Asteroids most likely delivered water to the moon – here's how we cracked it

June 1 2016, by Jessica Barnes, The Open University

Credit: The Conversation

One of the moon's greatest mysteries has long been whether it has any water. During the Apollo era in 1960s and 70s, scientists were convinced it was dry and dusty – estimating there was less than one part in a billion water. However, over the last decade, analyses of lunar samples have revealed that there is a considerable amount of water inside the moon – up to several hundred parts per million – and that it's been there since the satellite was very young.

But exactly where this internal water came from has remained an enigma. There have been many suggestions, such as comets or asteroids bringing it there. Another is that some of the water could have been there since the moon formed, from material that originally came from the Earth. Now our new study suggests that most of the water inside the moon must have been delivered by asteroids some 4.5 to 4.3 billion years ago.

The moon formed some 4.5 billion years ago – shortly after Earth. But whereas Earth has been constantly renovated through the effects of plate tectonics, the moon has been relatively quiet. The Earth's ever-changing face means that we know very little of its earliest history. The moon, however, has acted like a time capsule, helping us better understand its history – and the Earth's.

Digging for water

To probe how water got to the moon's interior, we performed calculations using published data for water in lunar samples and bulk estimates of water inside the moon. We also used data available for the water content and composition of meteorites and comets. The model also accounted for different types of water, (such as "heavy water" which is made up of relatively more deuterium than hydrogen). This is very useful because because water in different objects in the solar system has different signatures – most comets, for example, have heavy water.

Carbonaceous chondrite meteorite that fell in Mexico in 1969 (weight 520g). Credit: H. Raab/wikimedia, CC BY-SA

By calculating different mixtures of water from different sources and comparing the results to what we observe for the moon, we discovered that water-rich carbonaceous asteroids are the most likely candidates for bringing the majority of "volatile elements" (elements and compounds with low boiling points) to the moon – such as water, nitrogen and carbon. We also found that comets most likely delivered a maximum of 20% of such elements to the lunar interior.

Based on the data and models currently available, we think that these impacts happened over a couple of hundred million years after the moon formed, just before its huge magma ocean solidified. The asteroids and comets crashed into this magma ocean and were likely retained (rather than boiled off) due to a thermal lid which formed at the surface of the huge pool of magma.

The results are important because they tell us about the kinds of objects that struck both the moon and the Earth more than four billion years ago. Potentially it could also help us understand the origin of water in the Earth. In fact, water inside the Earth is so similar in composition to the water in the moon that, along with other geochemical evidence, it seems likely that our water also came from asteroids.

Of course, this is not an open and shut case, there is still a lot that we do not know about water and other volatiles in the moon and how they relate to each other. For example, we still need to fully understand the processes that operated inside the moon over geological time and work out what happened to the volatiles when lavas were erupted to the lunar surface. We can gain a huge amount of information from further study of samples returned from the Apollo and Luna missions. There are some 382kg of such samples, but only 2% have been investigated for analyses of volatiles.

But ultimately, we need to explore the entire moon to properly understand it. Our work is timely especially in light of the plans to send robotic and human prospecting missions to previously unexplored regions of the moon. In fact, the Apollo astronauts covered a distance on the lunar surface equivalent to a return journey from Edinburgh to Glasgow, so there is every possibility that rocks from the far side and polar regions of the moon may tell a different story.

In addition to the water trapped in glasses and minerals, there is also water-ice and other volatiles on the surface of the moon. As national space agencies gear up for the next era of lunar missions they are primarily focused on investigating how much water is on the surface, where it is and in what form. This will be crucial to determine whether water can be used as a resource for sustaining a moon base or enabling further exploration of the solar system. My feeling is that our nearest neighbour still has a lot to show and tell, and that the next 10 to 20 years are going to be eye-opening.

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