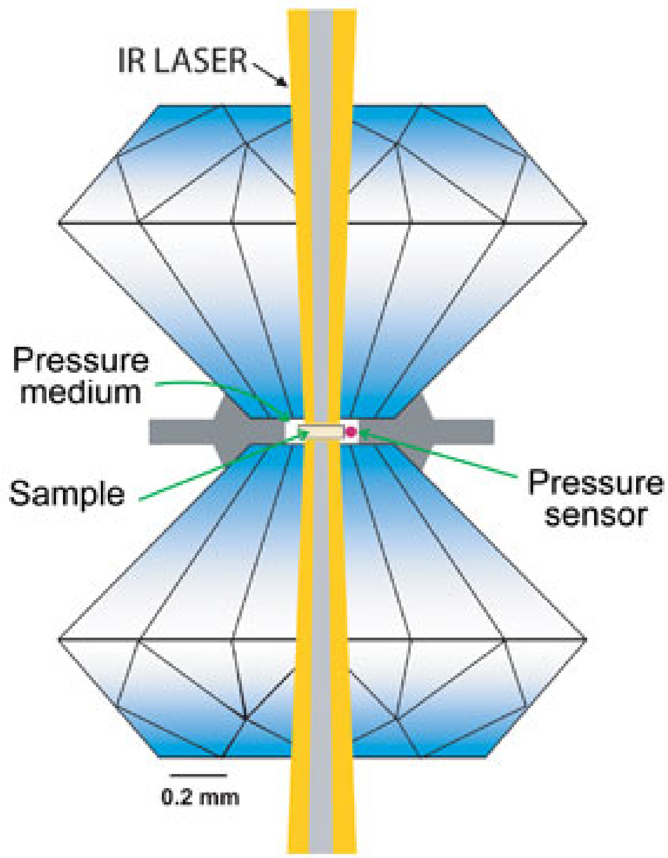
ENGINEERING & SCIENCE
California Institute of Technology

Random Walk



Jackson's lab designers, David Mispagel and Anneline Van Benthem-Weil, recreated in linoleum an infrared laser beaming through a diamond-anvil cell. In the cell (right), two semi-flawless diamonds squeeze a sample grain of deep-mantle rock while an infrared (IR) laser heats it. With Earth's deep-mantle conditions thus simulated, its material properties can be scrutinized from the relative comfort of the lab.

Getting at the Core

If you want to know what's going on deep inside Earth, step into the brand-new lab of Jennifer Jackson, assistant professor of geophysics in Caltech's Seismological Laboratory. Jackson started at Caltech last December, and just five months later her lab—the Institute's first to use a so-called diamond-anvil cell to study mineral transitions under the intense heat and pressure of core-mantle boundary conditions—was up and running. Hers is one of fewer than a dozen labs in the United States equipped to tackle this kind of research. Her tools: a couple of gem-quality diamonds, a laser, and a speck of super-dense deep-mantle mineral of the perovskite family, made of iron, magnesium, aluminum, and silica.

Jackson has several goals in mind. She'd like to figure out how Earth's metallic core interacts with its rocky mantle, how iron-rich materials melt at high pressures, how seismic waves move under these conditions, and, ultimately, how our planet evolved to its present state. As she describes it: "We're at a middle stage in Earth's evolution, and we're using mineral physics both to understand its present state and to draw a line back to where it started."

Drills can't help Jackson's research because their casing collapses under the pressure as they inch deeper into Earth's crust. The deepest a drill ever penetrated is a mere 12 kilometers—a scratch on the surface considering the core is some 2,900 kilometers deep—and it took 24 years and more than $100 million to accomplish. But squeezed together, diamonds can both exert and withstand extreme conditions, as long as they're slowly coaxed into them. (Unfortunately, they don't survive the return trip—they develop ring fractures on decompression.) Jackson begins with two diamonds, a quarter of a carat each, with their tops and tapered tips ground flat. These gems are Type Ia, meaning they're both natural and semi-flawless, because impurities in synthetic or slightly dirty diamonds obscure the signals from the object of Jackson's study—a perovskite grain sandwiched between the diamonds, squeezed by the gems inside a metal collar. Together these parts comprise the diamond-anvil cell, and you wouldn't want to stick your finger in one of them.

A diamond-anvil cell can exert a pressure up to that inside Earth's core, which is calculated to be 360 gigapascals (GPa)—"approximately one million elephants standing on your head," as Jackson describes it—corresponding to a depth of about 6,400 kilometers. Jackson takes her samples up to 130 GPa for now, to study lower-mantle properties, but she plans to go higher. To better mimic mantle and core conditions, she also beams an infrared laser through the samples to heat them to temperatures near that of the core, which is thought to exceed 6,000 degrees Celsius. The exact figure has an uncertainty of 2,000 degrees, and is a subject of great interest because it carries implications about the true composition of the core, how heat is generated inside it, and when exactly it formed. We still don't know whether Earth retained its original core after the planet formed four and a half billion years ago, or whether Earth completely restratified after the impact that is thought to have ejected the moon and possibly melted the planet some 50 million years later. Figuring out the core's temperature could also yield insight into when Earth's magnetic field developed.

Inside Jackson's lab, the samples are pressurized, heated, or both, in incremental steps. Then she takes them to Chicago, to the Advanced Photon Source at Argonne National Laboratory, a synchrotron source of the world's most brilliant X rays. At the facility she uses X-ray scattering methods to identify the minerals' internal structures and studies how seismic waves disperse through the material under different conditions. Comparing these measurements to observations of how seismic waves travel through the whole planet after an earthquake, scientists have begun to parcel out finer and finer zones deep inside Earth.

As for *The Core*, 2003's Hollywood interpretation of what Jackson studies, she says she appreciates how the movie got people excited about such a recondite topic. But in her version, she wouldn't have put amethyst caves in the upper mantle because, as she points out, "that's clearly not allowed." *—EN*