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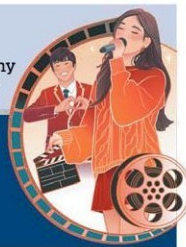
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Chang'e 5 samples help rewrite moon's history

Chinese scientists discover evidence of far more recent lunar volcanism

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Chinese scientists have discovered that lunar volcanism was still occurring about 800 million to 900 million years later than previously thought after analyzing lunar samples returned by the Chang'e 5 mission, suggesting the moon cooled down much more slowly.

Researchers from the Chinese Academy of Sciences' Institute of Geology and Geophysics presented their results in three papers published in Nature on Tuesday.

Their analysis of basalts, a type of rock formed during volcanic eruptions, not only indicated that the lunar samples were the youngest to be dated, but also provided new data on the composition and water content of the moon's interior, offering new insights on the moon's thermal evolution.

The Chang'e 5 lunar mission returned with 1,731 grams of lunar samples on Dec 17, more than 40 years after the US Apollo and Soviet Union Luna missions retrieved their samples. The samples were then distributed to 13 research institutes on July 12, with the research team at the Institute of Geology and Geophysics receiving about 5 grams.

Volcanism is a sign that a celestial body is still dynamic, and studying planetary volcanism can reveal a planet's deep composition and thermal evolution. Lunar volcanism was most active on the near side of the moon, covering about 17 percent of the lunar surface.

Geochemist Li Xianhua, an academician at the Institute of Geology and Geophysics, said scientists have always been interested in figuring out exactly when the lunar volcanism started and ended, as well as the mechanism of formation of the most recent volcanism.

Previous radioisotope dating of lunar samples brought back by the

Apollo and Luna missions suggested that most lunar volcanic activities ceased by around 2.9 billion or 2.8 billion years ago. Those samples were collected within 30 degrees of the moon's equator and could not represent the large lunar surface.

Chang'e 5 landed in the Oceanus Procellarum region, far from the Apollo and Luna sampling sites and believed to be one of the youngest rare basalt sites on the moon. Scientists had used crater-counting chronology, another dating method based on the number of craters, to predict that it might have seen lava flows between 3 billion and 1 billion years ago.

"But 3 to 1 billion years is a very long gap with many uncertainties, and because of the lack of young samples, the age and formation mechanism could not be determined," Li said.

After studying the isotopes of the rocks, Li and his colleagues confirmed that the Chang'e 5 basalts came from the same eruption lava, which occurred around 2 billion years ago, delaying the end of the Moon's volcanic activity by 800 million to 900 million years. Their finding also helps create a benchmark to better calibrate crater-counting chronology models.

Meanwhile, the cause of the moon's most recent volcanic activity remained a puzzle. Li said the scientific community had proposed two possible explanations: a lunar mantle rich in radioactive elements to provide a heat source; or one rich in water to lower the melting point.

Scientists discovered previously that the volcanically active region on the moon was rich in some specific heat-producing elements — potassium, rare earths and phosphorus. The elements were believed to be associated with the near side's volcanism by providing a heat source.

But researcher Yang Wei and his team members found that the high

content of those elements in the samples did not originate in the moon's mantle, where lava would ordinarily have been formed. Yang said the previous studies used remote sensing techniques without returned samples, meaning the deeper composition could not be detected.

Their finding rules out the hypothesis that the heat source came from radioactive "heat-generating" elements and "indicates that we need to rethink and explore new models to understand the thermal evolution of the moon," he said.

A third paper looked into the water content of the samples. The moon is widely believed to be very dry, while earlier studies confirmed the existence of water molecules on the moon.

The recent analysis of the water composition shows that the deep lunar mantle of the sampling area was much drier 2 billion years ago than that of older regions with volcanism. "This means the moon was still dynamic 2 billion years ago," Li said. "But this was not caused by the rich content of water in the lunar mantle, which would have made it easier to melt."

He said the water in question was not liquid or ice, but was indicated by the presence of hydroxyl found in minerals.

"The above results raise new questions on the study of the thermal evolution of the moon," Li said. "It is still unclear why the moon cooled down so slowly, and it will require a new theoretical framework and evolutionary model to provide new directions for future lunar exploration and research."

Yin Qingzhu, a cosmochemistry professor from University of California, Davis, in the US, called the findings a "major achievement" that has been long-awaited worldwide.

"How the moon was able to maintain magmatic activity to 2 billion years ago under these very unfavorable conditions will be a new research topic in the future," he said. "It will lead to the next extensive discussion and in-depth research in the global planetary science community."

YOUTH

Dong Shuechang from Northwest China's Ningxia Hui autonomous region captured the solar eclipse on June 21, 2020, in his photography work *The Golden Ring*, becoming the winner of the 2021 Astronomy Photographer of the Year competition in mid-September.

Hosted by the Royal Observatory Greenwich, the competition received 4,500 entries from 75 countries and regions.

Dong's image also won in the competition's "our sun" category.

The Golden Ring shows the moon blocking out most of the solar disc and leaving only a thin ring of sunlight shining through.

Dong started to prepare for the trip to take the shots toward the end of 2019.

He got the necessary gear in place, planned the location for the photographs, route and transportation, and thought ahead of how he'd like to present the theme, composition, expression and color in the photos.

