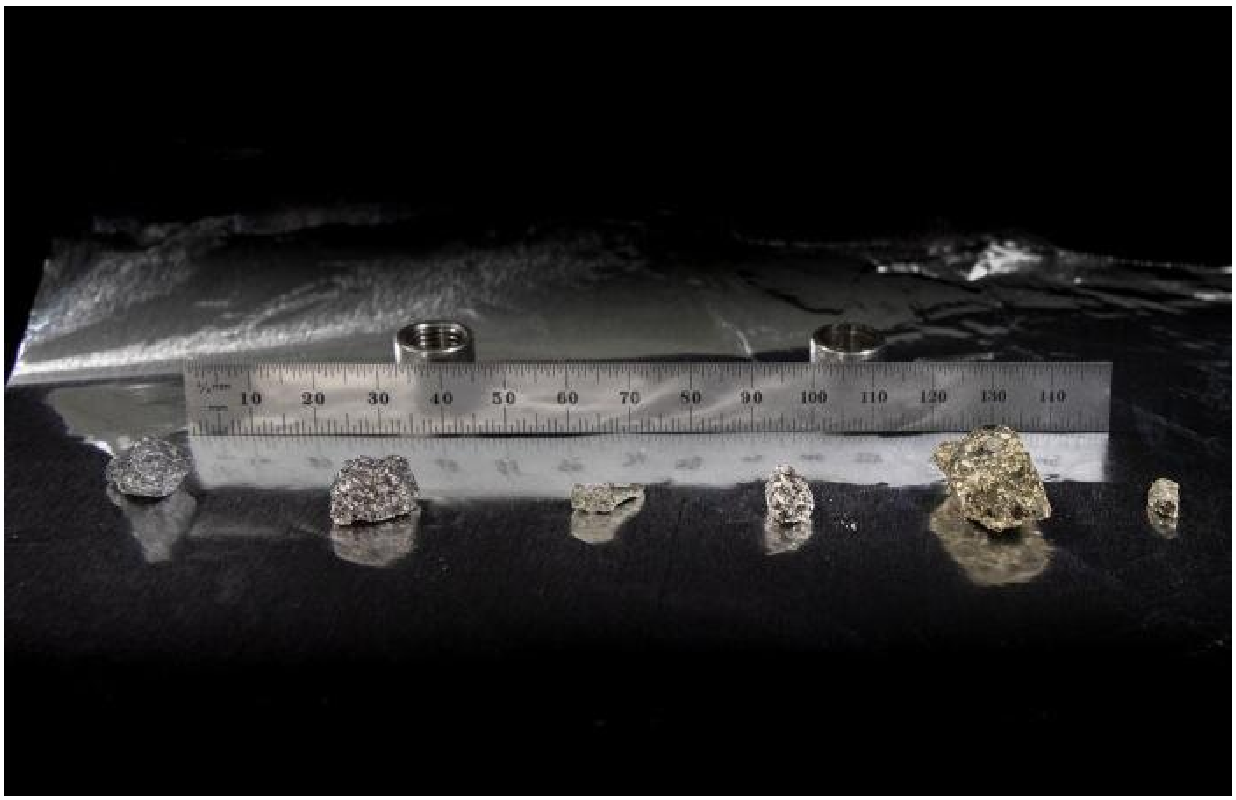
50 years after NASA's Apollo mission, moon rocks still have secrets to reveal

April 4 2023, by Jeremy P Rumsey



The lunar and meteorite samples consist of a variety of rocks, some more gravel-like and some similar to lava rock found in Hawaii. The samples have different chemical compositions and represent various geological and astronomical events throughout the moon's history. Better understanding which atoms are present in the samples provides a better understanding of how the solar system was formed and what mineral resources are available for advancing space travel to Mars. Credit: Genevieve Martin/ORNL, U.S. Dept. of Energy

How did we get from stardust to where we are today? That's the question NASA scientist Andrew Needham has pondered his entire career.

In 1969, astronauts of Apollo 11 were the first to set foot on the moon and to study the lunar surface. Over the next several Apollo missions, ending in 1972, they brought back moon rocks for scientific research to unlock mysteries of the universe.

Scientists knew the rocks contained clues to the origins of the solar system as well as minerals that could be of interest for advancing space travel beyond the moon. But back then, in-depth analysis was hindered because of a low inventory of rock samples and a lack of advanced research technology.

