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# THE HUGE CORE AND TECTONIC EVOLUTION OF MERCURY

**Vidmachenko Anatoliy Petrovych<sup>1</sup>**

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**1.** Doctor Phys.-Math. Sci., Professor, Professor of Department of Physics  
National University of Life and Environmental Sciences of Ukraine, Kyiv, UKRAINE  
**ORCID ID: 0000-0002-0523-5234**

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**Abstract** A distinctive feature of Mercury's internal structure is its metallic core, which occupies about 85% of the planet's radius. The core accounts for up to 75% of the planet's mass. Mercury's core consists mainly of iron and up to 20% of nickel impurities. It is believed that elements such as sulfur and silicon may be present in the core within 5%. They can lower the melting point of the iron-nickel mixture. And this is important in order to explain the partially liquid state of its core. To explain the high content of metals compared to silicates, it was proposed that Mercury's predecessor had a more typical ratio of metals to silicates. However, at the initial stage of its history, this body experienced a powerful collision with another large body. After such an impact, a significant part of the original silicate mantle and crust could have been "stripped off", leaving only a metallic core with a thin shell. Recent data suggest that Mercury's vast core is not homogeneous, but has a differentiated structure, divided into a solid inner and a liquid outer part. The Mariner 10 spacecraft detected a weak global magnetic field, formed by convective motions of an electrically conductive liquid in the planet's core. This should occur only if there is at least a partially molten core. The differences in parameters between the smooth plains in the inner ring of the Rachmaninoff Basin and the surrounding surface are evidence that these internal smooth plains are the product of relatively young volcanism. The presence of a solid part of the inner core indicates that the core of Mercury is gradually cooling and starting to crystallize from the middle. The surface of Mercury is a kind of reflection of the chronicle of the rather turbulent history of the entire planet, which is manifested by numerous impact craters, the absence of an atmosphere, large plains and unique tectonic structures.

The most striking feature of Mercury's internal structure is its disproportionately large metallic core [4]. It occupies about 85% of the planet's radius and is the dominant structure of Mercury (Fig. 1). According to estimates, the core accounts for up to 75% of the planet's total mass. For example, the Earth's core occupies less than 17% of the volume.

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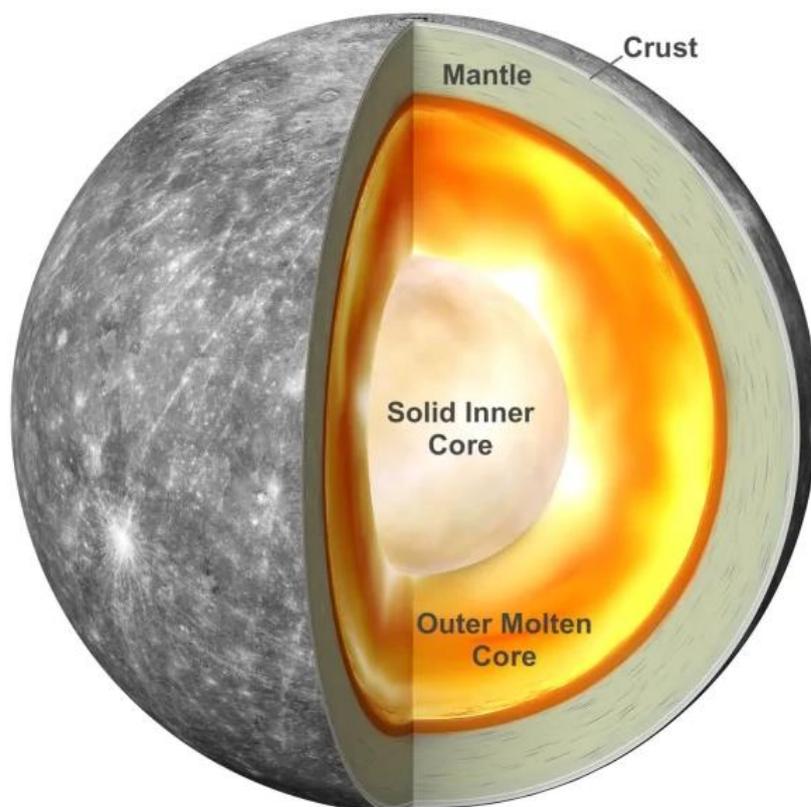


