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Earth's "Missing" Billion Years: Study Links the Great Unconformity to Early Tectonics

New findings shed light on a widespread gap in the geologic record, where more than a billion years of Earth's history appear to have been erased.

By Rebecca Fowler
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Highlights

- The Great Unconformity is a major gap in the geologic record where more than a billion years of Earth's history appear to have been erased.
- Researchers analyzed basement rocks beneath the Great Unconformity in the North China Craton to identify the causes of this gap.
- Their analysis found tectonic forces associated with early supercontinent formation were largely responsible for the Great Unconformity.

The Great Unconformity is a widespread gap in the geologic record where more than a billion years of Earth's history appear to have been erased. This "missing chapter" occurs where sedimentary rocks from the Cambrian Period sit directly atop much older igneous and metamorphic rocks, often called crystalline basement . The gap reflects both the erosion of older rocks and long intervals when little or no sediment was deposited.

Scientists have long debated what geologic forces may have caused so much of the rock record to vanish. To date, there have been two main theories: One proposes that during the icy Cryogenian Period, about 700 million years ago, a Snowball Earth glaciation event eroded kilometers of continental crust. The other attributes tectonic uplift from the formation and breakup of supercontinents as the main cause of erosion.

According to recent findings published in Proceedings of the National Academy of Sciences , the latter theory prevails: Tectonic forces associated with early supercontinent formation were largely responsible for the Great Unconformity.



The Great Unconformity in the Grand Canyon separates ~1.75 billion year-old Vishnu Schist from ~505 million year-old (Cambrian) Tapeats Sandstone. Photo: Nicholas Christie-Blick.

To test the two theories, the research team analyzed basement rocks beneath the Great Unconformity in the North China Craton, an ancient and stable block of continental crust.

“If glaciation had been the dominant driver, you’d expect to see a clear pulse of erosion at the time of the Cryogenian ice ages,” said coauthor Nicholas Christie-Blick, a geologist at Lamont-Doherty Earth Observatory, which is part of the Columbia Climate School, and professor emeritus of Earth and Environmental Sciences. “We don’t see that pattern in the North China data.”

Tracking cooling and uplift beneath the Great Unconformity

The team collected samples of ancient crystalline basement rock from five sites across North China, including in the craton interior and along its edges. In the interior, early Cambrian layers rest on basement rocks, representing a gap of more than a billion years. Near the craton’s edges, the age difference between the basement rocks and the overlying Cambrian layers is much smaller.

To determine when the basement rocks cooled and rose toward the surface, the researchers analyzed minerals such as zircon, monazite and mica, which record temperature changes over time. They combined the mineral data with statistical models to reconstruct how each sample cooled as it moved from deep in the crust toward the surface.

Data from samples in the craton interior indicate the basement rocks cooled most rapidly between about 2.1 and 1.6 billion years ago. During that time, the rocks cooled by at least 370 degrees Celsius as they rose through the crust, corresponding to about 12 kilometers of uplift and erosion. After 1.6 billion years, cooling continued more gradually, adding another 9 to 13 kilometers of uplift and erosion by about 520 million years ago.

“The basement rocks in the cratonic interior of North China formed at depths of about 25 kilometers,” said coauthor Liang Duan, a geologist at China’s Northwest University. “To fully exhume them to the surface requires roughly that amount of erosion.”

Our data “show that about 60 percent of the erosion had occurred before 1.6 billion years ago,” Duan said. Using thermochronology dating methods, the findings “indicate that roughly 75 percent had occurred before about 1.35 billion years ago.”

Consistent with that timing, the data do not show a distinct pulse of rapid cooling during the Cryogenian ice ages. While some cooling during that time cannot be ruled out, the evidence suggests glacial erosion was limited in the craton’s interior.

Zircon cooling ages from one sample in the cratonic interior range from about 620 million to 544 million years ago, indicating the rocks had already reached relatively shallow levels in the crust by that time. The youngest of these ages overlaps with evidence of a late Precambrian ice age in North China, suggesting glaciation could have contributed to erosion then. However, the largest episode of cooling happened much earlier.

The study also compares temperature records from other cratons, including Laurentia, Baltica and Amazonia, which are the ancient geological cores of North America, Europe and South America. These cratons show a similar pattern, with increased uplift and erosion occurring before about 1.6 billion years ago.

The authors estimate that more than half of the total early uplift and erosion beneath the Great Unconformity—about 13 kilometers of rock associated with more than 400 degrees Celsius of cooling—happened during an earlier period.

Rethinking the origins of the Great Unconformity

The Great Unconformity is often interpreted as the result of ancient global ice ages. The new findings suggest that much of the erosion beneath the Great Unconformity occurred over long periods of tectonic activity rather than during a single glaciation event.

The authors note that their estimates rely on standard assumptions about how temperature changes with depth. Still, the North China data align with temperature records from the interiors of other cratons and support a tectonic explanation for most of the rock removed at the Great Unconformity.

The study’s coauthors are Rong-Ruo Zhan, Northwest University and University of Padova; Massimiliano Zattin and Valerio Olivetti, University of Padova; Bo Wan, Chinese Academy of Sciences; and Rong-Hao Wei, Zhao Yang, Jianqiang Wang, Longlong Gou, Kai-Yun Chen, and Xingliang Zhang, Northwest University.

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