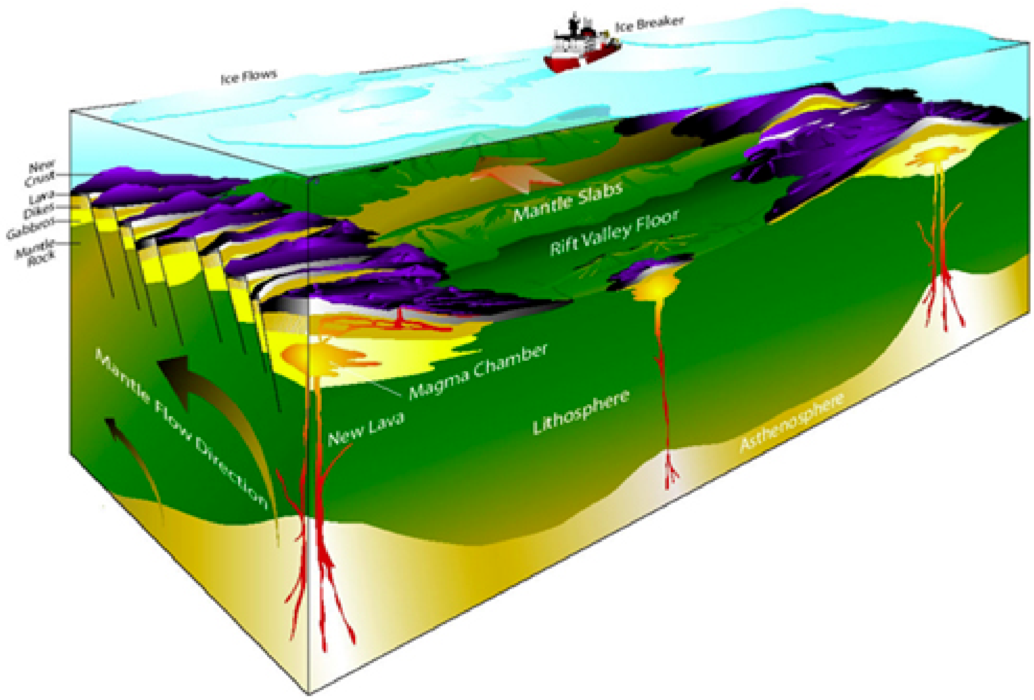
Ultraslow spreading centers



In two of the deepest and most remote parts of the world, scientists have discovered a new class of "ultraslow" spreading ridge, where cold, solid slabs of mantle are being heaved to the surface to build new seafloor. The new findings may require the rewriting of marine geology textbooks and cause geoscientists to rethink their understanding of the mid-ocean ridge system.

Henry Dick and colleagues at the Woods Hole Oceanographic Institution (WHOI) found the ultraslow ridges on the Southwest Indian Ridge, the plate boundary between Africa and Antarctica, and the Gakkel Ridge, which stretches 1,800 kilometers under the Arctic Ocean from Greenland to Siberia.

Along most of the mid-ocean ridge system — the more than 55,000-kilometer long volcanic mountain chain that encircles the globe — volcanoes are regularly spaced and new seafloor forms magmatically from melted mantle that rises between separating tectonic plates and cools to form new crust.

A block model of the ultraslow spreading Gakkel Ridge showing both amagmatic (center) and magmatic (front and back) segments. Included for scale is a drawing of the U.S. Coast Guard Cutter Healy, the icebreaker that researchers used to study the ridge. Image by Dr. Henry J.B. Dick & Paul Oberlander / Woods Hole Oceanographic Institution. Click here for larger image.

On ultraslow ridges, those with spreading rates less than 12 millimeters per year, the volcanoes are widely spaced and linked by amagmatic segments. Despite the non-volcanic nature of these sections, the WHOI team reports in the Nov. 27 *Nature* that they nonetheless produce new seafloor as cold, solid blocks of the mantle rock peridotite rise through the rift valley floor and accrete to its walls.

"Dick and colleagues show that ridges exhibit fascinating behavior when the spreading rate is ultraslow," wrote Jason Phipps Morgan, a marine geologist at the GEOMAR Research Center for Marine Geosciences in Kiel Germany, in a *Nature* commentary.

Traditionally, marine geologists have classified ridges by their spreading rates, with each category exhibiting certain morphology. Slow-spreading ridges (those that move less than 55 millimeters per year) are wide and have deep rift valleys. Faster ridges (those that move 80 to 180 millimeters per year) are narrow and tall with only a slight depression at their summits. Intermediate ridges (55 to 70 millimeters per year) alternately exhibit features of both slow and fast ridges.

Although ridge morphology is not strictly dependent on spreading rate, the researchers found that the variables that affect it, such as ridge geometry, mantle composition and thermal flow, have a much greater influence when the spreading rate drops below 20 millimeters per year. Roughly one-third of the mid-ocean ridge system, about 20,000 kilometers, falls into that category.

On the slowest of these ridges, researchers found that the magmatic portions exhibit a deep rift valley with staircase-like faults along the walls, while the amagmatic portions have a central trough about one kilometer deep that can be up to 50 kilometers across. However, the authors note, these features can also be seen in ridges with spreading rates up to 20 millimeters per year.

The only "ultraslow ridges that are currently active include highly oblique sections of the Southwest Indian Ridge and several sections of the Arctic Ridge System in addition to the Gakkel," Dick says. The features of these ridges are so different from their faster spreading relatives that they constitute an entirely new class of ridge, the authors say.

For example, on most of the mid-ocean ridge, oceanic crust averages about 6 kilometers thick and has a typical layered structure: Extrusive lavas overlay dikes, which overlay gabbros, which sit on top of mantle rocks. However, "in ultraslow ridges, it appears that in many places, the crustal layer is extremely thin or missing altogether," says co-author Jian Lin, a marine geologist at WHOI.

The team also noted an uncommon lack of transform faults. On the mid-ocean ridge, transform faults are believed to take up the stress between adjacent blocks of new seafloor. The finding that the Gakkel ridge appears to lack transform faults therefore has implications for the current understanding of their role in plate tectonics, Lin says.

In rocks dredged from the seafloor along ultraslow ridges, researchers found abundant amounts of serpentine, a weak rock created when peridotite is exposed to seawater. One idea that requires further study, Lin says, is whether serpentine could be filling the cracks between the blocks, and therefore, possibly also fulfilling the role of transform faults.

Weak serpentine could also be responsible for the unusual seismic behavior at ultraslow ridges. Because ultraslow ridges are colder than faster ridges, geologists expected the lithosphere to be thicker and more brittle and therefore have larger earthquakes. However, Lin says, the earthquakes recorded on ultraslow ridges have been unusually small.

"The apparent lack of larger quakes could be due to a combination of two effects," he says, "the lack of transform faults, where larger earthquakes could otherwise occur, and the abundance of serpentine rocks, which are mechanically very weak." Both factors could be preventing the stick-slip action that causes quakes along faults in areas with more rigid rocks.

More research, however, is needed. And despite the remoteness and prohibitive logistics involved in studying ultraslow ridges, more work will be done, Lin says. "There is a lot yet to be learned about the seafloor geology, volcanism, seismics, rock rheology, geochemistry, hydrothermalism and biology of ultraslow ridges."

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