Fig. 1. **Structure of Mercury: crust, mantle, solid inner core, liquid outer core** (<https://focus.ua/static/storage/thumbs/600x/f/06/5b7f4fd0-a3332f3c10ec75132b6fb2c7accb706f.webp>)

Mercury's core is composed mainly of iron, with significant (10-20%) nickel impurities. Such a huge amount of nickel and iron in the core [8] may explain the high value of the average density of Mercury, which is second only to that of Earth. There are also estimates that elements such as sulfur and silicon may be present in the core within 5%. It is such impurities that can lower the melting point of the iron-nickel mixture. After all, this is important in order to explain the partially liquid state of its core [14]. Such a huge core has called into question the existence of standard models for the formation of terrestrial planets by simple accretion of materials in the protoplanetary disk. Several hypotheses have been proposed to explain such a high content of metals compared to silicates [8].

The leading theory has been that Mercury's predecessor had a more typical ratio between metals and silicates. However, at the initial stage of its history, this body experienced a powerful collision with another body of rather large dimensions. As a result of such an impact, a significant part of the primary silicate mantle and crust could have been "torn off". But after that, only a metallic core with

a thin shell remained. Another hypothesis attributed a significant loss of the silicate shell to the intensive evaporation of light elements under the influence of the young and very hot Sun. A third possibility could be that Mercury was formed from planetesimals as certain building blocks; and they were already significantly enriched in metals as a result of the processes of fractionation and aerodynamic sorting in the inner parts of the protosolar nebula. Therefore, the size of the core of the planet Mercury is a kind of “paleontological” evidence of catastrophic unique events and extreme conditions at the beginning of the formation of our Solar System.

Data obtained in recent years indicate that the huge core of Mercury is not homogeneous, but has a differentiated structure, divided into a solid inner part and a liquid outer part. The very first hints of the existence of a partially liquid state of the core appeared after the detection of a weak global magnetic field by the Mariner 10 spacecraft [7, 17]. Its existence is explained by the dynamo effect, that is, the formation of a magnetic field due to convective movements in the core of the planet of an electrically conductive liquid [13, 19]. This should occur only if there is at least a partially molten core. Further evidence was obtained from ground-based radar observations, which were able to detect small fluctuations in the rotation of Mercury (the so-called libration). If the entire planet were solid, the amplitudes of the recorded librations would be significantly smaller. This would suggest that Mercury's crust and mantle, its outer solid shell, would “slip” over the liquid outer core.

The enhanced color image in Fig. 2 highlights the differences in reflectance, color, and texture between the smooth plains in the inner ring of the Rachmaninoff Basin and the surrounding surface. This provides evidence that these inner smooth plains are the product of relatively young volcanism [18, 22, 24, 25]. It may be the youngest documented example of volcanic activity on Mercury to date. Although volcanism [9] on Mercury was thought to have ended early in the planet's history before the “MESSENGER” data, the images of the Rachmaninoff Basin obtained on September 29, 2009 (Fig. 2) proposed that volcanism probably extended into the second half of the solar system's history. The final confirmation and detailing of the core structure carried out by the “MESSENGER” mission became possible with high-precision measurements of the structure of the gravitational field and the features of Mercury's rotation. Analysis of the obtained data allowed us to propose models of the internal structure that best agreed with the observations.

The proposed models confirmed the presence of an outer core in a liquid state and indicated the existence of a solid inner core of significant dimensions. The radius of the inner solid core was estimated at almost 1000 km. This was about half of its total radius, which should be about 2020 km. The presence of a partially

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molten core in Mercury is a kind of key to understanding its magnetism and thermal history. After all, the magnetic field on Mercury should also be generated in its liquid outer part.

