Meeting of mantle, core no longer a bore

Although it lies hidden some 2,900 kilometers beneath the surface, laboratory and theoretical studies are revealing that the boundary between the Earth's metallic core and rocky mantle is neither as simple nor as static as once assumed.

This week, at the fall meeting of the American Geophysical Union in San Francisco, researchers from a variety of fields described their developing ideas about the kind of activity that may occur at the boundary. Highlighting one session, Raymond Jeanloz from the University of California, Berkeley, and his colleagues said the boundary may play an important role in creating the geomagnetic field. Traditional theories hold that the field originates almost solely within the core itself, with little influence from structures outside the core.

Jeanloz's theory concerning the magnetic role of the boundary developed after several years of experiments using lasers and anvils with tiny diamond tips to mimic the intense heat and pressure at the base of the mantle. While scientists had generally assumed the mantle and core are reticent neighbors that never interact, the diamond anvil experiments indicate that vigorous chemical reactions should occur between the iron-rich core and the rocks of the mantle — creating blobs of metallic alloys that sit in the rocky matrix of the lower mantle.

Since these blobs would conduct electricity much better than the surrounding rock, they would influence the electromagnetic field, says Jeanloz, who is working with Xiaoyuan Li at Berkeley, as well as Elise Knittle and Quentin Williams at the University of California, Santa Cruz. "The magnetic field we see at the surface of Earth, we think, is affected very strongly by the presence of these electrically conducting metallic bodies in the deepest mantle," Jeanloz says.

In Earth's outer core, swirling currents of liquid iron power the magnetic field, which can be thought of as lines that emerge from the planet's surface in the Southern Hemisphere and wrap around to dive back into Earth in the Northern Hemisphere. Anchored in the core's fluid iron, these field lines follow the movement of the outer-core currents.

Because the mantle and crust are relatively nonconductive, they do not interact with the electromagnetic field. Moving field lines, therefore, can sweep through these regions relatively unhindered. Conversely, pockets of conducting material in the base of the mantle would dramatically slow the field's progress, causing a pileup of field lines, Jeanloz says. Like a sponge blocking water flow in a stream, the metal-rich blobs would allow magnetic field lines to pass through, but only slowly. The magnetic field reaching the Earth's surface would therefore be a warped version of the one created at the core.

"We used to think that what we see related directly to what was going on in the core. What we are now saying complicates the issue," Jeanloz says.

Many researchers now are drawn to the idea that the mantle and core react chemically to generate hybrid formations at the boundary. However, some controversy accompanies the proposal that these formations affect the magnetic field. "I'm not convinced they will have quite as big an effect as Raymond claims," says magnetic-field researcher Jeremy Bloxham from Harvard University.

At this week's meeting, Harvard graduate student Jeffrey Love and Bloxham presented calculations involving a uniform conducting shell at the bottom of the mantle — a much simpler version of Jeanloz's conducting blobs. The uniform shell appeared to influence only slightly the development of the magnetic field.

In the same session, David J. Stevenson of the California Institute of Technology in Pasadena identified several simple processes that might be combining iron from the core with silicates and oxides from the mantle — a mixture whimsically dubbed a core-mantle cocktail. As an example, Stevenson focused on regions where slowly convecting mantle rocks hit the bottom of the core interface and spread out, resembling the spray pattern formed when a stream of water hits the bottom of a sink. This diverging flow would create a low-pressure zone in the mantle that could suck up iron fluid from the core, Stevenson says.

During the past few years, seismologists have contributed their own revelations concerning the core-mantle boundary by discovering that the interface is not a flat sheet but instead a bumpy area (SN: 6/11/88, p.378). Now researchers from other fields are beginning to examine theories about chemical and dynamic reactions at the boundary that may make this one of the most geophysically active regions in the Earth. *— R. Monastersky*

Chemistry ties CFCs firmly to ozone hole

A new study for the first time "convincingly" identifies the dominant chemical process by which the Antarctic ozone hole forms, its authors say. In so doing, the study also appears to indict chlorofluorocarbons (CFCs) for much of the ozone loss.

Since discovering it several years ago, atmospheric scientists have puzzled over the destruction of stratospheric ozone above Antarctica. While many researchers strongly suspected emissions of manufactured CFCs played a role, the chemistry by which CFCs' chlorine breaks down ozone in the upper atmosphere couldn't operate at the lower altitudes where an ozone "hole" now forms. That led some to question chlorine's overall role in the hole.

About 18 months ago, Mario Molina, an atmospheric chemist at NASA's Jet Propulsion Laboratory in Pasadena, Calif., offered a hypothesis to explain chlorine's role in the hole. Unlike chlorine's destruction of ozone in the upper stratosphere, this pathway required the linkage of two chlorine monoxide (ClO) molecules into a fragile dimer (Cl_2O_2). Upon exposure to the sun's ultraviolet light, the dimer would ultimately decompose into two chlorine atoms and a molecule of oxygen (O_2). The recycled free chlorines were then available to destroy more ozone.

The potential hitch in this hypothesis was the general rarity of atmospheric ClO molecules. At levels normally found in the stratosphere, there was little likelihood that two would collide to form a dimer.

Using millimeter-wave spectroscopy, physicists at the State University of New York in Stony Brook studied stratospheric levels of this ClO during September and October of 1986 and 1987. And consistent with Molina's hypothesis, their ground-based measurements of the skies above Antarctica's McMurdo Station found "a huge excess" of ClO — levels on the order of at least 1 part per billion — notes Robert de Zafra, one of the scientists. In fact, data published by his group in the Dec. 1 Nature show this ClO excess occurred only between 17 and 23 kilometers — the precise altitudes where simultaneous, direct balloon measurements by others showed ozone destruction was occurring. Moreover, the Stony Brook researchers found that ClO excesses disappeared at night and quickly returned with the morning sun.

Such variations in ClO concentrations — by altitude and between day and night — "corroborate one of the important predictions [of the dimer hypothesis]," Molina told Science News. And while data collected by others from airplanes at about the same time last year also showed an excess of ClO in the Antarctic ozone hole, Molina says the "high quality" of the Stony Brook data provides stronger — and the first formally published — measurements pointing to dimer formation as the most likely route to ozone destruction over Antarctica.

These high ClO measurements also confirm for the first time that CFCs — contributing about two-thirds of the atmospheric chlorine — are largely responsible for the Antarctic ozone hole, notes Mark Schoeberl, an atmospheric scientist at NASA's Goddard Space Flight Center in Greenbelt, Md. *— J. Raloff*