New analysis of Apollo sample rewrites a chapter of the moon's early history

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Apollo 17 astronaut Harrison Schmitt collects lunar samples with an adjustable sampling scoop during the 1972 moon mission. Recent research led by Lawrence Livermore National Laboratory planetary scientist Evan Bjonnes utilized advanced computer simulations to challenge and refine our understanding of the moon's early impacts and their broader implications for planetary science. Credit: NASA

When Apollo 17 astronauts collected a small rock from the moon more than 50 years ago, they had no way of knowing it would still be challenging scientists' understanding of lunar history today.

The fragment, known as sample 76535, formed nearly 50 kilometers underground but shows almost no signs of the violent shocks usually expected when deep rocks are blasted to the surface. That puzzle has intrigued scientists for decades, and many believed the rock was blasted to the surface by the massive impact that formed the moon's largest crater, South Pole–Aitken Basin.

New research led by Lawrence Livermore National Laboratory (LLNL) planetary scientist Evan Bjonnes offers a simpler explanation with broad implications. By running advanced computer simulations of giant lunar impacts, the team showed that the impact that formed the Serenitatis Basin, a massive impact basin on the moon's near side, could have lifted the rock to the surface during the later stages of its formation.

The findings suggest that impact occurred about 4.25 billion years ago, roughly 300 million years earlier than previously thought, pushing the timeline of lunar impacts further back in time. That shift also reshapes how scientists estimate the bombardment history of Earth and other inner planets. The research was published last week in *Geophysical Research Letters*.

"This rock may be small, but it carries a huge story about the moon's early history. It's like a time capsule from 4.25 billion years ago," Bjonnes said.

Solving a decades-old puzzle

Scientists have long agreed on two key facts about the Apollo sample: its chemistry and texture show it formed deep in the lunar crust, and it lacks the strong shock features that typically accompany a violent trip to the surface. Earlier studies proposed that only an enormous impact, like the one that created the South Pole–Aitken Basin, could excavate rock from such depths. But there was a catch—carrying the rock from that far-side basin to the Apollo 17 site would likely require an additional impact, all while avoiding shock strong enough to leave tell-tale scars.

Bjonnes and his team found a more direct path. Using computer simulations of large lunar impacts together with models of the moon's crust, they showed that during the later "collapse" stage of forming a giant crater, material from tens of kilometers down can be drawn upward gently enough to preserve a rock like sample 76535. In those simulations, a Serenitatis-scale impact can move deep material to within a few kilometers of the surface, precisely the kind of process that could place the sample where Apollo 17 found it.

"We sought a simpler, local explanation. And the models kept showing the same thing," Bjonnes said. "Big impacts can lift deep rocks to the surface without over-shocking them."

Why the timing matters

If sample 76535 dates the Serenitatis impact to 4.25 billion years, other major lunar basins may also be older than currently charted. That moves scientists to rethink how quickly the moon cooled and how frequently large impacts struck the inner solar system.

Because Earth's earliest surface record has been largely erased by plate tectonics and geology, scientists often calibrate Earth's impact history using the moon. Re-dating a cornerstone lunar impact therefore recalibrates our picture of early Earth, including how the other inner planets may have evolved, Bjonnes said.

"By pushing Serenitatis back in time, we're shifting the entire timeline of when big impacts happened across the solar system," Bjonnes said. "That has ripple effects for understanding Earth's early environment too."

Apollo samples, fresh insights

The findings underscore the enduring value of the Apollo collection and the power of modern tools to extract new meaning from historic materials.

"It's amazing that more than half a century later, Apollo samples are still revealing brand-new insights," Bjonnes said. "They continue to provide valuable new clues about the moon's past."

The study also offers practical guidance for future missions. Astronauts exploring large lunar basins, Bjonnes said, should keep an eye out for rocks that seem "out-of-place" on the surface. With crater collapse lifting deep rocks upward at many basins, similar samples may be accessible to help fill gaps in the moon's early story.

More information: Evan Bjonnes et al, Evidence for an Early Formation of Serenitatis Basin at 4.25 Ga Shifts Lunar Chronology, *Geophysical Research Letters* (2025). DOI: 10.1029/2025gl116654

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