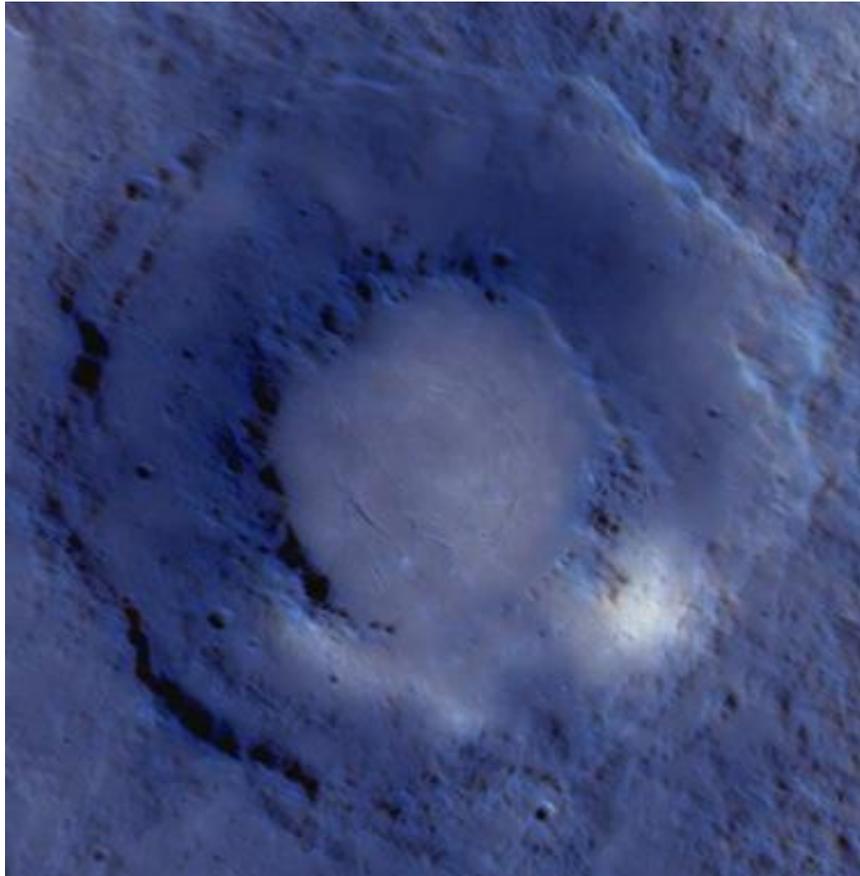


Fig. 2. **Images of the Rachmaninoff basin with a double ring obtained using “MESSENGER”**  
([https://photojournal.jpl.nasa.gov/jpegMod/PIA13475\\_modest.jpg](https://photojournal.jpl.nasa.gov/jpegMod/PIA13475_modest.jpg))

And the presence of a solid part of the inner core testifies to the fact that the core on Mercury gradually cools and begins to crystallize from the middle. These facts indicate the similarity of the Mercury core to the Earth's core. The crystallization processes release the latent part of the heat of fusion and add lighter elements, which should promote convection in the liquid part of the outer core, supporting the operation of the dynamo mechanism.

Thus, the structure and state of the core structure reflect the current characteristics of the thermal state of the planet and its changes over time. The enormous size of the core makes it the main factor in the thermal and geological

evolution of Mercury. After all, they determine the scale of its compression [2], cooling and features of volcanic activity. And the surface of Mercury is a kind of reflection of the chronicle of the rather turbulent history of the entire planet, which is manifested by numerous impact craters [26], the absence of an atmosphere [10-12], large plains and unique tectonic structures [20]. In many ways, it resembles the surface of the Moon [23]. Including the presence of water ice in the shaded parts of the polar regions [1, 3, 5, 20].

This indicates a certain similarity of the processes that operated on these two bodies. Among them, one can note the intensive bombardment by meteoroids in the early Solar System with the formation of a huge number of impact craters. Their sizes vary from insignificant depressions with diameters of hundreds of meters to multi-ringed impact basins with gigantic sizes up to thousands of kilometers. The degree of preservation of such craters is very different: from well-defined young structures with sharp ridges and bright ray systems, to severely destroyed old and partially filled craters.

