Tomographic imaging shows massive five-fingered Icelandic mantle plume

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Iceland. Credit: Jeff Schmaltz, MODIS Rapid Response Team, NASA/GSFC

(Phys.org)—A trio of researchers with the University of Cambridge and the University of Strathclyde has found evidence of a giant, five-fingered Icelandic mantel plume. In their paper published in the journal *Earth and Planetary Science Letters*, Charlotte Schoonman, Nicky White and David Pritchard describe how they carried out tomographic imaging of the area and developed a theory regarding why the plume has fingers.

Prior research has shown that Iceland and a large part of the area around it was very strongly impacted by a mantle plume beneath the area. Mantle plumes are chimney-like structures that move hot rock from deep within the planet to the surface. The one in that part of the world was responsible for the creation of the volcanoes that led to the formation of Iceland. Using tomographic imaging, the researchers found that the plume was semi-star shaped with five tendrils. Intrigued, they began searching for an explanation.

They noted earlier studies demonstrating how star-like structures form when fluids with different viscosities are mixed in a confined space, such as in a glass container. They further noted that at approximately 100 kilometers below the surface of the earth, there is a layer called the asthenosphere. It is a layer of soft rock that flows horizontally between two other layers of non-moving hard rock. The researchers suggest that the semi-star-shaped Icelandic plume got its shape the same way the stars did in the lab. Hot, runny rock was pulled up from below, and it then spread horizontally as it met the asthenosphere—at least on one side. On the other side of the plume, moving west, the crust beneath Greenland was so hard and thick that it created a barrier. Thus, the plumes only moved north and south and especially east—as far as Scotland and Norway.

The researchers suggest the fingers from the plume may even explain why coastal Norway and northern Scotland manage to stay above the water line despite both existing over unusually thin parts of the crust. The plume material is buoyant, they note, which suggests parts of

Norway and Scotland are actually floating.

More information: C.M. Schoonman et al, Radial viscous fingering of hot asthenosphere within the Icelandic plume beneath the North Atlantic Ocean, *Earth and Planetary Science Letters* (2017). DOI: 10.1016/j.epsl.2017.03.036

Abstract
The Icelandic mantle plume has had a significant influence on the geologic and oceanographic evolution of the North Atlantic Ocean during Cenozoic times. Full-waveform tomographic imaging of this region shows that the planform of this plume has a complex irregular shape with significant shear wave velocity anomalies lying beneath the lithospheric plates at a depth of 100–200 km. The distribution of these anomalies suggests that about five horizontal fingers extend radially beneath the fringing continental margins. The best-imaged fingers lie beneath the British Isles and beneath western Norway where significant departures from crustal isostatic equilibrium have been measured. Here, we propose that these radial fingers are generated by a phenomenon known as the Saffman–Taylor instability. Experimental and theoretical analyses show that fingering occurs when a less viscous fluid is injected into a more viscous fluid. In radial, miscible fingering, the wavelength and number of fingers are controlled by the mobility ratio (i.e. the ratio of viscosities), by the Péclet number (i.e. the ratio of advective and diffusive transport rates), and by the thickness of the horizontal layer into which fluid is injected. We combine shear wave velocity estimates with residual depth measurements around the Atlantic margins to estimate the planform distribution of temperature and viscosity within a horizontal asthenospheric layer beneath the lithospheric plate. Our estimates suggest that the mobility ratio is at least 20–50, that the Péclet number is O(104), and that the asthenospheric channel is 100±20 km thick. The existence and planform of fingering is consistent with experimental observations and with theoretical arguments. A useful rule

of thumb is that the wavelength of fingering is 5±1 times the thickness of the horizontal layer. Our proposal has been further tested by examining plumes of different vigor and planform (e.g. Hawaii, Cape Verde, Yellowstone). Our results support the notion that dynamic topography of the Earth's surface can be influenced by fast, irregular horizontal flow within thin, but rapidly evolving, asthenospheric fingers.