# Modeling study proposes a diamond layer at the core-mantle boundary on Mercury

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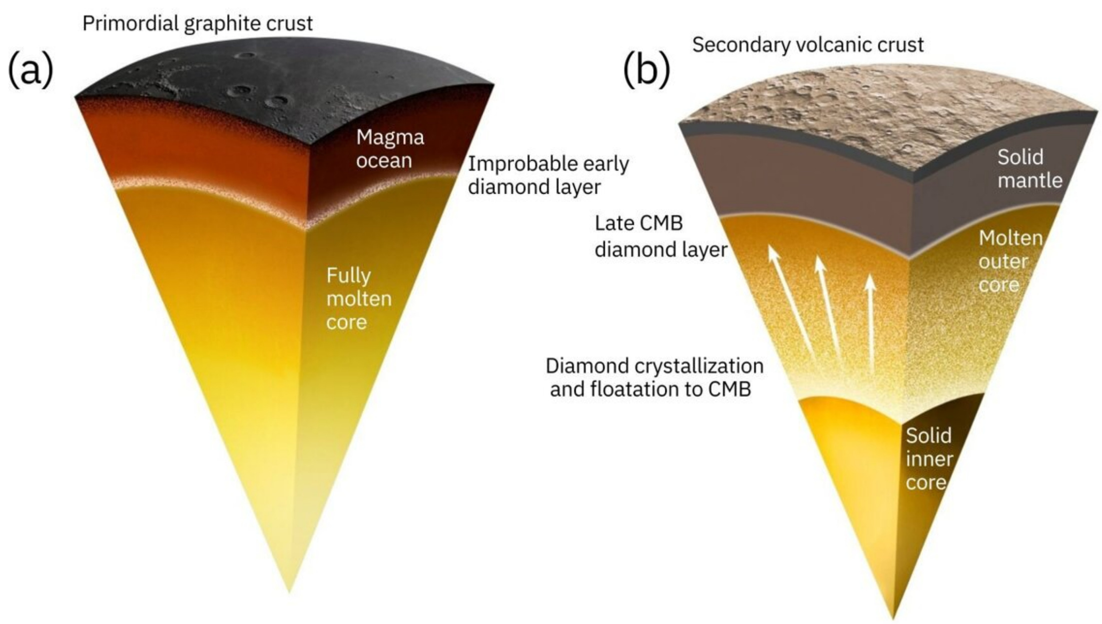


Proposed scenario for the formation of diamond at Mercury's core-mantle boundary. (a) Crystallization of the carbon-saturated silicate magma ocean and the potential, yet unlikely, early production of diamond at its base. Graphite was the major phase to form in the magma ocean and accumulated at the surface to form a primordial graphite crust. (b) During crystallization of the inner core, diamond exsolved and floated to the core-mantle boundary. Such a late diamond layer would have continued to grow throughout core crystallization. Credit: Dr. Yanhao Lin and Dr. Bernard Charlier.

A recent study in *Nature Communications* by scientists from China and Belgium suggests that Mercury's core-mantle boundary (CMB) includes a diamond layer, potentially up to 18 kilometers thick, deep within the planet's interior.

Mercury, the smallest and innermost planet in our solar system, has long puzzled scientists with its remarkably dark surface and high core density. Previous missions, such as NASA's MESSENGER spacecraft, had revealed that Mercury's surface contains significant amounts of graphite, a form of carbon.

This led the researchers to believe the planet's early history involved a carbon-rich magma ocean. Phys.org spoke to one of the co-authors of the study, Dr. Yanhao Lin, from the Center for High Pressure Science and Technology Advanced Research in Beijing.

"Many years ago, I noticed that Mercury's extremely high carbon content might have significant implications. It made me realize that something special probably happened within its interior," Dr. Lin said.

## What we know about Mercury

Most detailed information on Mercury comes from NASA's MESSENGER and Mariner 10 missions.

Previous observations by the MESSENGER spacecraft had revealed that Mercury's surface is unusually dark due to the widespread presence of graphite.

The abundance of carbon on the surface is believed to have come from an ancient layer of graphite that floated to the surface early on. This suggests that Mercury once had a molten surface layer or magma ocean containing a significant amount of carbon.

Over time, as the planet cooled down and solidified, this carbon formed a graphite crust on the surface.

