Newly returned moon rock samples chronicle the dying days of lunar volcanism

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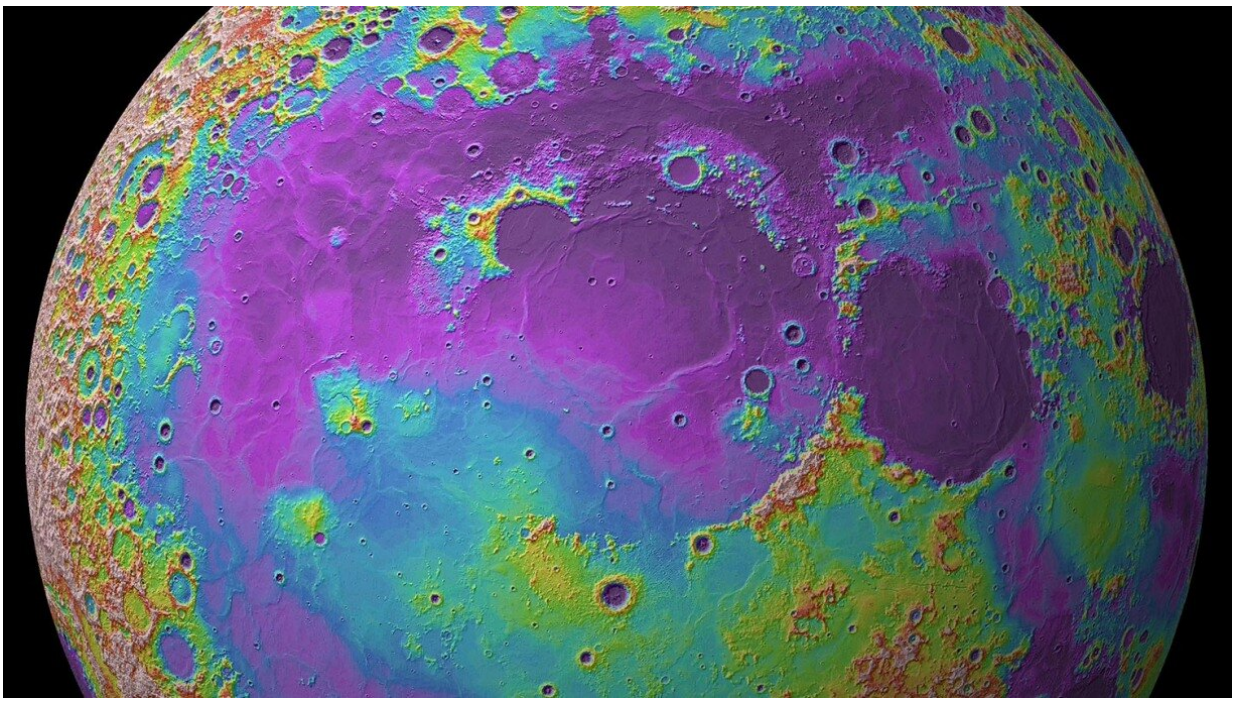

Analysis of newly returned rock samples from Oceanus Procellarum, a vast volcanic plain on the Moon (seen here in a topographic rendering with purple colors indicating lower elevations), has revealed the timing of when widespread lunar volcanism drew to a halt. Credit: Rendering by Jay Dickson

Billions of years ago, lakes of lava on the surface of the moon eventually dried to form the vast dark patches—the lunar maria—visible today on the lunar nearside. Now, thanks to rock samples recently returned to

Earth by China's Chang'e 5 mission, scientists have a new estimate for when one of the last of those lava flows ran dry.

In a study published in the journal *Science*, an international team of researchers found that basalt rocks gathered from the vast volcanic plain known as Oceanus Procellarum—a region thought to have hosted the most recent volcanism on the moon—are about 2 billion years old. The firm radiometric age not only puts an endpoint to the moon's most active volcanic period, but also serves as a guidepost to calibrate the timing of other events on the moon before and since.

