Researchers discover 'missing' piece of Hawaii's formation

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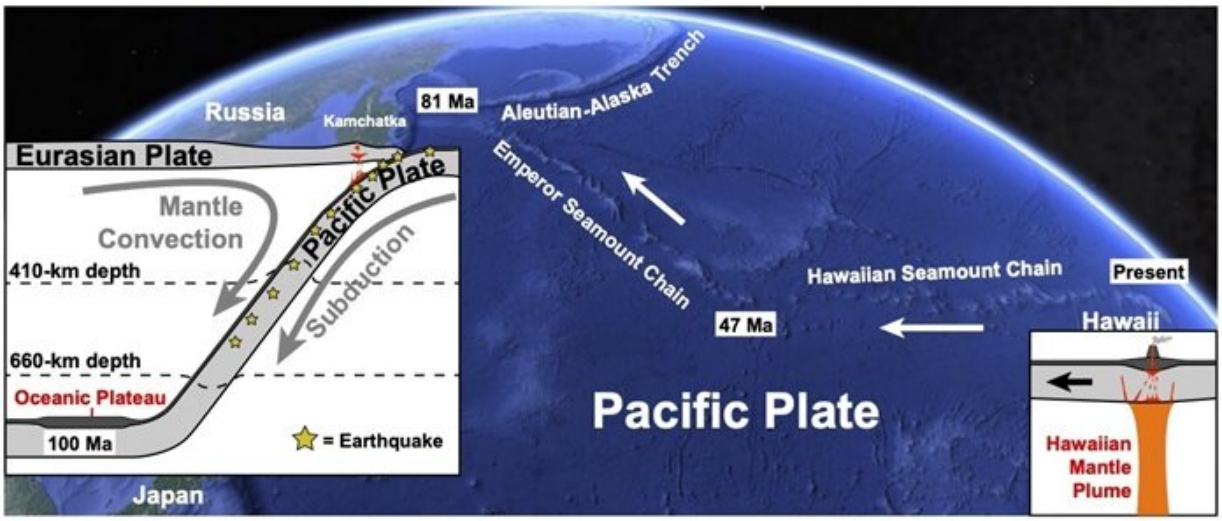

The journey of Hawaii's pancake from its creation at the mantle plume to where it slipped under the Pacific plate and sunk deep into the Earth's mantle. Credit: Michigan State University

An oceanic plateau has been observed for the first time in the Earth's lower mantle, 800 kilometers deep underneath Eastern Siberia, pushing Hawaii's birthplace back to 100 million years, says a Michigan State University geophysicist.

The discovery came when Songqiao "Shawn" Wei, an Endowed Assistant Professor of Geological Sciences in MSU's Department of

Earth and Environmental Sciences, noticed something unusual in his data using groundbreaking techniques. Wei's research will be published on Nov. 20 in the journal *Science*.

The Earth's mantle is mostly solid, but at a mid-ocean ridge it melts creating new oceanic crust between two tectonic plates such as the Pacific Plate. Typically, this new Pacific Ocean crust has a uniform thickness of four miles, Wei said.

As the plates continue to move, a hot plume of solid rocks slowly rises in the mantle melting the tectonic plate to create volcanoes like the Hawaiian Islands. The mantle plume has a mushroom-like shape with a wide head that is thousands of miles across and a thin tail that is only of a few hundred miles across.

Wei said once this mushroom head reaches the Earth's surface in the ocean, it stretches and flattens out, while it melts the overriding tectonic plate to form a pancake-shaped 20-mile-thick oceanic plateau. This process continues as more of the mantle reaches the surface and the overriding plate continues to move. Over time, what remains is a dotted trail of islands.

"Normally, you would see a pancake-shaped oceanic plateau created by the mushroom's head followed by a dotted chain of islands created by the mushroom's tail," Wei said. "The Hawaiian Islands are the end of the tail but where is Hawaii's pancake head?"

There are still debates on whether every mantle plume creates a "pancake" during its earliest history, and the ultimate destination of these pancake-shaped oceanic plateaus. Trying to find ancient oceanic crust, including old oceanic plateaus, is difficult because the crust might have subducted or slid into or underneath an oceanic trench and disappeared from the Earth's surface.

Although scientists generally believe the oceanic crust is preserved in the Earth's mantle after subduction, it is usually too thin to be observed using conventional technology, such as seismic tomography. Up until now, this is what Wei thought happened to Hawaii's "pancake" until he detected a surprising signal in the data.

"I spotted an unusually thick chunk of oceanic crust about 500 miles beneath the Earth's surface," he said. "The thickness of this piece of crust made it distinguishable, but it was still too thin and too deep to be easily found."

Wei and his team compiled the largest dataset of a specific type of seismograms and conducted big data analysis and numerical simulations on the High-Performance Computing Cluster managed by the MSU Institute for Cyber-Enabled Research. His collaborators include: Peter M. Shearer from Scripps Institute of Oceanography; Carolina Lithgow-Bertelloni and Lars Stixrude from the University of California, Los Angeles; and Dongdong Tian from MSU.

The team also combined the strengths of seismic tomography, seismic reflection and mineral physics. Seismic tomography from previously published work creates a 3-D image which revealed a vague image of the ancient Pacific Plate in the mantle. Seismic reflection results —the core observation of this work—helped the researchers find the thick crust at great depths. Mineral physics was used by the team to prove that the detected signal indicates a piece of oceanic plateau.

Plate reconstruction modeling helped the researchers link the newly found oceanic plateau to the Hawaiian "pancake" that was created during the formation of the Hawaii hotspot approximately 100 million years ago.

One hypothesis is that the Hawaii "pancake" broke into two pieces.

One piece was part of the Izanagi Plate which subducted into the Aleutian Trench and disappeared about 70-80 million years ago. The other piece was part of the Pacific Plate and after it entered the Kamchatka Trench 20-30 million years ago, the heavy oceanic crust sunk deep into the Earth's mantle later until Wei and his team spotted it.

This discovery not only provides clues of Hawaii's early history, but also sheds light on the evolution of other hotspots, seamounts and oceanic plates.The researchers plan to use this new technique combining seismic tomography, seismic reflection and mineral physics to find other "missing pancakes" and to continue looking for evidence of older pieces of Earth's oceanic crust in the deep Earth.

More information: Songqiao Shawn Wei et al. Oceanic plateau of the Hawaiian mantle plume head subducted to the uppermost lower mantle, *Science* (2020). DOI: 10.1126/science.abd0312

Provided by Michigan State University