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EARTH'S CORE

Earth's core, at more than 2,900 kilometers (1,800miles) below the surface, is the most remote and inaccessible part of the planet. Yet scientists have made remarkable progress characterizing the innermost portions of Earth. Recent discoveries have increased our knowledge of the composition and motion of Earth's core.

What we know about the interior of Earth comes from several lines of indirect evidence, including the analysis of earthquake waves and the study of meteorites. Earthquake waves travel at different rates depending on the material they are moving through. The speed of travel of these waves is thus a clue to the type of rock, providing evidence for the nature of Earth's interior. Meteorites, because they represent material created when the solar system formed, provide clues to the composition of the solar system. And, since Earth formed from the same pool of material, its composition should be similar to that of meteorites.

Composition

The core must be made of a dense material to account for the observed overall density of Earth--5.5 g/cm^3. For some time scientists have believed that the core is composed primarily of metallic iron, perhaps alloyed with some nickel--a composition that would provide the necessary density. That hypothesis is further supported by the presence and composition of iron meteorites in the solar system (see Geo-Currents in the January/February 1996 issue of Rocks & Minerals).

Other studies, however, have determined that the liquid outer core is not dense enough to be composed purely of iron and nickel (see table 1). Sulfur, a relatively light element, has been proposed as another component of the outer core. More recent evidence suggests that, in addition to sulfur, other light elements must be present. Geochemical studies indicate that the maximum amount of sulfur that could be present is 1.7%, whereas about 12% sulfur would be required to produce the observed density of the outer core. The cap on the amount of sulfur is based on the premise that the bulk composition of Earth is approximately the same as that of chondritic meteorites. Likely candidates for other elements in the outer core include carbon, silicon, oxygen, and potassium.

Motion

Another new hypothesis resulting from geochemical studies suggests that chemical changes in the core may contribute to the motion of the liquid outer core. Specifically, the release of light elements (e.g., carbon) from the inner core to the outer core and the release of heavy elements (e.g., iron) from the mantle to the outer core may generate energy that contributes to the geodynamo that generates Earth's magnetic field (see Geo-Currents in the March/April 1994 issue of Rocks & Minerals).

Scientists studying seismic (earthquake) waves have discovered that the Earth's inner core is anisotropic. An anisotropic material is one in which energy waves move at different speeds depending on their direction of travel. In the core, seismic waves moving from north to south (or south to north) travel somewhat faster than those moving from east to west (or west to east). Thus earth-quake waves will take different lengths of time to travel the same distance through Earth depending on the direction they are moving. It has been suggested that the orientation of iron atoms in a hexagonal close-packed arrangement could produce the observed anisotropy. Hexagonal close packing (see fig.) is characteristic of the high-pressure crystal form (polymorph) of metallic iron.

Careful analysis of earthquake waves recorded over the past few decades has revealed an anomaly that has varied systematically over that time period. The observed changes in seismic wave behavior, coupled with the recent discovery that the inner core is anisotropic, has led scientists to the conclusion that the inner core is rotating faster than the rest of Earth. It appears that, at its equator, the inner core moves at a rate some tens of kilometers per year faster than the crust and mantle, so that the core completes one additional rotation about every four hundred years. Scientists hope that this discovery can lead to a better understanding of Earth's core and the conditions that exist there.

Table 1. Composition and density of Earth.

Layer	Composition	Density (g/cm^3)
inner core	iron with 10-20% nickel	12.6-13.0
outer core	iron with [a] 12% lighter elements	9.9-12.2
mantle	peridotite (composed of ferromagnesian silicates)	3.3-5.7
oceanic crust	upper part basalt, lower part gabbro	[a]3.0
continental crust	variable (average approximates granodiorite)	[a]2.7

a asymptomatically equal to

Source: Monroe, J. S., and R. Wicander. 1995. Physical geology: Exploring the Earth, 2d ed., p. 248. Minneapolis/St. Paul: West Publishing Co.

DIAGRAM: Hexagonal close packing, showing the atoms as spheres. Under very high pressure conditions, such as in the core, metallic iron adopts this structure (it displays cubic crystals under lower pressure). Hexagonal close packing is also typical of a few other native metals: magnesium and some platinum group elements. (Modified from: Mason, B., and L. G. Berry. 1968. Elements of Mineralogy. San Francisco: W. H. Freeman and Co.)

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Dr. Jane M. Matty, an environmental geologist at Central Michigan University, welcomes suggestions and news items for this column.
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