Georgia Tech

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# ANALYZING THE EARTH'S INTERIOR: NEW STUDY OF DEEP STRUCTURES OFFERS INSIGHT ON 'QUAKES, VOLCANOES & PLANET'S FORMATION

New simulations and analyses of the materials which make up the largest region of the earth's interior may provide important insights into deep earthquakes, certain volcanic activity -- and even the formation and evolution of the planet.

In a report published in the August 21 issue of Science, researchers from the Georgia Institute of Technology and the Carnegie Institution of Washington offer new evidence that the earth's mantle consists of two distinct layers containing different proportions of key mineral components.

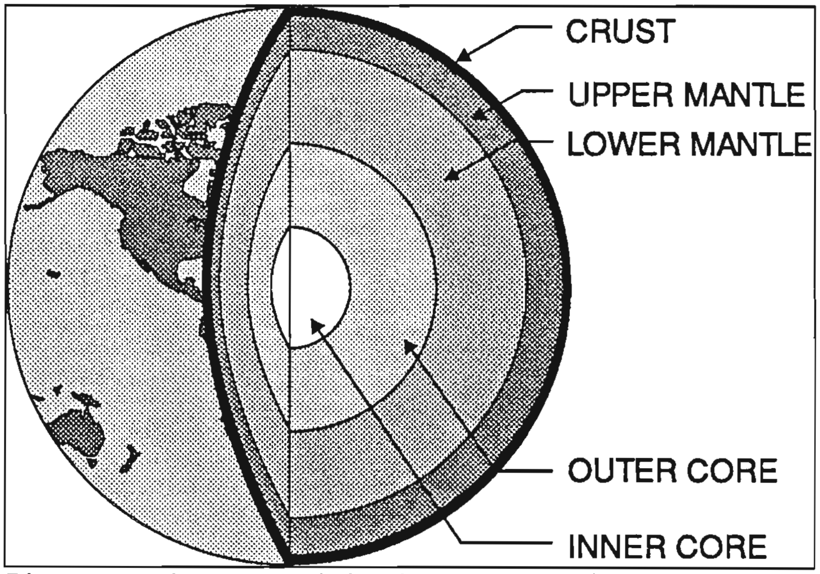


***Diagram showing the earth's interior as suggested in a recent paper in Science. The paper argues that the mantle is composed of two distinct layers of different compositions.***

"The question of whether the mantle exists in one or two layers has been a central issue in geophysics for a number of years," said Dr. Lars Stixrude, assistant professor in Georgia Tech's School of Earth and Atmospheric Sciences. "The conclusion of our paper is that the lower mantle does differ in composition from the upper mantle."

The mantle is the middle layer of the earth's interior, located above the core and below the thin crust on which the planet's surface features lie. It is a layer of extremely hot, pressurized material which extends from about 100 kilometers to approximately 2,900 kilometers below the surface.

The existence of two distinct layers in the mantle -- by volume the largest region of the earth's interior -- would have slowed cooling of the planet after its formation,

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affecting theories about how the earth evolved.

"If we knew that the lower mantle had a different composition, that would go a long way toward constraining models of how the earth formed in the first place," Stixrude explained. "It has been a difficult question to answer because the lower mantle exists at such high temperatures and pressures."

Information about the mantle could also give scientists a better understanding of ancient "volcanic plumes," vast flows of lava which may have originated in the lower mantle. The remnants of these once-vast plumes may be responsible for modern volcanic "hot spots" like the Hawaiian islands.

The differences between the upper mantle and lower mantle could also help account for certain deep earthquakes which cannot be adequately explained by conventional earthquake theories, Stixrude added.

Scientists study the mantle by measuring how it affects the speed of seismic waves -- created by earthquakes -- which pass through it.

"When earthquakes happen, they send out seismic waves which travel through the mantle and give us information about the elastic properties of the earth's interior," Stixrude explained. "We can measure minerals that we believe exist in the mantle and compare their elastic properties to the ones we measure from the earth through seismology."

Those comparisons allow scientists to infer information about the composition of the mantle.

Scientists can study the chemical composition of the upper mantle by analyzing lava flows which originate there. But to see how materials would behave at the extreme pressures and temperatures found in the lower mantle, scientists use a device known as a diamond cell. The cell subjects materials to pressures of as much as 10 million times the normal atmosphere and temperatures of up to 3,000 degrees Kelvin.

Stixrude used density information obtained from diamond cell laboratory simulations carried out at the Geophysical Laboratory and Center for High Pressure Research at the Carnegie Institution to make comparisons with data obtained from seismic sources.

The simulations, the first to simultaneously replicate both the high temperature and high pressure conditions of the mantle, were done by Russell J. Hemley, Yingwei Fei and Ho-Kwang Mao, who used x-ray diffraction measurements to obtain the density information.

The resulting comparison suggests that the lower mantle is composed almost entirely of $(Mg,Fe)SiO_3$ perovskite. Scientists have believed that the lower mantle is composed of approximately equal amounts of perovskite and (Mg,Fe)O magnesiowustite.

"If the lower mantle had a composition similar to the upper mantle, it would consist of approximately equal proportions of perovskite and magnesiowustite," Stixrude explained. "We found that is not consistent with seismically-observed properties, though a composition of almost pure perovskite is consistent with what we measure."

Analysis of seismic wave information shows a "discontinuity" located about 670 kilometers below the surface. This boundary may represent a change in the phase at which the materials exist, or both a phase change and a change in the chemical composition of the materials there, Stixrude reported.

"We really don't understand why that compositional change should coincide with the phase change," he said.

Proof of the theory must await more sophisticated analysis of seismic data at subduction zones, areas where the massive plates which make up the ocean floor plunge downward into the mantle. Because they are cooler than the surrounding mantle, those plates should affect the boundary between the upper and lower mantle, pushing it deeper.

How did the two layers originate?

While the mantle area remained molten during formation of the earth, crystals of denser materials may have sunk into what is now the lower mantle, while lighter materials floated above it into what is now the crust, Stixrude speculates.

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**NOTE: Until September 15, Dr. Stixrude may be contacted at (510) 642-9075. After that date, he can be reached at (404) 894-3893.**