Magnetic "Jerk" Gaining Wider Acceptance

Something seems to have happened within the earth's core that jerked the magnetic field in 1969 during its slow drift across the globe

As if the failure of a magnetic compass needle to point toward the geographic north pole were not enough, a compass needle will not even point in the same direction next year as it does this year. And knowing where it has pointed in the past will not enable one to predict precisely where it will point in the future.

The problem with following the orientation of a little bar magnet is that the earth itself is not a giant, unchanging bar magnet; rather, its magnetic field is generated by the still mysterious motions of a core of molten iron subject to much the same eddying and swirling so evident in a weather map.

Although the 2900-kilometer-thick mantle screens out much of the magnetic activity of the underlying core, geophysicists are becoming increasingly confident that the normally reticent core has sent a sharp magnetic signal to the surface that could help illuminate the core complex workings and some properties of the mantle as well. Vincent Courtillot, Joël Ducruix, and Jean-Louis Le Mouël of the University of Paris first reported in 1978 that the earth's magnetic field had shivered or jerked in about 1969. Geophysicists have been arguing about it ever since.

The arguments arise in part from the awkwardly irregular nature of the magnetic field. The dipole field of the classic bar magnet and iron filings experiment is there, all right, but errant core motions superimpose geographic variations in field strength and orientation that change with time. In addition, the core as a whole does not quite keep pace with the rotation of the rest of the earth, falling about a meter behind the encircling mantle every hour. The resulting westward drift of the field across the face of the earth is not all that steady either, slowing down or speeding up over the years. The French researchers reported that, after generally slowing during most of the century, the rate of westward drift suddenly began speeding up in 1969. That sudden acceleration is now called a jerk. Recently Ducruix, C. Gire, and Le Mouël have proposed a second jerk in 1912 that was a sudden reversal from an accelerating to a slowing westward drift.

The French researchers have gained a number of supporters in recent years, particularly in Europe; Americans have been more reluctant. Everyone agrees that in 1969 westward drift over Europe speeded up abruptly. Whether the same acceleration affected the rest of the globe and resulted from fluid motion in the core remains controversial in some circles. The most obvious problems are in the data. The magnetic observatories that provide them are unevenly scattered around the world, about 70 of the 85 best being in the Northern Hemisphere. Huge gaps in coverage exist in some areas such as the Pacific. The influence of the sun's solar wind on the magnetic field adds noise to the record and imposes an 11-year cycle on any other variations. And the jerk, while obvious in the European records, is obscure or undetectable at many other sites, as in much of North America.

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In order to overcome these difficulties, a number of researchers have applied objective methods of analysis to the worldwide observations. Stuart Malin of the National Maritime Museum, London, and Barbara Hodder of the Institute of Geological Sciences in Edinburgh used the 1961–1978 observations of 83 observatories in a classic method of spherical harmonic analysis developed by Karl Friedrich Gauss in 1839. It allows one to calculate the proportions of the internal and external contributions to any variation. Malin and Hodder found that most of the 1969 jerk had an internal origin, as have other workers using other selections of the observations.

Objective analysis has helped persuade some in the field, but it has not convinced everyone. Leroy Alldredge of the U.S. Geological Survey in Denver, a staunch opponent of this global jerk, points out that such sophisticated analysis is usually applied to records in which a 1969 jerk is already assumed for non-European sites. The outcome of the analysis is thus predetermined, he says. David Gubbins of the University of Cambridge, who has performed his own spherical harmonic analysis, agrees that the method has distinct limitations, but he nonetheless believes that something happened in the core that produced the 1969 jerk.

Like many others, Gubbins finds a site-by-site inspection of the raw observations more convincing than the most sophisticated global analysis. "There was a rapid internal change in 1970," he says, "and it was certainly evident outside Europe." It was also obvious in India and in parts of Central America, Asia, and North America, he says, areas too widely separated to participate in a purely regional change in the magnetic field.

Robert Langel of the Goddard Space Flight Center, Greenbelt, Maryland, has likewise convinced himself that something happened around 1969. He and Ronald Estes of Business and Technological Systems, Inc., Seabrook, Maryland, have constructed a series of models of how the magnetic field has varied during this century. Langel finds fairly sharp, definite changes in the way the field varied in both 1969 and 1912, but he is still reluctant to call the events "jerks." The observations may suffice to demonstrate the existence of a global event, he says, but they may not be good enough to provide a sound measure of its abruptness. While the arguments about the existence of such a global event continue, largely in the United States, "some of us are still trying to figure out what it is," he says.

Questions of its existence aside, Raymond Hide of the Meteorological Office, Bracknell, England, has suggested what might be called the rubber band model of how the fluid core could generate a jerk. Like a rubber band, the magnetic field lines deep in the core could slowly become twisted until—as happens in the winding up of a model airplane—they suddenly form a loop or knot. The resulting disturbance would spread through the core as waves in the magnetic field lines. By the time it reached the mantle and propagated to the surface, it would be a global disturbance in the observed magnetic field. Hide emphasizes that the need for a long, slow twisting would necessarily space jerks by many decades, as observed, and the inherent rapidity of loop formation would still ensure a sharp jerk. Indeed, a jerk may be a particularly prominent example of the twisting of the east-west–oriented, ring-shaped core field that presumably generates the north-south dipole field observed at the surface.

