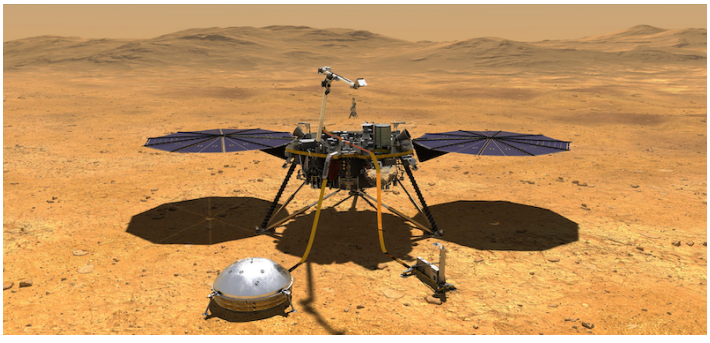
Evidence Builds for Martian Magma Chambers

A mineral physics interpretation of NASA seismic data hints that Mars has a chemically evolved crust.

By **Rachel Berkowitz**

Our red planet neighbor might have an Earth-like magma plumbing system hidden in its crust. On the basis of seismic data from a retired Mars robot, researchers at the University of Oxford in the UK have proposed that observed subsurface layers correspond to different types of igneous rock [**1**]. This new geological picture indicates that Mars once hosted vast magma chambers capable of supplying a chemically evolved crust but without our home planet's key driver of volcanic activity: plate tectonics. The finding suggests that geological complexity can evolve on a much wider range of rocky planets than previously thought.

"Mars is a fascinating planet because, unlike Earth, it never developed plate tectonics," says seismologist Tobermory Mackay-Champion, who led the work. That history means that much of its ancient crust has survived largely intact, preserving a record of the planet's earliest evolution and offering a rare window into how young rocky planets might develop.

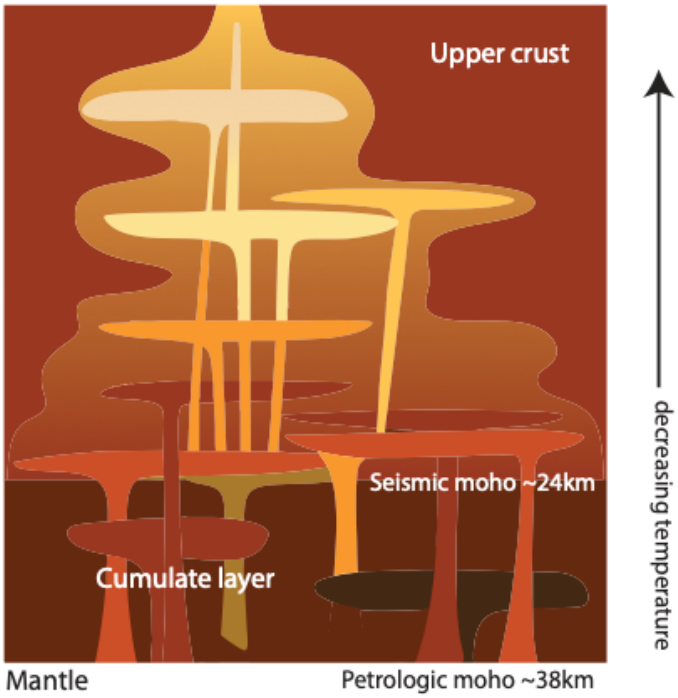


This artist's conception depicts NASA's InSight lander after it has deployed its seismometer and other instruments on the Martian surface.
Credit: NASA; JPL-Caltech

NASA's InSight lander scrutinized that record from 2018 and 2022. Its seismometer measured waves, generated by meteoroids and marsquakes, that traveled through the planet at speeds dependent on the rock layers they passed through. Previous investigations explained these seismic velocities in terms of porosity, crack closure, hydrous alteration, and modification of the upper mantle. But one layer, around 24 km beneath the surface, has remained a mystery. Within this layer, seismic waves travel through the Martian lower crust much faster than expected. Mackay-Champion says, "We knew that something changes there, but we didn't know what."

To examine the mysterious boundary, Mackay-Champion and his colleagues reached into their petrophysical toolbox. Starting with hundreds of possible Martian rock compositions, the researchers used thermodynamical methods to predict which minerals would be stable in each rock at the pressures and temperatures found beneath the Martian surface. Then, they used mineral physics data from Earth to calculate how fast seismic waves should travel through those minerals. Last, they compared those predictions with seismic data collected by InSight and used statistical methods to identify which rock types best matched the observations.

The team concluded that the boundary around 24 km marks a change in composition. Above it, the crust is consistent with basalt or "mafic" rock—the most common volcanic rock on Earth, which is rich in magnesium and iron. Below it is a thick layer of dense "ultramafic" rocks even richer in magnesium and iron that were left behind after magma separated into crystals and molten rock. These rocks form only under specific



Seismic data support a picture of vast magma systems that may have led to differentiated mineral layers in Mars' crust. Lighter colors correspond to more evolved molten rock types, which generally persist at shallower depths and lower temperatures. **Credit: T. Mackay-Champion *et al.*** [**1**]

geological conditions.

Several independent observations indicate that the differentiated crust types may have formed in multiple regions of Mars. Consequently, the thermal conditions required to produce the rocks are far more consistent with large-scale mantle upwelling than a small, isolated intrusion that InSight might have happened upon from its single vantage. Mackay-Champion interprets the results to indicate that Mars once hosted much larger and more complex underground magma systems than he and his colleagues had previously imagined. These systems did not simply transport magma to the surface but repeatedly stored, reworked, and separated it into different rock types throughout the crust. "That's surprising because this kind of complex system has long been associated with plate tectonics on Earth," he says.

Doyeon Kim, a planetary seismologist at Imperial College London, says the new work adds "an important petrological perspective" to debates about Mars' layers. It also highlights how varied interpretations of Martian crustal composition can be when they are based on seismic constraints from only one station. "Even on Earth, where we have dense seismic networks, three-dimensional seismic models can be difficult to interpret without complementary observations that are sensitive to different physical properties," he says. Nonetheless, the proposed magma system is an "exciting possibility."

Life requires persistent sources of energy, liquid water, and certain chemical elements. On Earth, plate tectonics has long been considered an important factor in supplying those ingredients. But, Mackay-Champion says, "Mars shows that plate tectonics is not essential for planets to develop the geological conditions needed to support life." Large magmatic systems can help do the job too by recycling heat, fluids, and essential elements through the crust. Additionally, magmatic systems are effective at creating large metal deposits. Mars may hold significant near-surface metal deposits—a useful resource for future missions.

The work—like all studies of Mars' interior—relies heavily on modeling and inference. Kim concludes, "the study provides a strong motivation for future, denser seismic deployments on Mars."

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REFERENCES

1. T. Mackay-Champion *et al.*, "Seismic evidence for a melt-depleted lower crust and transcrustal magmatism on Mars," **Nat. Astron. (2026).**