IT'S IN THE SHEAR: FASTER PLATES, MORE DEFORMATION, MORE VOLCANOES

Most of the volcanism that occurs on Earth happens at the boundaries between tectonic plates, such as subduction zones and mid-ocean ridges. Some volcanoes do form in the interior of the plates, however — and the source of that volcanism is more difficult to explain. Now, researchers have found a way to connect this volcanism to mantle circulation on a global scale.

Intraplate volcanism — not including deep mantle plume-fed volcanism, such as at the hot spot of Hawaii — occurs somewhat mysteriously in many places around the world. Volcanoes have occurred far from either plate boundaries or mantle plumes, in places such as southwestern North America (for example, the proposed nuclear waste repository at Yucca Mountain in Nevada lies near a recently active volcanic field), eastern Australia, southern Europe and even Antarctica.

Scientists have theorized that a range of local processes — such as cracks in the lithosphere as a result of crustal extension, or small upwelling plumes — may be the source of the magma in these different regions. Another possibility is mantle melting from a process known as shearing: As a tectonic plate slides heavily across the upper mantle, it warps and stresses the region between the mantle and plate, creating a zone of deformation. That deformation, or shearing, can become amplified in existing regions of weakness, such as pockets of mantle that are more prone to melting. That, in turn, can cause the mantle to rise and melt, producing volcanism.

But these are all local processes, says Clint Conrad, a geodynamicist at the University of Hawaii at Manoa and the lead author of the new study published in Nature Geoscience. Focusing on these local processes may obscure the bigger picture, he says: how this intraplate volcanism can be connected to mantle convection on a global scale.

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> – Clint Conrad, University of Hawaii at Manoa

The link, Conrad says, is how rapidly the plate is moving, and thus causing shearing in the upper part of the mantle, or asthenosphere. In theory, he says, the faster the plate moves, the more shearing, and thus the more deformation will occur — enhancing melting. The most likely spots for intraplate volcanism, therefore, would be where the plates move most rapidly.

To test this idea, Conrad and his team used a model of global mantle flow to estimate rates of asthenospheric shear around the world. "We know the plate motions on the surface fairly well," he says. "What we don't know is the mantle flow" — the circulation of mantle beneath the plates. The team modeled the flow based on a range of existing data about Earth's present and its past, including seismic tomography — three-dimensional images of Earth's interior from seismic waves — and rates of isostatic rebound since the last glacial maximum. Using all of those data, Conrad says, "we can solve the fluid dynamic equations and calculate the flow in the mantle for the present day."

Using this mantle flow model, the team identified regions of particularly high shear — and then compared those regions with regions of intraplate volcanism, both on land and on the seafloor. "Basically, everywhere we see high shear, we see some volcanism," Conrad says.

The link that Conrad's team has drawn between volcanism and rapid asthenospheric shearing makes a great deal of intuitive sense, says William McDonough, a geologist at the University of Maryland. "The hard work was demonstrating, as clearly as they do, that there is a clean cause-and-effect relationship between where the volcanoes are and where there is shearing ongoing in the mantle."

It's important to understand the mechanisms that cause volcanism in any area, whether it is intraplate or at a plate boundary, Conrad says. "If we can understand the processes involved, we might be able to make additional predictions about which areas of Earth are more prone to volcanism." That, he adds, could be particularly helpful in assessing volcanic dangers.

Carolyn Gramling

NASA/JPL-Caltech

news shorts

Stardust's last days

After 12 years in service, NASA's Stardust spacecraft burned its last fuel and drifted quietly into outer space where it will permanently orbit the sun. Stardust was sent into orbit in 1999 to pass through a cloud of dust and gas surrounding comet Wild 2, which it did in 2004, sending back data and images about the cloud's makeup, as well as sending back to Earth a canister filled with sample particles. The spacecraft also flew past comet Tempel 1 this spring, capturing images of the crater left behind when a projectile launched by the Deep Impact spacecraft crashed into the comet in 2005.

NASA press release, March 24, 2011.