Extreme melting event defines Earth's early history

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Could Earth have had an even more violent infancy than previously imagined? New isotope data suggest that the Earth not only had a very violent beginning but also point to new information about our planet's chemical evolution.
New and precise measurements of a neodymium isotope ratio ($^{142}Nd/^{144}Nd$) led Maud Boyet and Rick Carlson of Carnegie Institution's Department of Terrestrial Magnetism to the discovery that all terrestrial rocks have an excess of ^{142}Nd compared to the expected building blocks of the planet. The results will appear in the June 16, 2005 edition of *Science*.

Prior research suggested that the Earth formed by the accumulation of planetesimals -- small cold bodies present in early solar system history. The chemical composition of these early bodies is reflected today in a type of stony meteorite called chondrites. Scientists had expected that the Earth would have a composition similar to these meteorites. However, this new research challenges these earlier conclusions by showing that terrestrial rocks have excess ^{142}Nd caused by the radioactive decay of the now extinct isotope ^{146}Sm.

One possible explanation of the difference in $^{142}Nd/^{144}Nd$ between Earth and chondrites is that the Earth's average composition is not chondritic, but on the basis of several chemical arguments this explanation is unlikely. More probable is that the portion of the Earth involved in creating crustal rocks was chemically differentiated very early in the planet's history – Boyet and Carlson's results suggest within the first 30 million years, or less than 1%, of Earth's history. As such, this evidence fits the growing number of observations from the Moon and Mars that the early history of planets was a very violent one, where collisions with planetesimals, the release of radioactive heat, and the energy involved in separating a metallic core all provide enough energy to melt the planet. Cooling and crystallization of the molten planet over timescales of millions to a few tens of millions of years then result in its chemical differentiation, segregating material according to density. This differentiation left most of the Earth's mantle similar in composition to the present-day upper mantle from which volcanic rocks are derived.

There must then be material that is complementary in composition to the bulk of the mantle. This complementary region, if the Earth is to have an average composition matching chondrites, must be enriched in potassium, uranium, and thorium -- radioactive elements that have provided most of the heat generation in the Earth's interior throughout its history. Furthermore, this complementary mantle reservoir must be very deep, because none of the magmas that have erupted at the Earth's surface have ever sampled it. Boyet and Carlson suggest that the reservoir coincides with the so-called D" layer imaged seismically at the very base of the mantle, just above the core. A radioactive-element-rich layer deep in the Earth is like a heating plate at the bottom of a pot: it will keep the bottom of the pot hot for a long time. Such a layer will also keep the top of the core hot and hence delay its cooling and crystallization. The scientists postulate that the early differentiation of the Earth and the deep layer produced by that process may be the reason that the Earth still has its magnetic field. The deep layer may also be responsible for generating hot plumes of upwelling mantle material that give rise to volcanic island chains such as Hawaii.

Source: Carnegie Institution