Scientists eye whirlpool in Earth's core

Reaching back to the compass readings of early polar explorers, geophysicists have now pieced together evidence of a slowly whirling vortex within Earth's liquid-iron interior. This result suggests that a long-nurtured theory of Earth's magnetism is on target.

Einstein described geomagnetism as one of the chief unsolved puzzles of physics. Neither Earth's liquid outer core nor its solid, yet superhot, inner core has struck scientists as likely sources of its magnetic field. Heat cooks the magnetism out of magnets, and liquefaction melts it away. Physicists were flummoxed.

Over several decades, an idea has emerged: Earth's core acts like a giant dynamo. Heat causes churning in the liquid outer core, which Earth's rotation transforms into a liquid whirlpool that swirls around the planet's axis. This circulation produces a magnetic field roughly aligned with that axis.

Basic physics says that electric currents give rise to magnetic fields and moving magnets generate electric currents. These two effects enable a churning outer core to magnify the small magnetic field that the planet captured from its surroundings as it formed. As opposing streams of molten iron, carrying tiny magnetic fields, sweep past one another, each induces currents in the other. This creates more magnetism, which induces more currents, and so on.

Supercomputer simulations suggest that dynamo motions could indeed arise within the core and create a field like Earth's. The simulations fall short of nailing the matter down, however. "You have to make approximations," says geophysicist Bruce A. Buffett of the University of British Columbia in Vancouver. "We really don't know how accurate these simulations are," he says.

In the Nov. 11 NATURE, however, geophysicists at Johns Hopkins University in Baltimore report that a whirlpool slowly spins in the liquid outer core far below the North Pole, much as the simulations predict. The finding provides physical evidence that the geodynamo model is on the right track, according to Buffett.

"That's really very encouraging," he says.

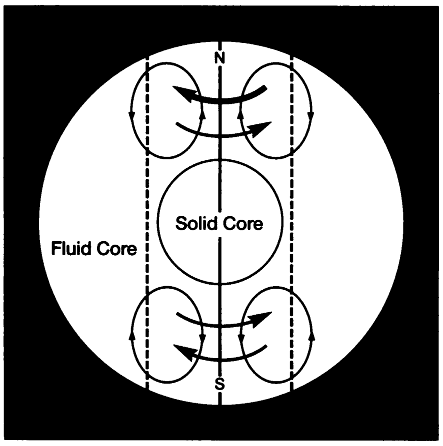
The finding derives from magnetic measurements made by sailors, explorers, and scientists from 1870 to 1990. Peter Olson and Jonathan Aurnou of Hopkins didn't analyze these data directly. They looked at the models of Earth's field at different times that were developed by three other groups. Analysis of the changes over time revealed rotation, Olson and Aurnou say.

A different line of evidence bolstering the geodynamo theory comes from recent supercomputer simulations. In the Oct. 28 NATURE, Gary A. Glatzmaier of the University of California, Santa Cruz and his colleagues suggest that not only can the geodynamo explain the basic conundrum that puzzled Einstein early in this century, but it also answers a compounding enigma that emerged in the 1960s.

The mysterious finding was that Earth's magnetic field can flip. Certain rocks bear the imprint of the field that existed when they solidified. Such rocks of different ages testify that the magnetic poles intermittently swap. Tens of thousands of years separate some reversals, while tens of millions of years separate others.

Simulations of the geodynamo by Glatzmaier's group predict such behavior if the temperature of the rock surrounding the core is uneven and varies over time—reasonable assumptions, comments Buffett.

Olson and Aurnou's failure to detect a whirlpool beneath the South Pole, Buffett says, threatens to throw a wrench in one wheel of the dynamo. Because Antarctic data are sparse, however, the failure does not definitely contradict the model, he says. Impending satellite data may well settle the question soon, says Olson. *—O. Baker*



Adapted from Glatzmaier & P. Roberts, 1997/CONTEMP. PHYS.

Heat-driven circulation of liquid iron in Earth's fluid core constitutes the geodynamo believed to produce the planet's magnetic field. Discovery of upwelling and westward circular motion (top, bold arrow) beneath the North Pole supports this model. A rock mantle surrounds the core.

Speedy X-ray bursts reveal atomic action

Atoms have stolen the spotlight from electrons in a new study of melting. By scanning a semiconductor with ultrafast X-ray pulses, scientists have directly observed its atomic lattice yielding to disorder.

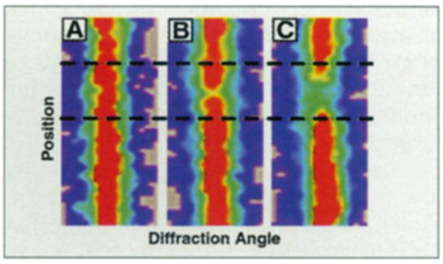
Processes such as melting and chemical reactions involve atomic reconfigurations that may take only femtoseconds (quadrillionths of a second). Last month, Ahmed H. Zewail of the California Institute of Technology in Pasadena won the 1999 Nobel Prize in Chemistry for developing ultrafast laser-pulse probes of such shifts (SN: 10/16/99, p. 247).

Laser pulses bounce off electrons of a crystal, allowing scientists to infer atomic motions. However, these wavelengths are too long to reveal such behavior precisely. So, researchers have pushed to see atomic details with ultrafast pulses of shorter-wavelength X-rays.

In the Nov. 12 SCIENCE, Craig W. Siders of the University of California, San Diego and his colleagues report using X-ray pulses lasting less than a trillionth of a second to prove that short, intense laser pulses melt thin germanium films instantaneously, without first heating the crystal.

Tracking atom behavior in extremely fast processes "is something that people in the field of ultrafast spectroscopy have been trying to do for more than 20 years. Now, finally, there is a way to do it," comments Michael W. Downer of the University of Texas at Austin.

The researchers jolt a crystal region with an extremely powerful, 30-femtosecond pulse of laser light. To create an X-ray burst, they split away a fraction of the energy of each pulse and use it to intensely heat a copper wire.



Siders *et al.*/SCIENCE

Shrinking of red bar (between dotted lines) in these X-ray–diffraction patterns shows a change of atomic structure from complete order before the laser hits (A) to a lack of order 40 picoseconds after the pulse (C).

Optical studies of laser-induced melting of germanium had shown an extraordinarily swift jump in surface reflection, suggesting it had liquefied. Gas or plasma formation was still a possibility, however.

By analyzing how X-rays bounce off atomic layers, Siders' team could directly see crystalline order vanish and reappear. Only a solid-liquid transition could reverse in this way, Siders explains. The change occurred at supersonic speed so could not have been garden-variety melting. "It's the first time we can conclusively say, 'This is ultrafast melting,'" he says.

The new X-ray technique may find use in studies of other fast processes. It could be applied to the chemistry of photosynthesis and vision, as well as to changes in materials under extreme conditions mimicking the interiors of planets or small stars, Downer says. *—P. Weiss*