Jerks may provide a view of the inner workings of the core, but they may also tell researchers about the window through which the jerks must be viewed. The electrically conductive mantle screens out much of the magnetic activity of the core before it can reach the surface. On the basis of the nature of the 1969 jerk, the French group calculated a relatively low mantle conductivity of less than 100 ohm^{-1} $meter^{-1}$. George Backus of the University of California at San Diego has since shown through theoretical considerations that the abruptness of the jerk is not limited by mantle conductivity in any simple way. Thus, contrary to initial expectations, extracting measurements of conductivity from magnetic observations will not be easy.

Another approach would be to watch how fast the earth rotates, of all things. The fluid core can alter the rate of earth rotation through the coupling of its magnetic field to the mantle. The higher the mantle's conductivity, the stronger the coupling. Searches for a correlation between the rate of rotation and magnetic field variations continue, but no single research group has found a long-term correlation that holds up throughout a complete record. Both kinds of records have their share of imperfections, but the synthesis of magnetic variations from worldwide observatories is a major stumbling block.

Geophysicists see a satellite or a series of satellites as the only practical solution to their magnetic data problems. They had one in orbit in 1980 but only long enough to get a single picture of the magnetic field. They say they need another one soon to see how the 1980 field is changing before it becomes unrecognizable.—**Richard A. Kerr**

Additional Readings

1. L. R. Alldredge, *J. Geophys. Res.* **89**, 4403 (1984).
2. J. Ducruix, V. Courtillot, J.-L. Le Mouël, *Geophys. J. R. Astron. Soc.* **61**, 73 (1980).
3. C. Gire, J.-L. Le Mouël, J. Ducruix, *Nature (London)* **307**, 349 (1984).

The Intelligence of Organizations

Humans work in organizations, and increasingly, so do computers; are there lessons to be learned?

Traditionally, artificial intelligence research (AI) has focused on human cognition, the individual human mind. More and more, however, researchers are turning their attention to a collective form of human intelligence: organizations.

This is not exactly a new idea. Carnegie-Mellon University's Herbert Simon became one of the founders of AI in the 1950's out of an interest in organizational decision-making, for which he subsequently won the Nobel Prize in Economics. But the last few years have brought an upsurge of interest in such things as parallel processors and robot assembly lines (*Science*, 10 August, p. 608), societies of machines that turn out to face all the same issues of communication, coordination, and organizational structure that human societies face. Those problems, and the organizational metaphor, were the subject of a panel discussion last month at the annual meeting of the American Association for Artificial Intelligence (AAAI)*.

A straightforward example of the organizational approach was described by Thomas W. Malone of the Massachusetts Institute of Technology (MIT), who addressed an increasingly common situation in laboratories and offices: high-performance personal computers are scattered around on desks and laboratory benches, with a lot of them sitting idle at any given time. This is obviously a waste, says Malone. However, if the computers can communicate with each other through a local area network, some of that idle power can be harnessed using a system called "Enterprise," which he has developed along with Richard Fikes and Michael Howard of the Xerox Palo Alto Research Center.

Enterprise is based on the "contract network" scheme first proposed by Reid Smith of Schlumberger-Doll Research Center. "If you have a computation-intensive task to do," Malone explains, "your computer sends out a 'request for proposals' over the network describing the task and its priority." Each of the other processors then checks its own priorities and its available data, he says, and responds with an estimate of how quickly it could finish that task. The lowest bidder gets the job.

"So by making lots of local decisions in the bidder and client machines," says Malone, "you get a globally coherent assignment of tasks without having to set up any one machine as a 'foreman.' " In fact, a mathematical analysis suggests that Enterprise will often be substantially better than having a foreman.

Victor Lesser of the University of Massachusetts, meanwhile, is concerned with how networks can cope with the uncertainties of the world.

Imagine something like an automated factory or an air traffic controller network, he says, where lots of sensors and processors are distributed over a wide area. "In classical distributed processing," he says, "each processor is assumed to produce accurate results based on correct and complete information." But in practice, doing things this way is either impossible or very costly and inefficient. "There is an enormous burden of communication and synchronization," he points out. "The processors spend most of their time waiting for someone else. Worse, as you build larger and larger systems, you can't assume that all the processors will be functional. You can't assume that you have global information. You can't assume that all the communication channels are working."

An effective way to cope with such uncertainties is an AI technique known for historical reasons as the "blackboard" architecture, which dates back to the HEARSAY speech understanding system that Lesser helped design at Carnegie-Mellon in the mid-1970's. The idea in HEARSAY was that multiple "agents" would analyze the incoming sounds from differing points of view. One would identify phonemes, for example, another would piece together words,

*The fifth annual meeting of the American Association for Artificial Intelligence, 6 to 10 August 1984, the University of Texas at Austin.