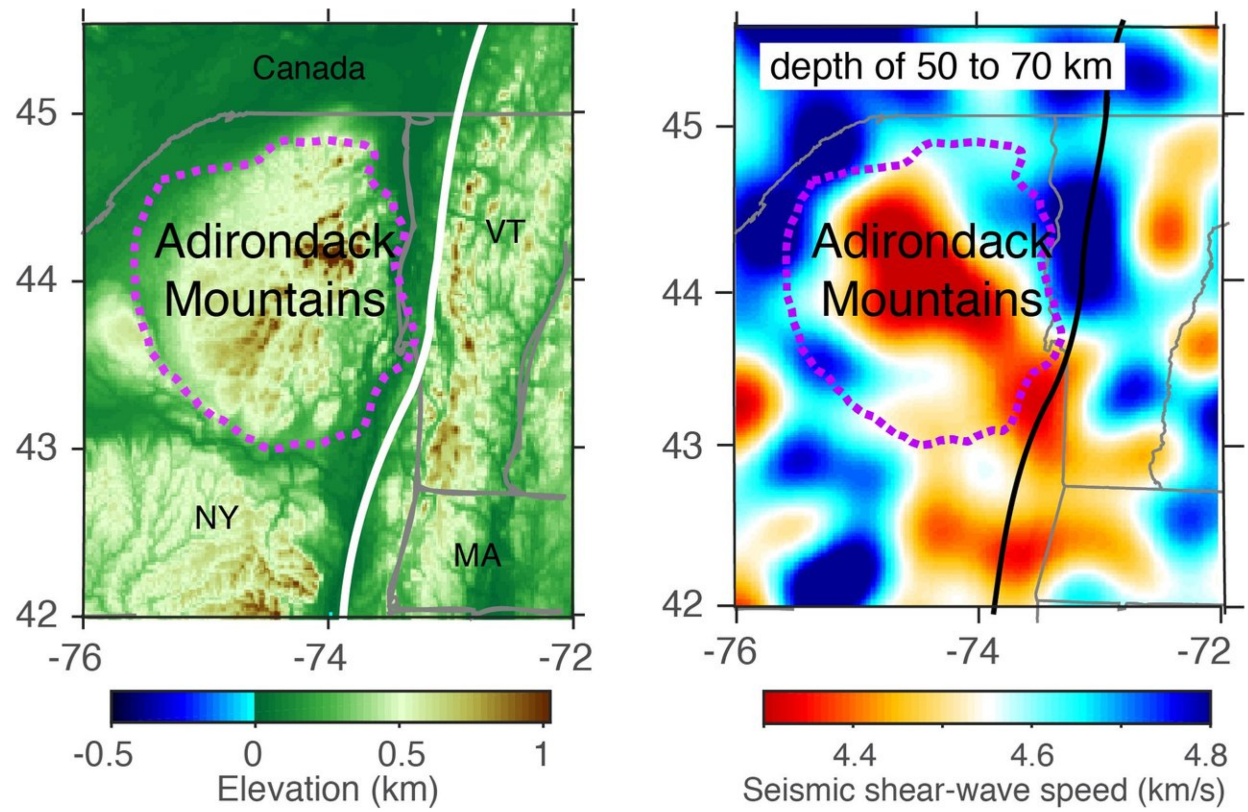
Geoscientists offer new evidence for how the Adirondack Mountains formed

June 26 2018



UMass Amherst geoscience researchrs say a column of lighter material appears to have squeezed up under the Adirondacks, possibly expanded by heat, to form the dome-shaped mountain range. Credit: UMass Amherst/X. Yang

The formation mechanism of the Adirondack Mountains in upstate New York has long posed a geologic mystery, say seismology researchers at the nearby University of Massachusetts Amherst. A few have been proposed, but until recently tools for evaluating them were not in place, say postdoctoral fellow Xiaotao Yang and assistant professor Haiying Gao.

Now, using an advanced seismic imaging method and data available only in the past five years, they have constructed a detailed model of the tectonic plate—the crust and the uppermost rigid mantle of the lithosphere under the northeast United States—down to about 62 miles (100 km), in which they discovered a "pillow" of low-density, relatively light rock material. They say a column of this lighter material appears to have squeezed up under the Adirondacks, possibly expanded by heat, to form the dome-shaped mountains.

"For the first time, we have some direct evidence of structures beneath the Adirondack Mountains, and we show that this feature and a past period of uplift are connected to a much larger-scale, regional situation," Yang says.

"We propose that geologic processes triggered the flow of this lower density, relatively light and buoyant low-velocity material from a large reservoir into a fracture or a vacant space and it accumulated there in a column and was lifted up. It also may have been hot and thermally expanded." Details appear in the American Geophysical Union journal, *Geophysical Research Letters*.

One way the researchers can differentiate this pillow and column of anomalous material is by measuring the speed of seismic waves traveling through the Earth, Yang explains. "Seismic waves travel more slowly through the low-density, low-velocity material compared to surrounding rocks."

He and Gao mapped this low-velocity material at about 31 to 52 miles

(50-85 km) beneath the Adirondack Mountains. "These low-speed features may have resulted from the rising of asthenosphere, a weak layer beneath the lithosphere," the researchers note. "The upward force of the upwelling asthenosphere flow, together with possible thermal expansion, may have provided the mechanism that formed the Adirondack Mountains."

The question of how different mountains formed has been around for many years, Yang says, and for very large features such as the 1,500-mile Appalachian Mountain range, tectonic plate boundary collision processes are relatively well understood. But for mountains that lie entirely within one fairly stable tectonic plate, known as intercratonic mountains, uplift mechanisms that are not boundary related, are less clear.

"We want to know more about the formation of this kind of mountains," Yang says. "Before this study, we suspected that the plate is being pushed up from below to form a dome, but there was no evidence for or against this idea."

For this work, he and Gao used data from the National Science Foundation's EarthScope program, a portable array of seismometers deployed across the U.S. and moved systematically from west to east over a number of years in the Lower 48 states. Data in the northeastern U.S. has been publicly available since 2013. Before EarthScope, collecting such data was "hit or miss," Yang says, because seismometers were unevenly and sparsely distributed.

"EarthScope provided much finer data coverage," he adds. "It provided a really unique opportunity to allow us to conduct this study, not only because of the density of stations, but they were evenly distributed which gave us more of a 3-D understanding of the features. To get a clearer picture, we exploited an advanced technique, involving simulation of seismic waves propagating in 3-D Earth."

"Instead of using earthquake waves, our technique extracts seismic waves from background noises between each two stations, taking advantage of the densely distributed seismic stations. You also need a way to handle the process of a huge amount of data," he adds. For this, they used the Massachusetts Green High Performance Computing Center in Holyoke, Massachusetts.

Based on their observations, he and Gao now believe that between 90 and 120 million years ago, the tectonic plate under the northeastern U.S. was passing over a geologic "hot spot," which is now under the western Atlantic Ocean, off the coast of Massachusetts, known as the New England seamounts. Some studies suggest that the New England region was uplifting at around that time, which could have resulted from hot spot heating. The hot-spot activities may also have contributed heat to processes forming the Adirondack Mountains.

In addition to funding from NSF and NSF's EarthScope program, this work was supported by start-up funding from UMass Amherst to Gao's seismology laboratory.

More information: Xiaotao Yang et al, Full-Wave Seismic Tomography in the Northeastern United States: New Insights into the Uplift Mechanism of the Adirondack Mountains, *Geophysical Research Letters* (2018). DOI: 10.1029/2018GL078438

Provided by University of Massachusetts Amherst

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