"In fact, I had everything covered in my head," says the 23-year-old, adding that he figured all he had to do was open the camera and press the shutter.

However, that didn't go as he expected. The COVID-19 pandemic put a brake on his plans in early 2020. "All of a sudden, everything became uncertain."

Thanks to the effective pandemic control in China, Dong moved with his plan in the middle of last year. As he finally hit the road, it was still a rough ride. He and his friends encountered some problems on their way to Ngari prefecture in the Tibet autonomous region to take photos of the solar eclipse.

"We were inches away from driving into a lake, and met a wild animal," he recalls.

He had to juggle between finishing education assignments online — as a fourth-year student majoring in logistics management at Tianhua College of Shanghai Normal University — and getting ready for the shoot. When Dong and his friends finally reached their destination, the sky was blocked by thick clouds.

"You had to be there to feel the frustration of about 100 photographers who were ready and waiting for the solar eclipse," he says.

But magic seemed to happen. The clouds moved away and the sun came out. Dong clicked.

"I try to keep it simple — a clean picture with a highlighted subject," Dong says.

Through two different exposures, Dong superimposed two eclipse photos. "It made the image simple yet dynamic."

He also controlled light and shade so that the image retained the mountains on the moon's surface blocking the sun's light. The idea was to show the relationship among the sun, the Earth and the moon, he explains.

Emily Drabek-Maunder, who is an astronomer at the Royal Observatory Greenwich, says: "Solar eclipses have been capturing the interest of humans for thousands of years across the world. This image demonstrates both the beauty and simplicity of an eclipse, but also the science behind this astronomical event."

"Our sun can still be seen as a ring circling the moon as it passes in front of the sun, and mountains on the lunar surface can be seen hiding some of this light on the lower right-hand portion of the image. This is a stunning achievement."

Another judge of the photography contest, Steve Marsh, says



Moon shot wins prize

Photographer takes award with image of a solar eclipse, Yang Feiyue reports.



Dong's work is a perfect capture of the natural phenomenon through a perceptual, calm and professional approach. The image gave Marsh the impression that "you could reach into the sky and place this onto your finger".

Early interest

Dong was drawn to the mystery of the universe in childhood. He was amazed by the asteroid images in British physicist Stephen Hawking's book, *A Brief History of Time*, that his father bought for him.

Later, the family bought him a toy telescope that enabled him to see the moon up closer.

He went on to explore astronomical documentaries and films. During the winter vacation in his first college year in Shanghai in 2018,

Dong's mother gave him the book, *Xingkong Sheying Bijì* (Star Photography Notes) written by award-winning photographer Wu Zhong, which encouraged him further to pursue his passion.

"Astronomy photography enables me to record details that are usually missed by the naked eye," Dong says.

He adds that when he uses telephoto lens to take photos, he can see, for example, the details of the Milky Way, as well as its red, green and blue colors that "can be brought into sharp relief through photography".

Such photography prompted Dong to acquire knowledge of the field.

"I got to know how temperature and air composition can result in

different star colors, such as blue and yellow that are shown in the images," he says.

"It is also thrilling when you can see something (in photos) in the great distance like the Andromeda Galaxy."

Dong met with Wu and sought his advice to hone his skills. Dong learned how to take control of elements and color in an image.

"You need to know what you want to express and how to find your own angle," he adds.

For the purpose, a high-sensitivity camera that brings down noises is required, and photos of different exposure time are needed for overlay later, he says.

Beaten trail

He threw his hat in the ring of the 2019 Astronomy Photographer of the Year competition. "It was well-known to people in the circle, so I wanted to put my skills to test through it."

Dong's self-confidence got a shot in the arm after winning the best newcomer award with his work, *Sky and Ground, Stars and Sand*.

"It was unexpected and a big encouragement," he says.

Dong went on to win the championships at several major photography competitions, including the 2021 photography contest by the Beijing Planetarium and the Chinese undergraduate astronomical photography contest this year held by the Fudan Astronomy Society.

He has also worked for professional photography organizations, including SKRAW and CSA.

Dong says more than three years of chasing the stars has brought excitement and accomplishment in his life, although the process was often mixed with sweat and tears.

Sichuan province, and Tibet, Ningxia Hui and Xinjiang Uygur autonomous regions are ideal for star observation.

"They have less pollution and moisture, and more clear skies, which don't interfere with the clarity of the atmosphere," Dong says.

He also prefers taking pictures in deserts, where the wind is usually slow and sand dunes are easier to climb for better sky views.

Dong graduated from college in July and got a job dealing with promoting cameras in Shanghai. The job allows him to keep abreast of advanced camera techniques and get in touch with photography experts.

In late September, Dong went on a photography trip, sponsored by the Chinese National Geography magazine, to Qomolangma, also known in the West as Mount Everest.

"The idea was to record grand nature, especially in places off the beaten tracks, and find differences in the region over the past 100 years," Dong says.

The adventure led him to learn to hike in the wilderness and study formations of glacier and climate in mountainous areas.

His breath was taken away by the biodiversity, including forest trees, tropical and meadow plants, snowy peaks, glaciers and moraine lakes in a valley 4,000 meters above sea level.

The stunning views of the giant mountain peaks turned pink by the sunrise made Dong forget his altitude sickness. "I will surely go back again."

Speaking about his future plan, Dong says he will explore new photography fields and better ways to integrate science and art.

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