IS OUR MOON SHRINKING?

The Moon

A new analysis suggests that the Moon is actively shrinking and producing moonquakes along thousands of cliffs called thrust faults spread over the Moon's surface. The faults are likely the result of the Moon's interior cooling and shrinking, causing the surface crust to shrivel and crack like a raisin's skin. It has shrank some 50metres in the last million years.

Just as a grape wrinkles as it shrinks down to a raisin, the Moon gets wrinkles as it shrinks. Unlike the flexible skin on a grape, the Moon's surface crust is brittle, so it breaks as the Moon shrinks, forming "thrust faults" where one section of crust is pushed up over a neighboring part.

"Our analysis gives the first evidence that these faults are still active and likely producing moonquakes today as the Moon continues to gradually cool and shrink," said **Thomas Watters**, senior scientist in the Center for Earth and Planetary Studies at the Smithsonian's National Air and Space Museum in Washington. *"Some of these quakes can be fairly strong, around five on the Richter scale."*

These fault scarps resemble small stair-step shaped cliffs when seen from the lunar surface, typically tens of yards (meters) high and extending for a few miles (several kilometers). Astronauts **Eugene Cernan** and **Harrison Schmitt** had to zig-zag their lunar rover up and over the cliff face of the Lee-Lincoln fault scarp during the Apollo 17 mission that landed in the Taurus-Littrow valley in 1972.

Watters is lead author of a study that analyzed data from four seismometers placed on the Moon by the Apollo astronauts using an algorithm, or mathematical program, developed to pinpoint quake locations detected by a sparse seismic network. The algorithm gave a better estimate of moonquake locations. Seismometers are instruments that measure the shaking produced by quakes, recording the arrival time and strength of various quake waves to get a location estimate, called an epicenter. The study was published May 13 in Nature Geoscience.

Astronauts placed the instruments on the lunar surface during the Apollo 11, 12, 14, 15, and 16 missions. The Apollo 11 seismometer operated only for three weeks, but the four remaining recorded 28 shallow moonquakes -- the type expected to be produced by these faults -- from 1969 to 1977. The quakes ranged from about 2 to around 5 on the Richter scale.

"We think it's very likely that these quakes were produced by faults slipping as stress built up when the lunar crust was compressed by global contraction and tidal forces, indicating that the Apollo seismometers recorded the shrinking Moon and the Moon is still tectonically active," said Watters.

Other evidence that these faults are active comes from highly detailed images of the Moon by NASA's Lunar Reconnaissance Orbiter (LRO) spacecraft. The Lunar Reconnaissance Orbiter Camera (LROC) has imaged over 3,500 of the fault scarps. Some of these images show landslides or boulders at the bottom of relatively bright patches on the slopes of fault scarps or nearby terrain. Weathering from solar and space radiation gradually darkens material on the lunar surface, so brighter areas indicate regions that are freshly exposed to space, as expected if a recent moonquake sent material sliding down a cliff.

"Establishing a new network of seismometers on the lunar surface should be a priority for human exploration of the Moon, both to learn more about the Moon's interior and to determine how much of a hazard moonquakes present," said co-author **Renee Weber**, a planetary seismologist at NASA's Marshall Space Flight Center in Huntsville, Alabama.

Examples of fresh boulder fields are found on the slopes of a fault scarp in the Vitello cluster and examples of possible bright features are associated with faults that occur near craters Gemma Frisius C and Mouchez L. Other LROC fault images show tracks from boulder falls, which would be expected if the fault slipped and the resulting quake sent boulders rolling down the cliff slope.

"It's really remarkable to see how data from nearly 50 years ago and from the LRO mission has been combined to advance our understanding of the Moon while suggesting where future missions intent on studying the Moon's interior processes should go," said LRO Project Scientist **John Keller** of NASA's Goddard Space Flight Center in Greenbelt, Maryland.

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