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Mapping of magnetic stripes to discover how fast ocean crust is created

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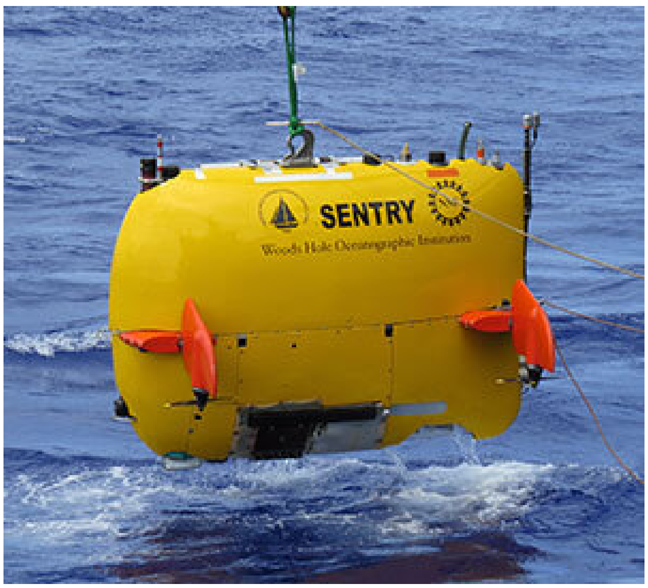


The Sentry, an autonomous undersea vehicle, was used to map the magnetic stripes in Pito Deep, a large chasm in the Pacific Ocean that provides a cross-section of samples of lower oceanic crust. Michael Cheadle and Barbara John, both UW professors of geology and geophysics, contributed to a paper titled "Three-Dimensional Magnetic Stripes Require Slow Cooling in Fast-Spread Lower Ocean Crust" that was published Sept. 23 in *Nature*. Credit: Michael Cheadle

Two University of Wyoming researchers are part of the first-ever mapping of magnetic stripes—one of the foundations of plate tectonics—within the lower gabbroic section of fast-spreading oceanic crust.

In the process, the group may have potentially solved a 30-year-old question of scientific debate: At what speed does fast-spreading oceanic crust form?

"This has never been done before. The magnetic stripes are a record of how the Earth's magnetic field changes through time and, in particular, how the Earth's magnetic field flips or reverses when the magnetic North Pole becomes the magnetic South Pole and vice versa," says Michael Cheadle, a professor in the UW Department of Geology and Geophysics. "This mapping in the third dimension is exciting in itself because the magnetic stripes, first discovered in the early 1960s, provided some of the key evidence for the theory of plate tectonics—the theory that explains how and why we get mountain ranges, ocean basins, volcanoes and earthquakes."

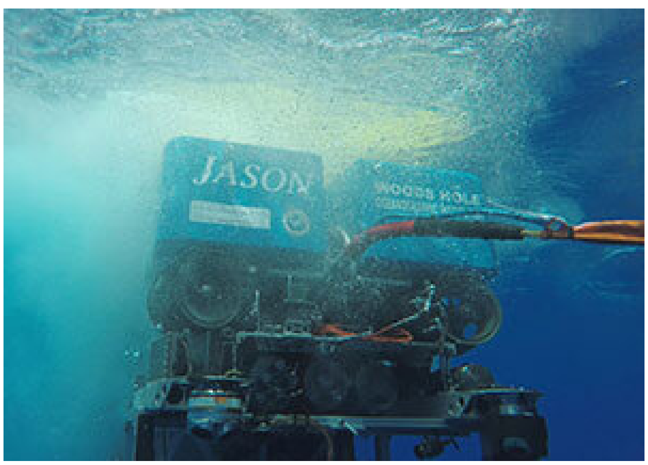
Cheadle is a third author of a new study that is highlighted in a paper titled "Three-Dimensional Magnetic Stripes Require Slow Cooling in Fast-Spread Lower Ocean Crust" that was published today in *Nature*, an international weekly journal of science.

