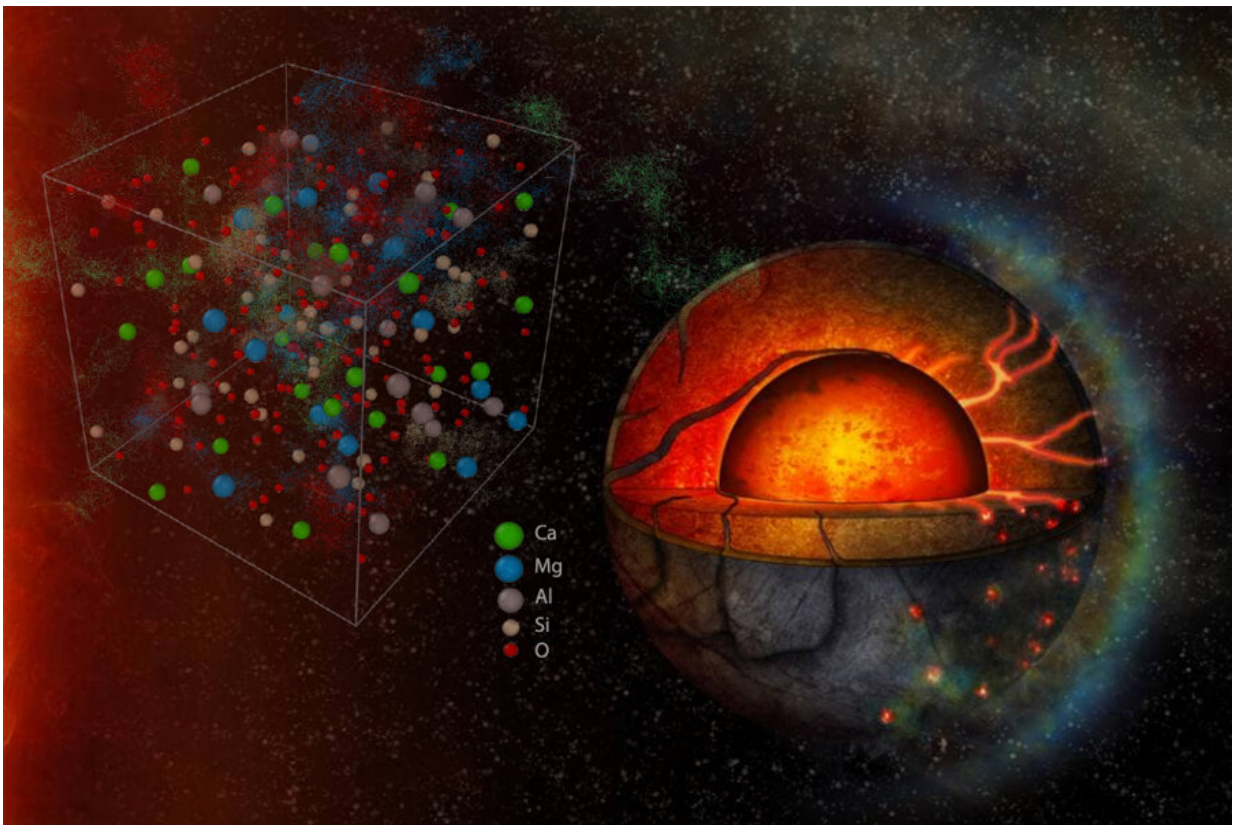


Mysteries of Earth: Researchers predict how fast ancient magma ocean solidified

February 27 2023, by Bill Wellock



An illustration of Earth as it existed during part of its formation billions of years ago, when an ocean of magma covered the surface of the planet and stretched thousands of miles deep into the core. A typical cell from a simulation conducted by FSU researchers with the relative positions of atoms are shown in the left. Credit: Suraj K. Bajgain // Lake Superior State University

Early in the formation of Earth, an ocean of magma covered the planet's surface and stretched thousands of miles deep into its core. The rate at which that "magma ocean" cooled affected the formation of the distinct layering within the planet and the chemical makeup of those layers.

Previous research estimated that it took hundreds of million years for that [magma ocean](#) to solidify, but new research from Florida State University published in *Nature Communications* narrows these large uncertainties down to less than just a couple of million years.

"This [magma](#) ocean has been an important part of Earth's history, and this study helps us answer some fundamental questions about the planet," said Mainak Mookherjee, an associate professor of geology in the Department of Earth, Ocean and Atmospheric Science.

When magma cools, it forms crystals. Where those crystals end up depends on how viscous the magma is and the relative density of the crystals. Crystals that are denser are likely to sink and thus change the composition of the remaining magma. The rate at which magma solidifies depends on how viscous it is. Less viscous magma will lead to faster cooling, whereas a magma ocean with thicker consistency will take a longer time to cool.

Like this research, previous studies have used fundamental principles of physics and chemistry to simulate the high pressures and temperatures in the Earth's deep interior. Scientists also use experiments to simulate these extreme conditions. But these experiments are limited to lower pressures, which exist at shallower depths within the Earth. They don't fully capture the scenario that existed in the planet's early history, where the magma ocean extended to depths where pressure is likely to be three times higher than what experiments can reproduce.

To overcome those limitations, Mookherjee and collaborators ran their

simulation for up to six months in the high-performance computing facility at FSU as well as at a National Science Foundation computing facility. This eliminated much of the statistical uncertainties in previous work.

"Earth is a big planet, so at depth, pressure is likely to be very high," said Suraj Bajgain, a former post-doctoral researcher at FSU who is now a visiting assistant professor at Lake Superior State University. "Even if we know the viscosity of magma at the surface, that doesn't tell us the viscosity hundreds of kilometers below it. Finding that is very challenging."

The research also helps explain the [chemical diversity](#) found within the Earth's [lower mantle](#). Samples of lava—the name for magma after it breaks through the surface of the Earth—from ridges at the bottom of the ocean floor and [volcanic islands](#) like Hawaii and Iceland crystallize into basaltic rock with similar appearances but distinct chemical compositions, a situation that has long perplexed Earth scientists.

"Why do they have distinct chemistry or chemical signals?" Mookherjee said. "Since the magma originates from underneath the Earth's surface, that means the source of the magma there has chemical diversity. How did that chemical diversity begin in the first place, and how has it survived over geological time?"

The starting point of chemical diversity in the mantle can be successfully explained by a magma [ocean](#) in the Earth's early history with low [viscosity](#). Less viscous magma led to the rapid separation of the [crystals](#) suspended within it, a process often referred to as fractional crystallization. That created a mix of different chemistry within the magma, rather than a uniform composition.

Doctoral student Aaron Wolfgang Ashley from FSU as well as Dipta

Ghosh and Bijaya Karki from the Department of Geology and Geophysics at Louisiana State University were co-authors of this paper.

More information: Suraj K. Bajgain et al, Insights into magma ocean dynamics from the transport properties of basaltic melt, *Nature Communications* (2022). [DOI: 10.1038/s41467-022-35171-y](https://doi.org/10.1038/s41467-022-35171-y)

Provided by Florida State University

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