However, the researchers challenge the assumption that graphite was the only stable carbon-bearing phase during Mercury's magma ocean crystallization. This is when the planet's mantle (middle layer) cools and solidifies.

Early assumptions about the graphite crust relied on lower temperature and pressure predictions at the CMB. But newer studies propose that the CMB is deeper than once thought, prompting researchers to reassess the graphite crust.

Additionally, another study has also suggested the presence of sulfur in Mercury's iron core. The presence of sulfur may have an effect on Mercury's magma ocean crystallization, thereby questioning the original claim over the presence of only graphite during that phase.

## Recreating conditions of Mercury's interior

To recreate the conditions of Mercury's interior, the researchers used a combination of high-pressure and temperature experiments and thermodynamic modeling.

"We use the large-volume press to mimic the high-temperature and high-pressure conditions of Mercury's core-mantle boundary and combine it with the geophysical models and thermodynamic calculations," explained Dr. Lin.

They used synthetic silicate as the starting material to resemble Mercury's mantle composition. This is a commonly used method for studying the interiors of planets.

Pressure levels of up to 7 Giga Pascals (GPa) were achieved by the researchers, approximately seven times the pressure found at the deepest parts of the Mariana Trench.

Under these conditions, the team studied how minerals (those found in Mercury's interior) melt and reach equilibrium phases and characterized these phases, focusing on those of graphite and diamond.

They also analyzed the chemical composition of the experimental samples.

"What we do in the laboratory is to mimic the extreme pressures and temperatures of a planetary interior. It is sometimes a challenging thing; you need to push the devices to fit your needs. Experimental setups must be highly precise to simulate these conditions," explained Dr. Lin.

They also used geophysical modeling to study the observed data about Mercury's interior.

"Geophysical models mainly come from the data collected by spacecraft, and they tell us the fundamental structures of a planet's interior," said Dr. Lin.

They used the model to predict phase stability, calculate CMB pressures and temperatures, and simulate graphite and diamond stability under extreme temperatures and pressures.

## Diamonds form under pressure

By integrating the experimental data with geophysical simulations, the researchers were able to estimate Mercury's CMB pressure at around 5.575 GPa.

At roughly 11% sulfur content, the researchers observed a considerable 358 Kelvin temperature change in Mercury's magma ocean. The researchers propose that though graphite was likely the dominant carbon phase during the magma ocean crystallization, the crystallization of the core led to the formation of a diamond layer at the CMB.

"Sulfur lowers the liquidus of Mercury's magma ocean. If the diamond forms in the magma ocean, it can sink to the bottom and be deposited at the CMB. On the other hand, sulfur also helps the formation of an iron sulfide layer at the CMB, which is related to carbon content during planetary differentiation," explained Dr. Lin.

Planetary differentiation refers to the process where a planet becomes internally structured, i.e., the center or core, to which the heavier minerals sink, and the surface or crust, to which the lighter minerals rise.

According to their findings, the diamond layer at the CMB has an estimated thickness between 15 and 18 kilometers. They also suggest that the present temperature at Mercury's CMB is close to the point where graphite can transition into diamond, stabilizing the temperature at the CMB as a result.

## Carbon-rich exoplanetary systems

One of the implications of these findings is for Mercury's magnetic field, which is anomalously strong for its size.

Dr. Lin explained, "Carbon from the molten core becomes oversaturated as it cools, forming diamond and floating to the CMB. Diamond's high thermal conductivity helps transfer heat effectively from the core to the mantle, causing temperature stratification and convection change in Mercury's liquid outer core, and thus affecting the generation of its magnetic field."

In simpler terms, as the heat is transferred from the core to the mantle, it influences the temperature gradients and convection in Mercury's liquid outer core, which affects its magnetic field generation.

Dr. Lin also pointed out the crucial role played by carbon in the formation of carbon-rich exoplanetary systems.

"It also could be relevant to the understanding of other terrestrial planets, especially those with similar sizes and compositions. The processes that led to the formation of a diamond layer on Mercury might also have occurred on other planets, potentially leaving similar signatures," concluded Dr. Lin.

**More information:** Yongjiang Xu et al, A diamond-bearing core-mantle boundary on Mercury, *Nature Communications* (2024). DOI: 10.1038/s41467-024-49305-x.