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UCT study seeks to understand volcanic process on Mars

A University of Cape Town's (UCT) Department of Geological Sciences study that used martian meteorite to understand the volcanic process on Mars has been published in the journal *Nature Communications Earth and Environment*. Martian meteorite are rare rocks from Mars that have landed on Earth, ejected by large impacts and surviving atmospheric entry, serving as our primary physical samples of Mars for study.

It's findings reveal that Mars contains long-lived geochemical reservoirs in its mantle, producing chemically distinct magmas – closed-system behaviour – but that its volcanic systems are also dynamic and capable of open-system mixing and assimilating crustal material during magma ascent to surface.

The study formed part of Dr Chad Peel's PhD thesis. Supervised by Dr Geoffrey Howarth, an associate professor attached to the Kimberlite research group (KRG) and the Terrestrial and Planetary Petrology (TAPP) research group at the Department of Geological Sciences, the study sought to answer some fundamental questions about the composition of the deep interior of Mars.

"Our study used a group of martian meteorites called shergottites to understand how volcanic systems on Mars formed and evolved, and what they reveal about the planet's deep interior," said Peel, the lead author. "These meteorites originate from volcanic eruptions on Mars that were later blasted off the planet's surface during impact events and into space before eventually landing on Earth".

Scientists have long recognised that shergottites fall into "depleted", "intermediate", and "enriched" groups based on their geochemical compositions. However, it has been unclear whether these geochemical differences reflect distinct mantle sources inside Mars or mixing with crustal material as magmas rose to the surface.

To address this, researchers measured rare earth elements inside the very first crystals that formed from martian magmas, olivine, and in trapped melt pockets within those crystals. These inclusions act as snapshots of the original magma before any later modification.

"Our results show that Mars contains long-lived geochemical reservoirs in its mantle, producing chemically distinct magmas but that its volcanic systems are also dynamic and capable of open-system mixing and assimilating crustal material during magma ascent to surface," said Peel.

Interest in how planetary interiors work

Peel said he has always been fascinated by how planetary interiors work.

"I was drawn to this topic because martian meteorites represent the only physical samples we have of Mars, making them an incredibly precious scientific resource. This project gave me the unique opportunity to use these samples to address one of the most fundamental and big-picture questions in planetary science, what is the composition of the martian mantle and how has it evolved?," he said.

"Our main goal was to determine why martian volcanic rocks have such diverse geochemical compositions. Do these differences reflect variations in the martian mantle, or do they result from mixing and assimilation as magmas rise through the crust? By analysing the trace-element chemistry of the earliest-formed minerals, we wanted to directly test whether martian magmas behaved as closed or open systems. We hoped to build a clearer picture of the origin and evolution of martian magmas and the dynamics of the planet's interior," Peel explained.

Insights into the composition of Mars' mantle

This research provides important insight into the composition of Mars' mantle, helping refine models of how the planet formed and how it cooled over time.

"It enhances our understanding of the evolution of martian volcanoes, revealing whether magmas rose directly from the mantle or interacted with the crust during ascent. Ultimately, our research contributes to a more accurate and complete understanding of Mars' geological history and interior evolution," said Peel.

Peel said their study captured a rare "before and after" record inside a single martian meteorite, known as LAR 12011.

"This meteorite preserves both an original depleted magma and a later enriched magma trapped inside olivine crystals, providing direct evidence of open-system processes such as magma mixing or crustal assimilation occurring on Mars," he said. "Such processes have long been suggested but have never been observed so clearly in these meteorites".

Peel said their work highlights the importance of pristine sample curation, as terrestrial alteration can obscure the original martian chemical signatures in some meteorites.

Research in the deep interior of planets

"Our latest study on Martian meteorites marks an exciting new direction for planetary research at UCT. Chad Peel, the first PhD student in South Africa to specialise in Martian meteorites, represents a major step forward in expanding this field locally," said Howarth.

Peel's work builds on a research path first established by his supervisor, Howarth, who began studying these rare rocks during a postdoctoral fellowship at the University of Tennessee under the mentorship of the late Professor Larry Taylor, a participating scientist on the early NASA Apollo missions. A key goal of Dr Howarth's research group, TAPP, is to advance the use of olivine as a tool for understanding magmatism on Mars and the composition and evolution of the planet's deep interior. This planetary work complements ongoing research within the Kimberlite Research Group, which uses kimberlite magmas and diamonds to investigate deep-Earth processes.

What's next for Dr Peel

Peel will continue to build on this momentum as he begins a postdoctoral fellowship at the University of Alberta under Professor Chris Herd, a participating scientist on NASA's Mars 2020 *Perseverance* mission.

This prestigious opportunity not only reflects Peel's exceptional achievements but also highlights the high calibre of research students being produced at UCT. His postdoctoral work will deepen his investigations into Martian magmatism and contribute to the development of curation protocols for samples returned from Mars, a crucial component of NASA's planned Mars Sample Return mission in the 2030s. This next step places Peel at the forefront of planetary science and further strengthens South Africa's emerging role in international space research.

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