Deep Rocks Stir the Mantle Pot

While the plate tectonics revolution has allowed geologists to make sense of the scheme of things at Earth's surface, the structure of deep Earth has long been hotly debated. One difficulty is that geologists don't often get to take a piece of deep Earth back to the lab to analyze. But every once in a while, petrologists—geologists who actually specialize in rocks—come across a deep Earth specimen that has been ejected from deep in the mantle by an exotic geologic process. Then they can take a direct look at the processes stirring the depths of the planet.

That's just what's been going on for the past several years as petrologists have scrutinized some of the deepest samples ever found. Reporting on their findings in this issue of *Science*, one team has announced that it has identified a rock from a region of the mantle where the answer to a long-standing controversy about the structure of deep Earth may reside.

The rock seems to come from between 300 and 400 kilometers down—from near the top of the so-called transition layer, where seismic data show that the upper mantle begins to give way to the lower mantle. Geophysicists have disagreed for decades about whether those two subdivisions mingle or are separated like oil and water, but the proof may be in the transition layer. If the upper and lower mantle do mix, there should be nothing special about the makeup of the layer. But if they do not, material trapped at the base of the upper mantle should give the transition zone a distinct composition. The new mantle rock doesn't settle the question, but it is evidence that such deep samples could help break the deadlock.

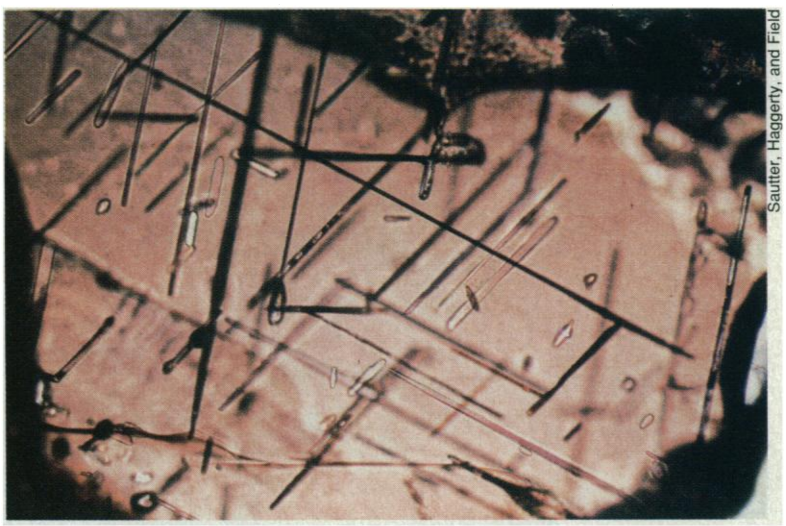
So where can more deep rocks be found? Petrologists won't be looking in their backyards, or even in drill holes. The deepest well in the world stops about 12 kilometers down—well over an order of magnitude short of the petrological quarry. Here and there, though, nature has provided conduits from the mantle: deep-rooted extinct volcanoes called kimberlite pipes. Kimberlite rocks are the major source of diamonds, blasted upward from the very base of the continents by the force of the eruption. Five years ago, for example, minerals embedded in diamonds from South African mines were shown to have originated at a depth of about 180 kilometers (*Science*, 23 May 1986, p. 933).

That is well short of the transition zone, of course, but kimberlites also include material from deeper in the mantle, apparently carried up to the bottom of the volcanic conduit by slowly rising mantle currents. Just last year, Stephen Haggerty of the University of Massachusetts at Amherst and Violaine Sautter of the University of Paris-South in Orsay doubled the previous depth record for mantle samples. Rummaging about the waste fields of an inactive diamond mine at Jagersfontein, South Africa, they found a couple of rocks showing signs of having formed at depths of between 300 and 400 kilometers. The rocks contained crystalline minerals so closely intertwined that one must originally have been dissolved in the other, which would have required pressures equal to those at depths of 300 kilometers or more.

At first, this new look at the mantle seemed to support the view that it is split into two layers by an impenetrable barrier—actually a jump in density—at a depth of 670 kilometers. If it is split, as geophysicist Don L. Anderson of the California Institute of Technology has argued, the great slabs of dense crust that sink into the mantle at ocean trenches should bottom out at the barrier. The enormous pressures there would squeeze the basaltic rock of the ocean crust into a rock called eclogite, forming an eclogite-rich transition zone. And eclogite is exactly what Haggerty and Sautter found in their deep mantle rocks. "Anderson's model for an eclogite layer at the 400-kilometer [boundary] is seemingly verified...," they wrote in *Science*.

Sautter, Haggerty, and Stephen Field of Stockton State College in Pomona, New Jersey, have now taken another look at their rocks, and that conclusion has to be qualified. They report on page 827 of this issue of *Science* that their 400-kilometer-deep rocks also contain a rock type called lherzolite. Lherzolite is a kind of background mantle rock—neither the remnant of a slab nor a source of crust-forming magmas. If the mantle is a single well-stirred pot, lherzolite should dominate the transition zone.

Now that Sautter and her colleagues have found both eclogite and lherzolite in their samples of the transition zone, geologists face the question of which rock is most abundant there, and thus which picture of the mantle is closest to the truth. The search for more deep mantle rocks in the kimberlite pipes of South Africa and elsewhere will go on, and Haggerty would not be surprised if it turns up rock from even greater depths, well within the transition zone.



Hard evidence. *These rods of the mineral orthopyroxene (the longest is 1 millimeter) formed from the encasing parent mineral when it rose from a depth of 200 to 400 kilometers.*

Whatever petrologists learn about mantle composition will have to be fit into the broad picture of mantle properties that comes from seismology. But together the two kinds of data may soon point to a resolution of one of the longest standing controversies in geophysics. "At the moment, it's a tossup," says Anderson, "but I think we're getting close to the point where we can tell the difference" between the two views.

■ Richard A. Kerr