EARTH SCIENCE

Bits of the Lower Mantle Found in Brazilian Diamonds

Diamonds are esteemed for their rarity, hardness, and flash, but to some mineralogists their most valuable features are their imperfections. Formed at depths of more than 180 kilometers, then blasted to the surface by deep-seated volcanic eruptions, diamonds can capture traces of surrounding minerals and ferry them to within human grasp. And if mineralogist Ben Harte of the University of Edinburgh and diamond specialist Jeffrey Harris of the University of Glasgow are right, some Brazilian diamonds have just delivered a long-sought prize: microscopic bits of mineral from the lower mantle, the rocky region of the planet more than 660 kilometers down.

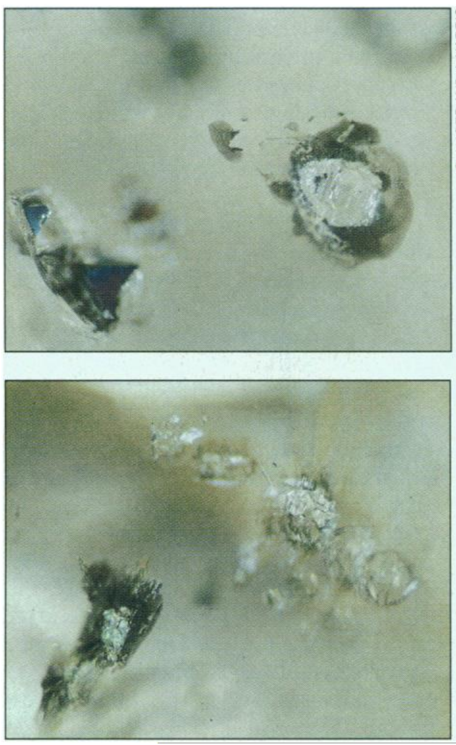
Harte and Harris aren't the first to claim that prize, but other researchers think they have the strongest case yet. "It's an outstanding discovery, and everything is compatible" with a lower mantle origin, says Stephen Haggerty of the University of Massachusetts, Amherst, who holds claim to a find from 300 to 400 kilometers down (*Science*, 10 May 1991, p. 783). The new discovery, announced at this year's meeting of the European Union of Geosciences in Strasbourg, is much more than a depth record. The lower mantle, the deepest rocky layer of the planet, is the focus of one of Earth science's longest running debates: Does the planet's internal heat churn the lower and upper parts of the 2900-kilometer-thick mantle into a uniform mass, or are the two layers segregated physically and chemically? The chemistry of mineral flecks like the ones found by Harte and Harris may hold clues to the answer.

The discovery is the fruit of university-industry cooperation. If academic researchers are interested in unusual mineral inclusions in diamond, it behooves them to be on good terms with the people who see a lot of diamonds—the diamond miners. As a consultant to the DeBeers Corp. on diamond mineralogy, Harris had the right connections. They paid off when DeBeers passed on to Harris some diamonds obtained by Sopemi (their associate organization in Brazil) from mines near Sao Luis that turned out to be chemically unusual.

Using a type of mass spectrometer called a microprobe, Harris and Harte were able to identify the 50- to 200-micrometer-sized bits of minerals trapped in the diamonds. Their composition suggested that the minerals and the diamonds containing them had originated hundreds of kilometers deeper than any accepted deep samples. One type of inclusion, a mineral type called ferropericlase-magnesiowüstite, had a magnesium-iron oxide composition that, according to theory and lab experiments, most likely formed in the lower mantle. Another inclusion, a magnesium silicate, can form in the upper mantle, where it is called enstatite. Together with the ferropericlase, however, it supports a lower-mantle origin for the inclusions: At shallower depths the two minerals should combine rather than existing separately.

Still, the two weren't enough to make an iron-clad case for a lower mantle origin. In the 1980s ferropericlase inclusions had been found in seven other diamonds at three sites on three continents; one of these diamonds also had enstatite. Barbara Scott-Smith of the Anglo-American Research Laboratories and her colleagues, including Harris, suggested that at least a few of the diamonds came from the lower mantle, but, as Harris says, "not many people took up [the suggestion]." A single lower mantle mineral was intriguing, it seemed, but hardly convincing.

What really strengthens Harte and Harris' case, say other researchers, is the presence in their diamonds of a second type of lower mantle mineral. In three diamonds from Sao Luis, enstatite and ferropericlase inclusions coexist with inclusions of calcium silicate, another mineral expected to form in the lower mantle. The combination of the three minerals in individual diamonds convinced Harte and Harris that their diamonds originated more than 660 kilometers down.



B. HARTE AND J. HARRIS

The real gems. Flecks of minerals trapped in diamonds can reveal the nature of the deep mantle (magnified 20 times).

The very fact that minerals from such depths made it to the surface strengthens the case for mantle mixing, say some researchers. After all, the diamonds probably weren't blown straight to the surface by a volcanic eruption drawing on the lower mantle. Mineralogists debate the depth from which volcanism can raise diamond-bearing rock, but the conventional view puts the limit at about 200 kilometers. Rising plumes of hot rock must have swept the diamonds up to the depths that can be plumbed by volcanism, says Haggerty. And that in turn implies that the boundary between upper and lower mantle at 660 kilometers can't be impenetrable, he notes.

A few mineralogists, however, think that diamond-bearing eruptions can have deeper roots, all the way down to the 660-kilometer boundary between the upper and lower mantle. In that case, there would be no need to invoke mantle mixing to carry the minerals along the first leg of their journey. But the chemical makeup of the inclusions should help resolve the issue. If the mantle doesn't mix, the lower layer should be a reservoir of heavier rock. Lower mantle minerals should be denser than those from the upper mantle, most likely because of an extra measure of iron or silicon. In the earlier, less certain lower mantle inclusions, Susan Kesson and J. D. Fitz Gerald of the Australian National University in Canberra found iron and silicon abundances not much different from those seen in samples of the upper mantle—evidence that the mantle is well mixed.

On average, the iron content of the Sao Luis ferropericlases also fits the mixed mantle picture, but only on average. Iron in individual inclusions ranges to extremely high levels. Harte thinks melting and recrystallization of minerals could have skewed their iron concentrations and thus garbled any information on mixing. And Harte and Harris have found another mineral inclusion associated with ferropericlase—a garnet—whose existence in the lower mantle does not fit anyone's model of mantle chemistry, whether the mantle is mixed or layered.

Such nagging uncertainties leave mineralogists eager for more glimpses of the lower mantle. Sad to say, they won't be getting them from Sao Luis diamonds, at least not for a while. DeBeers has abandoned the site in the face of hordes of local diggers, an armed insurrection, and general lawlessness. For any bits of the lower mantle remaining at the site, the journey from the depths of the planet was the easy part.

–Richard A. Kerr