Mars's two distinct hemispheres caused by mantle convection not giant impacts, study claims

January 17 2025, by Hannah Bird

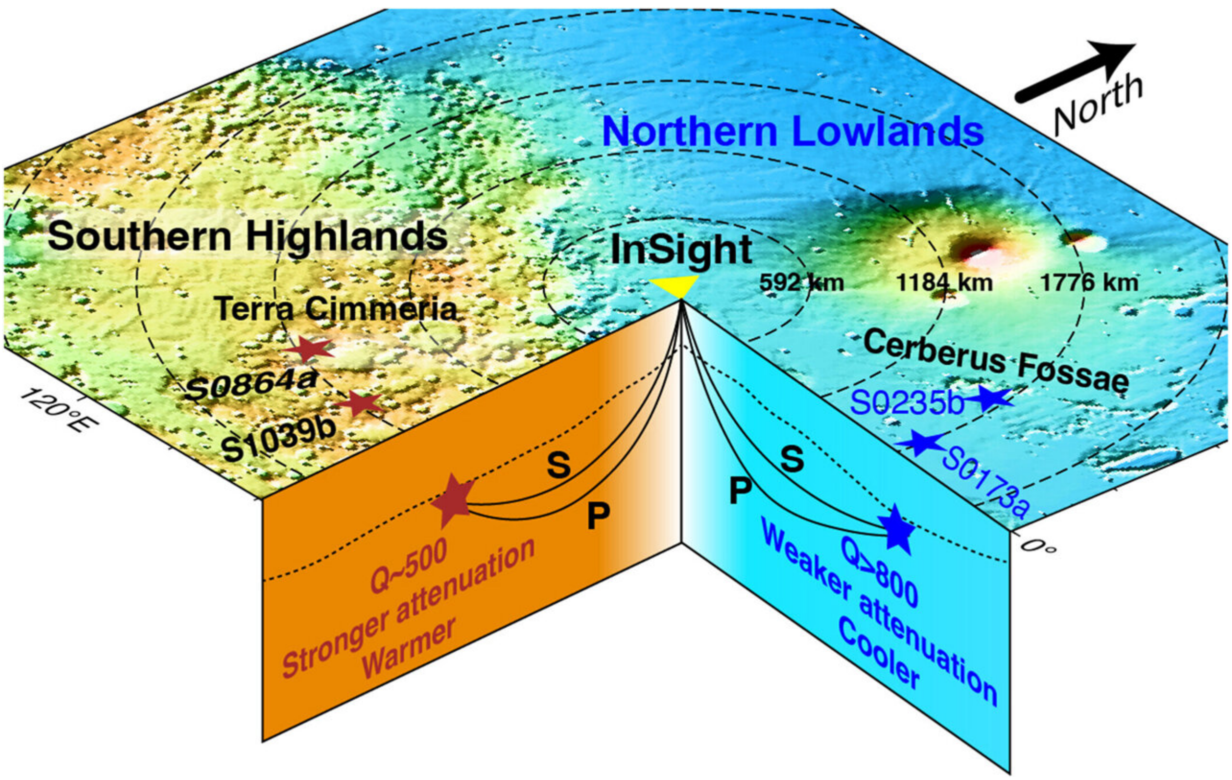

Illustration of convection origin for Mars's hemispheric dichotomy, based upon seismic wave attenuation from marsquakes. Credit: Sun and Tkalčić, 2024.

Mars has northern and southern hemispheres like Earth, but their defining characteristics are markedly different, a phenomenon known as

Martian dichotomy. The Southern Highlands are older, higher in elevation and more cratered than the Northern Lowlands. The elevated terrain of the former acts as a natural barrier to airflow, resulting in varied wind patterns and contributing to localized weather phenomena.

Explanations for the origin of this dichotomy primarily surround giant impactors (~2,000 kilometers in diameter) from space and large-scale convective movements of the mantle caused by differences in its temperature and density.

Research published in *Geophysical Research Letters* has attempted to further unravel this origin story through study of Martian earthquakes, or marsquakes. Much like on Earth, this seismic activity can be used to explore driving mechanisms beneath Mars's surface.

