MANTLE DYNAMICS

A Deep Root for Iceland?

The island of Iceland, where fiery lava erupts to melt glacial ice, is perched atop a mantle plume—a column of hot rock rising slowly from Earth's interior. Similar plumes feed long-lived volcanic centers around the globe, such as Hawaii and the Galápagos. For decades, researchers have debated whether these plumes rise from the bottom of Earth's lower mantle, 2900 kilometers down, or are rooted only a few hundred kilometers down in the upper mantle (*Science*, 23 May 1997, p. 1198). The answer would determine whether the bulk of Earth's rocky mass is forever sealed off in the lower mantle or can mix into the upper mantle and so shape the surface. Now seismologists tracing the origin of Iceland's fires present the strongest support yet for deep plumes.

By studying earthquake waves that probed the mantle deep below Iceland, seismologist Yang Shen of the Woods Hole Oceanographic Institution in Massachusetts and his colleagues detected signs of a narrow, hot plume at the traditional boundary between upper and lower mantle, about 660 kilometers down. "I think it's pretty strong," geophysicist Donald Forsyth of Brown University says of the evidence, which Shen and his colleagues reported at the annual fall meeting of the American Geophysical Union in December. "It indicates [that] something with higher temperatures continues down to the lower mantle; I don't know any way to get around it with an upper mantle source" for the Iceland volcanic hot spot.

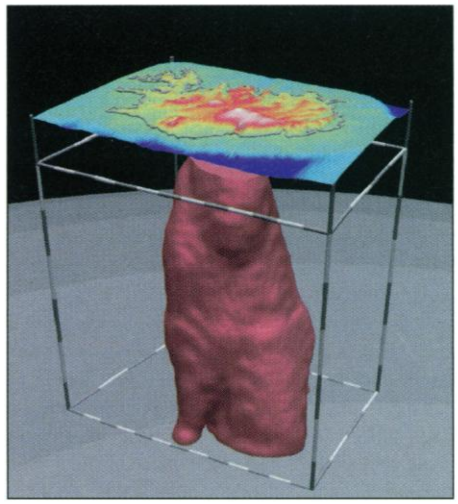
Seismic waves slow down as they pass through hot rock. By plotting wave speeds from distant earthquakes, seismologists had already created CT scan–like images of at least a shallow plume beneath Iceland. In these so-called tomographic images, a column of hot rock—perhaps a couple of hundred degrees hotter than its surroundings—extends from just beneath Iceland to about 400 kilometers down. It shows no sign of petering out with depth, but the tomographic image fades at that point because it depends on the paths of many seismic waves crossing within the plume. Seismic stations on Iceland itself can't see wave paths cross much below 400 kilometers, and distant stations have trouble resolving a narrow plume.

To get around this problem, Shen and his colleagues didn't image the plume itself but instead measured its effect on the depth of the upper mantle–lower mantle boundary. At the boundary, the crystal structure of a key mineral changes to the denser phase found in the lower mantle; when the temperature is unusually high, the transition happens at shallower depths. To gauge the boundary's depth, Shen used two kinds of waves: acoustic-like compressional seismic waves created by distant earthquakes, and shear waves, side-to-side vibrations touched off when compressional waves hit the boundary. Both kinds leave the boundary together, but they have different velocities, so the difference in their arrival times at the surface can be used as a measure of the precise distance to the boundary.

Combining 1500 pairs of waves, Shen found that the transition is 20 kilometers shallower than normal across a 300-kilometer region beneath Iceland. "I think it's convincing evidence for a plume from the lower mantle," says Shen. A narrow column of rock about 125 degrees Celsius hotter than its surroundings would have just this effect, he says. But the broad, flat base of a plume originating just above the boundary would affect the transition depth over a much wider area. "It's a big step in the direction" of proving a lower mantle origin, acknowledges seismologist Richard Allen of Yale University, but, he adds, "I don't know if I'm thoroughly convinced."

Allen and others would still like to see some sort of seismic indication of the plume in the 2200 kilometers of mantle below the mineralogical transition. Skeptics say that this transition may not truly mark the upper mantle boundary, which some have pushed closer to 1000 kilometers. A prime target for more seismic probing may be the zone of partially molten (and therefore more easily imaged) rock recently identified at the base of the mantle below Iceland (*Science*, 31 January 1997, p. 614). This could be the ultimate source of Iceland's fires.

–Richard A. Kerr



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Deep-rooted? Seismically imaged in its upper 400 kilometers, the Iceland plume appears to extend much deeper into the mantle.

SOLAR PHYSICS

That Winking, Blinking Sun

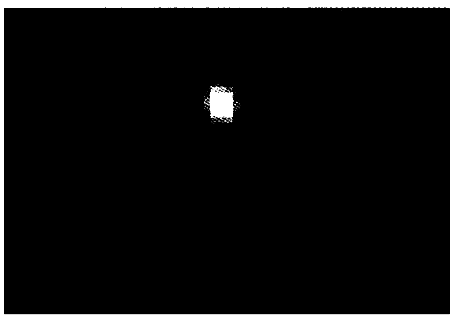
New observations from the Solar and Heliospheric Observatory (SOHO) satellite show that the sun is covered in tiny hot spots. These short-lived bursts of energy could shed light on a big puzzle in solar science: What heats the sun's atmosphere to fantastically high temperatures and powers the stream of charged particles that flows into space as the solar wind?

Solar physicist Richard Harrison of the Rutherford Appleton Laboratory, near Oxford, U.K., discovered these so-called blinkers while studying the surface of the sun in extreme ultraviolet light. Viewed in the ultraviolet, the sun looks dimpled like an orange. The pattern results from the convection of hot, ionized gases, which well up, cool, and sink back below the surface. As the charged particles in the gases move, they generate magnetic fields, which also influence their motion. As Harrison watched these features, he spotted something unusual.

All over the sun, spots about the size of Earth briefly flare to temperatures of up to a million degrees Celsius, far above the average solar surface temperature of about 5500 degrees. Because the blinkers are concentrated at the fringes of the convecting gas patches, Harrison believes that the magnetic field lines squeeze and heat the gas. The spots "seem to be occurring because these magnetic fields are getting rammed into one another," he says.

At any moment, about 3000 blinkers dot the sun. "This work is very exciting because it can help us to understand the heating mechanism for the solar atmosphere," says Helen Mason of Cambridge University. It's not clear, though, whether the blinkers pack enough punch to heat the entire atmosphere to million-degree temperatures. "The energy we see at the moment is insufficient," Harrison admits. However, visible blinkers might represent only a part of the total energy converted from tortured magnetic fields into heat, he argues.

–Andrew Watson



A. HARRISON/SOHO

Blink and it's gone. A hot spot flares in the second of three images made at 20-minute intervals.

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