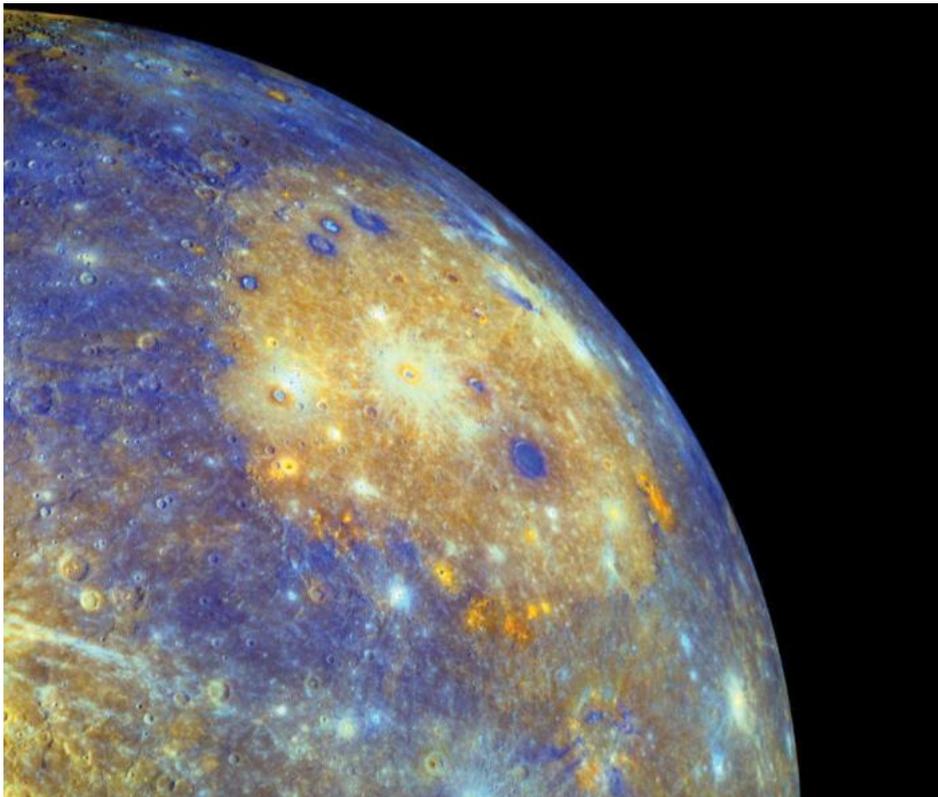


Fig. 3. **View from the “Messenger” spacecraft of the Caloris Planitia Basin (yellow) on Mercury in 2008 (<https://cdn.britannica.com/75/145475-050-916827A9/Caloris-Basin-Mercury-spacecraft-Messenger-2008.jpg>)**

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Many of the large craters and geological formations on the surface of Mercury are named after musicians, writers, and outstanding artists. The most famous and largest impact formation on Mercury is Caloris Planitia (Fig. 3). It is one of the largest impact basins in the entire Solar System, with a diameter of about 1550 km; this value is almost a third of the diameter of Mercury. Caloris Planitia [6] is believed to have been formed by the impact of an asteroid with a diameter of  $\approx 100$  km 3.8-3.9 billion years ago. The impact was powerful enough to cause the formation of seismic waves that focused on the opposite side of the planet, forming a unique “chaotic” relief there, called Weird Terrain.

The Caloris Planitia basin has a rather complex structure. It is surrounded by a ring of mountain ranges called Caloris Montes with a height of about 2 km. At the bottom of the basin are relatively smooth plains of volcanic origin, which are solidified lava flows that poured out after meteoroid impacts. The entire surface of these plains is covered with numerous concentric and radial ridges and grabens, which are tectonic depressions. They testify to the complex tectonic history of this basin, formed after its filling and subsequent formation.

In the center of the basin, a system of radial grabens, the Pantheon Fossae, diverge from a single point. Caloris Planitia is considered a key geological marker in the history of Mercury. The formation of this basin marked the end of a geological period called the Tolstoyan and the beginning of another, called the Caloriyan. The study of its structure, filling with volcanic material, and subsequent tectonic evolution allows us to understand the sequence of major geological processes on Mercury and to reconstruct the mechanics of giant impact events [15, 16].

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