The Moon revisited

With the renewed interest in the Moon, Katie Joy, Marissa Lo and Samantha Bell from the University of Manchester discuss the importance of our closest celestial neighbour, from both an exploration and scientific perspective

Above: The Artemis programme will see humans returning to the surface of the Moon

THE BRIGHTEST AND biggest object in our night sky, the Moon is the only other place in the solar system that humans have set foot – so far. It's been nearly 50 years since NASA's Apollo missions when humankind last walked on the Moon, but with the commencement of the Artemis programme, people are set to return within the decade.

Artemis

Katie Joy, a Professor in Earth Sciences and an expert on lunar samples, explains some of the background to the mission.

"This human exploration programme is being developed by the US space agency NASA and its international partners, and is named after the sister of Apollo in Greek mythology – a nice nod to the Apollo missions of the 1960s and 1970s.

"The plan is to develop new rocketry capability to deliver large-mass payloads and humans to the lunar surface, explore specific landing site areas, and deploy scientific payloads, such as seismic networks, thermal heat probes, Earth climate observation equipment and astronomy experiments. The mission scenarios being developed will be more sophisticated, with more people – importantly including more diverse crews – visiting the surface per mission, and to stay longer on the surface than Apollo.

"The goal for the first Artemis surface mission is 2024, although that is looking a bit optimistic because several steps need to occur first to test the heavy launch rocket and the Earth-Moon transfer vehicle. The missions will work towards establishing a base camp habitat, allowing for longer surface stays, in an outpost similar to the types of research bases people visit in Antarctica. Knowledge of how to use the resources found on the Moon will be used to work towards sending humans to Mars and other destinations (such as the moons of Mars and asteroids) in the next decade."

Beyond the Moon

While a key aim of Artemis is to learn how to live on another world and to use the Moon as a stepping stone to more distal parts of the solar system, Earth's only natural satellite has scientific significance well beyond its use as a convenient launch pad. Marissa Lo, a PhD student researching lunar volcanism, emphasises that lessons learnt from the Moon provide insights for Earth and other bodies in the solar system.

"From a space travel perspective, going back to the Moon and developing infrastructure there is important for facilitating efficient future space missions to bodies further afield. From a scientific research perspective, there's still so much to learn and understand about the Moon. The Moon is a key component in many different theories and models for how Earth formed, so understanding the origin and history of the Moon aids our understanding of Earth formation. The lessons learnt from the Earth-Moon system are also applicable to other rocky bodies in our solar system and possibly other exoplanetary systems as well.

"Unlike Earth, where tectonic plates are destroyed and recycled, the Moon is not tectonically active, so there's a much longer geological history to investigate. The Moon is like a record of different events that have happened in our solar system, the most obvious example of this is impacts, the evidence for which we can see as craters across the lunar surface."

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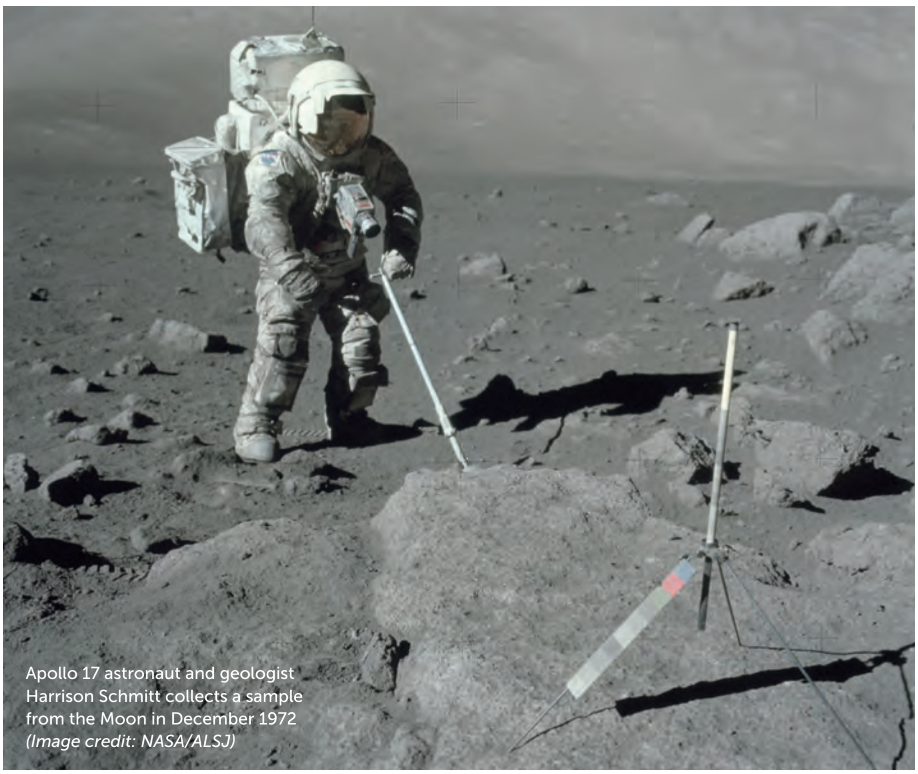
Lunar samples

Katie suggests that each Artemis landing will hopefully return 100 kg or more of lunar rock, which will expand our knowledge of the Moon's geological diversity from landing sites we haven't been to before. But, while we await acquisition of these samples, there is still plenty to glean from existing lunar samples.

