Fresh insight into the origins of Planet Earth

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Around 100 million years in the making: the Moon and the Earth

For the first time, an international team of researchers has incorporated extensive geochemical data on the formation of Earth into a model - with surprising results: more models can be used for the process of Earth's accretion than previously assumed.

Earth was formed during the creation of our Solar System when Moon and Mars-sized protoplanets collided, leaving the Earth to gradually "grow"; just how long it took for the Earth to reach its eventual size and what the accretion of the planet was like, however, is much disputed among the experts. "The latest models reveal that an accretion period of around 100 million years is the most consistent with the formation of the Moon and the Earth", says Bernard Bourdon, a professor from the Institute of Geochemistry and Petrology at ETH Zurich, Switzerland. However, there are also models that clearly suggest the Earth reached 70% of its size in just 10 million years.

The models for a rapid accretion of the Earth have to proceed from the basic premise that the colliding protoplanets blended fully with one other when the Earth was formed and achieved a chemical equilibrium between the elements in the Earth's metallic core and the silicate mantle, explains Bourdon. This would have occurred when the iron-loving elements sank to the Earth's center and the "silicate-loving" elements remained in the Earth's mantle.

The scientist harbored doubts that the Earth could have evolved in only 10 million years; he teamed up with John Rudge, a guest scientist from Cambridge, and Thorsten Kleine, at the time one of Bourdon's colleagues and currently a professor at the University of Münster, in an attempt to test the theory by fully considering all the known parameters in a model for the first time: on the one hand, the hafnium-tungsten and uranium-lead radioactive clocks; on the other hand, the distribution of the chemical elements between the core and the mantle. This distribution depends on the pressure and temperature conditions during the core formation, which probably varied during the accretion. The conditions of core formation can thus be extrapolated from the element distribution in the Earth's interior.

In their study published in *Nature Geoscience*, Bourdon and his team now demonstrate that there are several models that are compatible with the chemical observations. The notable thing is that there is no need for a full equilibrium between metals and silicates: "Up to now, it was always assumed that you could only explain the distribution of the elements through equilibrium; we show, however, that the distribution is just as easy to explain in disequilibrium", says Thorsten Kleine.

The observations are also compatible with a state of equilibrium of only about 40 percent; this means the cores of the colliding protoplanets could have reached the Earth's core directly without a major equilibration with the Earth's mantle. For Bourdon, the crucial thing is that the results show that the notion of a full equilibrium might be wrong since a disequilibrium would require more time for Earth's full accretion, thus being more consistent with the time when the Moon was formed. "If we assume that the Earth's mantle preserved signatures of the protoplanets, the end of Earth's accretion and the Moon's age coincide", says Kleine.

The age difference had always puzzled the scientists; after all, the termination of the Earth's accretion should actually coincide with the Moon's age as it ended due to the impact of a Mars-sized protoplanet that formed the Moon.The "radioactive clocks" are supposed to have been partially reset by this catastrophic collision. According to the new study, a large part of the Earth probably formed rapidly; however, it took at least 100 million years in all to reach its completion. The rapid accretion at the beginning and a slow completion are consistent with the time of the Moon's formation, says Bourdon.

More information: Rudge JF, Kleine T & Bourdon B: Broad bounds on Earth's accretion and core formation constrained by geochemical models: Nature Geoscience (2010), 3, 439 - 443 Published online: 23 May 2010 doi:10.1038/ngeo872