

Research reveals limitations of seismic data for mapping rock units in young oceanic crust

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Researchers report that an approach used for years to understand the structure of Earth's oceanic crust is flawed and geoscientists will have reconsider the correspondence between seismic data and rock units when mapping formations of young oceanic crust.

The new finding alters the view of how new crust is formed at mid-ocean ridges, how heat and chemicals flow through oceanic crust and how life can exist in the hot, inhospitable environment deep below the seafloor.

Scientists Gail Christeson and Kirk McIntosh from the Institute for Geophysics at The University of Texas at Austin's Jackson School of Geosciences, and Jeffrey Karson from Syracuse University, publish their findings in this week's edition of *Nature*.

Their research reveals that seismic data, widely used by geoscientists to create a picture of the geology below the seafloor, cannot reliably map the boundaries between rock units in young oceanic crust. Despite this limitation, seismic data may hold keys to understanding how fluids reside and circulate through the crust and the limits of the subsurface biosphere.

The researchers' article, "Inconsistent correlation of seismic layer 2a and lava layer thickness in oceanic crust," is based on the results of two

geophysical research cruises to the Hess Deep rift and the Blanco transform fault in the Pacific Ocean, rare locations where young oceanic crust is exposed along steep scarps revealing the layered geologic units.

Oceanic crust makes up two-thirds of the Earth's surface. It is made of igneous rock and formed at mid-ocean ridges, the largest volcanic system on our planet, from melting in the mantle. Eventually, oceanic crust is consumed at major earthquake-generating deep-sea trenches.

The oceanic crust has been studied by geophysicists and geologists for many years—geophysicists using remote sensing techniques such as seismic exploration, and geologists with samples and direct observations. In part because of their different perspectives and techniques, geologists and geophysicists have been at odds over the basic definitions of oceanic crustal structure.

Geologists typically describe an upper layer of basaltic lavas, a middle layer of basaltic intrusive rock units, known as dykes, and a lower layer of gabbroic rocks. The top layer of lavas formed when magma, or molten rock, erupted onto the seafloor. The middle layer of dykes were created as molten rock from the underlying magma chamber intruded into incrementally opening cracks at a spreading center, with younger dykes cross-cutting older dykes, eventually creating a massive collection of rock units referred to as a sheeted dyke complex. The incremental infilling of cracks above a magma chamber is the essence of seafloor spreading.

Geophysicists divide oceanic crust (beneath any sedimentary material) into two basic layers, layer 2 and layer 3. Layer 2 is typically subdivided further into layers 2A and 2B. Layer 2A, the subject of the report in *Nature*, is a commonly imaged horizon in the seismic data, known as the 2A reflector, which numerous studies have mapped over extensive regions of young oceanic crust.

The problem with trying to reconcile the two models of the structure of oceanic crust is that while seismic methods can be used to probe deeply into the crust and gather data over unlimited distances, the interpretation of results is usually by inference. Geologic methods, on the other hand, provide direct evidence and observation, but are limited by the few outcrops and drill holes where samples from the crust can be collected, and by the limitation of observing outcrop data with submersibles.

"Our work addressed the extent to which seismic boundaries within the crust correlate with rock units at the Hess Deep rift and the Blanco transform fault," explained co-investigator McIntosh, "where nature offers a rare glimpse of what lies beneath the seafloor and the Earth's crust-making processes."

"Places like Hess Deep rift and the Blanco transform provide windows into the internal structure of the oceanic crust in cliffs that are on the scale of the walls of the Grand Canyon— more than a mile high," said Karson, co-investigator on the project and a professor in the Department of Earth Sciences at Syracuse University.

Because of the exposures at Hess Deep and the Blanco transform fault, the researchers were able to compare the seismic structure of upper oceanic crust with the known geology of the crust exposed and mapped by previous submersible dives.

"Prior to our study, there were no links between the geologic and seismological structure of oceanic crust except at a few deep drill holes," said Christeson.

The research shows that while the layer 2A reflector is imaged near the top of the sheeted dyke complex at the Hess Deep rift, it is imaged far above the sheeted dykes section at the Blanco transform fault—a finding that does not support the hypothesis that seismic reflector 2A represents

a geologic boundary between two different rock units.

"Many researchers interpret seismic reflector 2A as the geologic boundary between the upper layer of lavas and the underlying sheeted dykes," said Christeson. "Our work shows that we can't reliably use seismic methods to map the boundary between lavas and dykes in young oceanic crust."

"However, the seismic data maps porosity," said Karson. "Microbes live in this pore space—a very exciting frontier of geology/biology."

The results also undermine an alternative hypothesis that the 2A reflector is associated with a chemical alteration boundary zone within the upper lava unit, raising the question: What are these seismic differences mapping?

"We propose that the 2A reflector corresponds to a chemical alteration front associated with a feature—possible a crack where minerals can precipitate as a result of increased temperature and decreased porosity," said Christeson. "Such a hydrothermal alteration zone can occur either within the lava section or near the top of the sheeted dyke complex of oceanic crust."

The work carried out at Hess Deep and the Blanco transform fault expands geologists and geophysicists' understanding of the relationship between the seismic boundaries and the rock units of oceanic crust and provides a new avenue of research to learn more about the porosity structure of the upper oceanic crust.

Source: University of Texas at Austin

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