Sam Bell, who has just completed her PhD studying the lunar mare basalts, notes that prior to the Apollo missions, interpretations of the geology of the Moon were limited to what we could observe remotely. It was the return and analysis of the Apollo samples (about 382 kg in total), as well as Russia's uncrewed Luna missions in the 1970s, which collectively returned about 326 g of lunar soil from regions not visited by the Apollo missions, that helped to address a range of important scientific questions, from what the Moon was made of, to how it formed, and when it was volcanically active.

"One of the major benefits of sample return was that for the first time we could date lunar samples collected from known locations on the surface. From this we could work out how old different craters are on the Moon and the rate of cratering in the inner solar system through time. This allowed us to estimate the surface age of other bodies in →



Apollo 17 astronaut and geologist Harrison Schmitt collects a sample from the Moon in December 1972 *(Image credit: NASA/ALSJ)*


Understanding the origin and history of the Moon aids our understanding of Earth formation. *(Image credit: NASA/JSC)*

the solar system, such as Mars and Mercury, based on the number of craters present."

At the end of 2020, China's Chang'e 5 mission visited a new location on the Moon, returning fresh samples to Earth, as Katie explains.

"China recently returned a robotic lander from the nearside of the Moon, bringing with it 1.7 kg of new lunar soil for scientists to study. Lunar sample return hasn't been done since the 1970s. It's hugely exciting! The first investigations are currently being published in the scientific literature, so I can't say too much about what we have found, but it is going to change our ideas about the Moon's volcanic and thermal history. Watch this space."

In late 2021 or 2022, the Chang'e 6 mission aims to return rocks from the Moon's farside, which Katie suggests has the potential to provide radical new insights.

"These rocks will be the first to be collected from a known geological locality on the farside and have the potential to throw all of our current ideas about why the near and farside of the Moon are so different up in the air. In fact I hope they do; I would love to see lunar geology get a big shake up in its ideas."

Lunar meteorites

Space missions are not our only source of Moon rock; Katie explains that lunar meteorites provide critical insights, too.

"Lunar meteorites are pieces of the Moon that are knocked off its surface when an asteroid or comet hits. Rocks ejected at speeds higher than the Moon's escape velocity spray out into space. Some become attracted towards Earth's gravity, landing on Earth's surface, if they survive travel through the atmosphere. We find such meteorites in desert environments, although we need to analyse them in the laboratory to work out if they came from the Moon (that is, if they have a similar chemistry to the Apollo samples) or if they have come from another body, like an asteroid or Mars. Once we are sure we have a lunar sample, we can apply our geochemical, mineralogical, or isotopic analytical arsenal to investigate its geological history.

"The really important reason lunar meteorites are so special is that they potentially sample a much wider range of places across the Moon than just those sampled by the Apollo, Luna and Chang'e missions. So, they give us a better understanding of the Moon's global geological diversity and evolution than the sample return missions can by themselves. Of course the challenge is we don't know exactly where the samples were launched from the Moon – another question we have to try and solve."

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Science and inspiration

Despite its proximity, we still know relatively little about the Moon. Katie suggests that we have barely scratched the surface when it comes to understanding the Moon's surface geology, let alone investigating the interior in any meaningful way, while Marissa notes that there are many other interesting environments still to be explored, such as caves in lava tubes that could be suitable protective habitats for humans and the polar regions where there might be ice deposits. As Sam explains, the presence of volatiles and water on the Moon is an essential topic:

"Scientifically, water and other volatiles give us vital clues into the lunar interior

We have barely scratched the surface of understanding the Moon's geology *(Image credit: NASA/JSC)*

and surface processes on the Moon, but they are also key resources that would be needed, for example, to create a permanent human base on the Moon. We need to understand where these resources are potentially located geographically, but also how they are stored within the rocks before we can consider their use to support human life."

Katie is often asked whether such exploration is worth it, given the number of challenges we face on Earth, such as health emergencies and climate change.

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"Human spaceflight does cost a lot of money, but these resources are not simply sent to space – they are used to develop technology that is beneficial for other sectors and to employ and skill up people back on Earth, meaning that the economic returns and human benefits far exceed the investment. The Artemis missions, for example, will include more countries than just the US, providing an opportunity for international cooperation and training of scientists globally. A key hurdle for the space agencies is how to make exploration sustainable. We must learn lessons on how we have explored and used resources on Earth, before carrying similar mistakes over to future ventures on the Moon and other planetary bodies."

The next decade promises to revolutionise our understanding of our closest celestial neighbour, but as Katie says, human exploration isn't purely about science.

"It's an opportunity to excite and inspire people about the world and universe around us. It's a great hook to get young people interested in science and technology subjects, and clued into the big challenges humanity faces."

A comment from Sam sums it up: "It will be so exciting for our generation to experience an Apollo-like era of lunar exploration." G

KATIE JOY
Professor Katie Joy is based in the Dept of Earth and Environmental Sciences at the University of Manchester. She works on a variety of projects using lunar samples and is helping to plan for future lunar robotic missions. One project aims to analyse lunar soil to better understand how the Moon's surface has interacted with the surrounding space environment, including gases emitted from the Sun and impacting comets and asteroids.
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MARISSA LO
Marissa Lo is a PhD student researching lunar volcanism at the University of Manchester. She uses images of lunar volcanic deposits and models of magma ascent to compile a volatile history of the Moon, and has also worked on a mission proposal for the European Space Agency projects CAVES and PANGAEA that investigate the use of lunar lava tubes and caves for future human habitation.
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SAMANTHA BELL
Dr Samantha Bell recently completed her PhD working on Apollo 15 mare basalts at the University of Manchester. She is now investigating the composition of Apollo 16 samples and the use of a new automated technique to more rapidly determine the source of space samples.
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