Scientists may have identified echoes of ancient Earth

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Clouds over Australia are shown. Credit: NASA

A group of scientists believe that a previously unexplained isotopic ratio from deep within the Earth may be a signal from material from the time before the Earth collided with another planet-sized body, leading to the creation of the Moon. This may represent the echoes of the ancient Earth, which existed prior to the proposed collision 4.5 billion years ago. This work is being presented at the Goldschmidt conference in Sacramento, California.

The currently favoured theory says that the Moon was formed 4.5 billion years ago, when the Earth collided with a Mars-sized mass, which has been given the name "Theia". According to this theory, the heat generated by the collision would have caused the whole planet to melt, before some of the debris cooled and spun off to create the Moon.

Now however, a group of scientists from Harvard University believe that they have identified a sign that only part of the Earth melted, and that an ancient part still exists within the Earth's mantle.

According to lead researcher Associate Professor Sujoy Mukhopadhyay (Harvard): "The energy released by the impact between the Earth and Theia would have been huge, certainly enough to melt the whole planet. But we believe that the impact energy was not evenly distributed throughout the ancient Earth. This means that a major part of the impacted hemisphere would probably have been completely vaporised, but the opposite hemisphere would have been partly shielded, and would not have undergone complete melting".

The team has analysed the ratios of noble gas isotopes from deep within the Earth's mantle, and has compared these results to isotope ratios closer to the surface. The found that 3He to 22Ne ratio from the shallow mantle is significantly higher than the equivalent ratio in the deep mantle.

Professor Mukhopadhyay commented, "This implies that the last giant impact did not completely mix the mantle and there was not a whole mantle magma ocean".

Additional evidence comes from analysis of the 129-Xenon to 130-Xenon ratio. It is known that material brought to the surface from the deep mantle (via mantle plumes) has a lower ratio than that normally found nearer the surface, for example in the basalts from mid-ocean ridges. Since 129-Xenon is produced by radioactive decay of 129-Iodine, these xenon isotopes put a time stamp on the formation age of the ancient parcel of mantle to within the first 100 million years of Earth's history.

Professor Mukhopadhyay continued: "The geochemistry indicates that there are differences between the noble gas isotope ratios in different parts of the Earth, and these need to be explained. The idea that a very disruptive collision of the Earth with another planet-sized body, the biggest event in Earth's geological history, did not completely melt and homogenize the Earth challenges some of our notions on planet formation and the energetics of giant impacts. If the theory is proven correct, then we may be seeing echoes of the ancient Earth, from a time before the collision".

Commenting, Professor Richard Carlson (Carnegie Institute of Washington), Past President of the Geochemical Society said: "This exciting result is adding to the observational evidence that important aspects of Earth's composition were established during the violent birth of the planet and is providing a new look at the physical processes by which this can occur".

More information: Dr. Sujoy Mukhopadhyay will present "Chemical heterogeneities survive giant impacts and mantle convection" to the Goldschmidt conference, Sacramento, California, on Monday 9th June. The Goldschmidt conference is the world's leading annual conference on geochemistry, goldschmidt.info/2014/

ABSTRACT

Chemical heterogeneities survive giant impacts and mantle convection, S. MUKHOPADHYAY, S.T. STEWART, J. M. TUCKER, R. PARAI AND , S. LOCK
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The giant impact phase of Earth's accretion likely produced multiple magma oceans. In particular, the Moon-forming giant impact is often thought to have produced a whole mantle magma ocean, which should have erased pre-existing chemical heterogeneities within the Earth. We argue that the ratio of 3He to 22Ne in the present day mantle does record multiple magma ocean episodes during Earth's accretion. However, the 3He/22Ne ratio of the Earth's shallow depleted mantle is significantly higher than the deep mantle indicating that the last giant impact did not generate a whole mantle magma ocean. Although the energy associated with the Moon-forming giant impact was sufficient to melt the whole planet, the impact energy is heterogeneously deposited; the impacted hemisphere is shocked to the point of partial vaporization, but the opposite hemisphere experiences modest heating that does not result in completely melting. As a result, chemical heterogeneities persist through the giant impact phase of accretion.
Additional evidence for the preservation of early-formed heterogeneities in the deep mantle is provided by 129Xe/130Xe ratios. Deep mantle plumes have a lower ratio of 129Xe/130Xe compared to the source of mid-ocean ridge basalts (MORBs). The Xe signature requires a region of the deep mantle to be less degassed and to have separated from the shallower MORB source by 4.45 Ga (since 129I, which produces 129Xe, is extinct after ~100 Ma); i.e., neither the giant impact phase nor mantle convection has efficiently homogenized the mantle. The persistence of noble gas signatures produced very early in Earth history, such as those associated with the 129I-129Xe system, may appear to be in conflict with other extinct nuclide systems such as 146Sm-142Nd or 182Hf-182W. While isotopic anomalies in ?142Nd and ?182W are present in the Hadean and Archean mantle, the present-day mantle appears to be homogeneous. The observation requires Sm-Nd and Hf-W fractionation within the first few hundred Ma but also the subsequent destruction of the chemical fractionation through recycling and mantle mixing. A simple explanation for why the noble gas signature still persists in the present-day mantle may be the lower recycling efficiency of the noble gases compared to elements like Nd and W.

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