"Earth and Mars are often considered sister planets and were formed in the same period (4.5 billion years ago), both located within the habitable zone of our solar system. Why is Earth teeming with life, while Mars appears so silent and devoid of life at present?" Professor Sun, of the Institute of Geology and Geophysics at the Chinese Academy of Sciences, says.

"We believe that the contrast between the two planets stems from differences in their internal structures and processes. Considering the dichotomy is one of the most striking features of surface elevation and internal structures on Mars, we hope to find answers to this question by investigating the causes of the dichotomy, and attempt to solve a puzzle that has intrigued scientists for 50 years."

"While the picture of the Earth's deep interior is getting less blurry, we still don't understand the interiors of other terrestrial planets," Professor Tkalčić, of The Australian National University, further explains the project's significance. "In this study, we probed the interior of Mars using the waves from marsquakes recorded by the InSight seismometer in very much the same way we do on Earth via earthquakes.

"Understanding the solar system is dependent upon our knowledge of the Earth, and vice versa—understanding our planetary neighbor will allow us to explore the Earth's past, present and future."

To investigate this, Professors Sun and Tkalčić used low-frequency marsquake data recorded during NASA's InSight mission that took place between 2018 and 2022, which aimed to study Mars's crust, mantle and core.

Obtaining the necessary data proved somewhat challenging considering Mars has "a single seismometer that recorded marsquakes and impacts for a limited time window, while on Earth, we have thousands of seismometers that continuously record the ground motion."

Professor Sun says, "Mars exhibits significantly less tectonic activity compared to Earth, resulting in fewer and generally lower-magnitude marsquakes. Moreover, the seismometer's surface location exposes it to diurnal winds, which, despite protective shielding, contribute to a significantly low signal-to-noise ratio."

After improving the signal-to-noise ratio through employing state-of-the-art techniques, the researchers identified a new cluster of six marsquakes in the Terra Cimmeria region of the Southern Highlands and compared them to 16 previously-known marsquakes from Cerberus Fossae in the Northern Lowlands, based upon how the seismic waves move from these marsquakes to the InSight seismometer.

Subsequently, the scientists determined the quality factor for each set, which is a physical measure of how much a seismic wave weakens as it travels through Mars's interior and surface. With Terra Cimmeria having a lower quality factor (meaning more seismic wave weakening) than Cerberus Fossae, the researchers determined a pattern of southern-northern seismic attenuation.

Therefore, they conclude that the southern mantle experiences higher temperatures and lower viscosity. This is also supported by the thicker southern hemisphere crust slowing heat loss from the interior, making it more fluid and consequently experiencing more vigorous convection.

"Experimental data correlating seismic quality factor with temperature suggests that the mantle beneath the Southern Highlands could reach temperatures of approximately 1,000°C, compared to around 800°C or slightly higher beneath the Northern Lowlands," Professor Sun notes.

Overall, Professors Sun and Tkalčić determine that mantle convection is the primary cause of Mars's unusual dichotomy, not giant impacts as the alternative hypothesis suggests.

But their research continues, as Professor Sun explains the next two-pronged approach to understanding the significant differences between present-day Mars and Earth.

"First, continuing our exploration of Mars's internal structure in comparison to Earth's, the crust at the InSight landing site is estimated to be roughly 50 kilometers thick, notably thicker than Earth's average continental crust (approximately 35 kilometers) and oceanic crust (approximately 10 kilometers or smaller). Therefore, we will explore why Mars, despite being nearly half the size of Earth, possesses such a thicker crust.

"Second, we will seek liquid water on Mars. It is well-known that water is essential for sustaining life. Evidence suggests that Mars once possessed vast oceans; however, much of its liquid water might have escaped into space or been sequestered within the crust. To examine this, we aim to employ seismological techniques to determine if liquid water persists within the Martian crust.

"Investigating these two features may help us understand the divergent evolutionary paths taken by Mars and Earth, and could offer clues about the potential future and ultimate fate of our own planet."

More information: Weijia Sun et al, Constraints on the Origin of the Martian Dichotomy From Southern Highlands Marsquakes, *Geophysical Research Letters* (2024). DOI: 10.1029/2024GL110921