Jim Head, a research professor in Brown's Department of Earth, Environmental and Planetary Sciences and co-author of the new study, says these samples—the first to be returned to Earth in 45 years—fill critical gaps in scientists' understanding of the moon's history.

He discussed the findings in an interview.

Q: Where did these samples come from, and why are they important?

These samples come from a region of the moon that's been largely unexplored by landed spacecraft. Previous samples from the Apollo missions and the Soviet Luna missions all come from the central and eastern part of the moon's near side. But it became clear as we collected more remote sensing data that the most recent volcanism on the moon was absolutely in that western portion, so that region became a prime target for sample collection. Specifically, the samples came from near Mons Rümker, a volcanic mound in the largest of the lunar maria, Oceanus Procellarum.

Q: This study looked at both the composition and age

of the samples. Let's start with age. Why is it important to know how old these samples are?

First of all, it helps us piece together just how long lunar mare volcanism lasted, which is critically important for all of our thermal evolution models for the moon. This isn't quite the youngest volcanic deposit on the moon, but it's one of the youngest. So having the age of this deposit puts some constraints on the timeframe of mare volcanism.

But it's also critical for establishing absolute ages of other features on the moon and elsewhere. When we look at a surface or a feature on the moon from which we don't have samples for radiometric dating, we try to estimate its age through the size-frequency-distribution of impact craters. Basically, as time goes by, larger impacts become more rare. So by counting craters of different sizes, we can establish a relative age of a surface. But between about one billion and three billion years ago, we don't have many good data points to tell us what the impact flux looks like. So having an absolute radiometric date for this surface helps us to calibrate the flux curve, which helps us to date other surfaces. And that's not true only for the moon. This helps us calibrate ages for Mars, Venus and elsewhere.

Q: What are the big takeaways in terms of the chemical composition of the samples?

The region from which these samples were taken is a unique terrane on the moon, which looks like it may have really high concentrations of radioactive elements—particularly thorium. So one idea for why volcanism lasted so much longer in this region compared to others was that you had all these radioactive elements concentrated together, which creates a lot of heat. That heat melts the mantle and you get volcanic flows.

However, in these samples we didn't actually see an elevated radioactive element composition. If these radioactive elements are driving the volcanism in this region, we expect to see enhanced radioactivity in the samples. But we didn't. Instead, the composition was similar to mare basalts from older deposits. So that casts some doubt on that hypothesis for long-lasting volcanism.

Q: Could you share details about your involvement with this mission?

Yes, it's been absolutely wonderful working with our Chinese colleagues on what's been just a fantastic mission. I've been traveling to China for about a decade to work with Chinese researchers and students. I've given lectures at the Chinese National Space Agency about my work with the Apollo program, and we've been able to discuss the science goals of their lunar program. And we've maintained that collaboration through visiting graduate students and other kinds of things on the basic planning of the mission and execution of the mission, and now the analysis of the samples. Right now, Yuqi Qian from the China University of Geosciences-Wuhan is visiting with us at Brown and has played a tremendous role in our work on this mission.

Brown has a long history of this kind of international collaboration, going back to our work with the Soviet Union on the Luna program and the Venera missions to Venus.

Q: What does the future hold for this collaboration?

China has major ambitions in terms of its lunar exploration program, and we hope to continue working with them. One potential mission is a robotic sample-return from the lunar far side—a region called the South Pole-Aitken Basin. We want to explore that area for a variety of reasons:

It could have exposed deposits of the lunar mantle, and it is the oldest large impact basin and we could radiometrically date that with the returned samples. So it's a real hot spot of future exploration.

We're also working with our Chinese colleagues on their Mars program and their recent Mars rover. So it's a really exciting time for international collaboration in exploration.

More information: Xiaochao Che et al, Age and composition of young basalts on the Moon, measured from samples returned by Chang'e-5, *Science* (2021). DOI: 10.1126/science.abl7957. www.science.org/doi/10.1126/science.abl7957

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