Cheadle and Barbara John, a UW professor of geology and geophysics, the paper's fourth author, and Jeff Gee, a professor of geosciences at the University of California-San Diego's Scripps Institution of Oceanography, designed the experiment, as well as carried out sample and data collection. Sarah Maher, a Ph.D. student at the Scripps Institution of Oceanography, is the paper's lead author. She and Gee completed the data processing and analysis.

The manuscript addresses the question of how fast-spread ocean crust—which accounts for 40 percent of oceanic crust and, therefore, 25 percent of the Earth's surface—cools and forms using novel applications of crustal magnetization. The shape of the magnetic stripes in the third dimension shows the ocean crust actually cools very slowly.

"So, we've just placed a major constraint on how a quarter of planet Earth's crust forms," Cheadle says of the study's results.

Cheadle, John and Gee were the three principal investigators on the cruise to Pito Deep in 2017. Located near Easter Island, Pito Deep is a large chasm, which is one of the few places in the Pacific Ocean that allows sampling of a cross-section of lower oceanic crust. Pito Deep is approximately 3.5 kilometers deep, which is about twice the depth of the Grand Canyon.



Jason II, a remotely operated robot submarine connected by cable to the ship, was used to collect the rock samples from the seafloor. Credit: Lucas Kavanagh

Ocean crust is created at midocean ridges and forms by freezing and crystallization of magma, which is produced by melting of the Earth's mantle. That magma has a temperature of 1,200 degrees Celsius when it first escapes from the mantle before it cools and solidifies into rock. As it cools below 580 degrees Celsius, it becomes magnetized and traps a record of the orientation of the Earth's magnetic field at that time. As a result, it records the periodic flips or reversals of the polarity of the Earth's magnetic field, when the magnetic North Pole becomes the magnetic South Pole, and vice versa. These polarity reversals lead to the normally magnetized and reversely magnetic stripes of ocean crust.

"The magnetic stripes can be considered to be a tape recording of the history of the Earth's magnetic field," Cheadle says. "And the pattern of that tape recording shows that fast-spread oceanic crust must have cooled very slowly."

The research team documented a subhorizontal magnetic stripe or polarity boundary that extends over 8 kilometers from the paleo-spreading axis. To do so, the group used Sentry, an autonomous submarine, to map the seafloor magnetization of gabbroic rock over two 8- to 10-kilometer-long regions and made direct measurements of the magnetic polarity of more than 200 oriented samples collected by Jason II, a remotely operated submarine. Gabbroic rock is the frozen magma that forms a magma chamber below volcanoes, which erupts lava on the seafloor.

Ocean crust preserves changes in magnetic field polarity and intensity as it cools through its lock-in or blocking temperature. This occurs either instantaneously, as in the lava section, which flash cools on eruption; or more slowly in the deeper gabbro section. The geometry of the recorded boundaries between normal and reversely magnetized rocks in the crustal cross-section thus reflects the past cooling history of the ocean crust.

The research leads to two important, testable predictions from the study's results, Cheadle says.

"First, we suggest that our cooling model is consistent with 100- to

200-meter offset faults that occur 8 to 10 kilometers off axis, allowing for deep hydrothermal circulation," Cheadle says. "If correct, this implies there is a significant area of relatively unexplored, likely diffuse, hydrothermal circulation occurring about 10 kilometers off axis at fast-spread ridges.

"Secondly, our results imply only shallow earthquakes would occur within 8 to 10 kilometers of the spreading axis," he continues. "Our results have widespread implications across multiple fields of geoscience, including formation of the Earth's crust, fluid flow within the oceans, geochemistry and seismology."

More information: Sarah M. Maher et al, Three-dimensional magnetic stripes require slow cooling in fast-spread lower ocean crust, *Nature* (2021). DOI: 10.1038/s41586-021-03831-6

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