Now, nearly 50 years later, Needham is studying those same rocks with characterization tools and techniques light-years ahead of their predecessors. One such technique is neutron scattering.

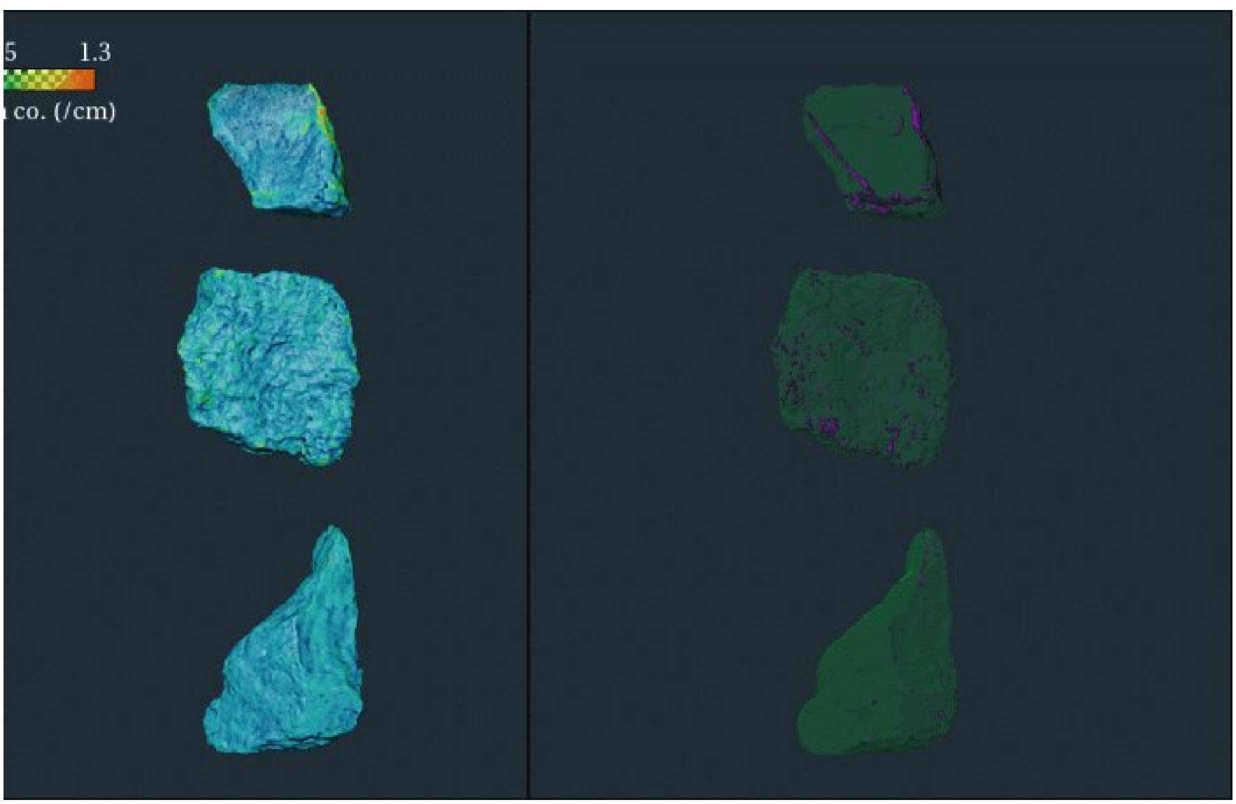
At the Department of Energy's High Flux Isotope Reactor, or HFIR—located at Oak Ridge National Laboratory—Needham studied a small collection of lunar and asteroid samples using the newly renamed neutron imaging instrument MARS, short for the Multimodal Advanced Radiography Station. At the time of the experiments, Needham worked for Jacobs as the contractor section manager for Astromaterials Curation at NASA's Johnson Space Center in Houston.

Like X-rays, neutrons are used to look inside materials to identify and measure elements and their atomic arrangement. Neutrons can also provide insights into how materials can be harnessed to improve technology. In Needham's case, he's using them to study the mineral content inside Apollo samples and meteorites, searching for clues to early planetary formations and where water might be stored on the moon.

"In the past decade, there's really been a renewed interest in looking for water in places like the moon," he said. "We used to think the moon was very dry, but now we know that water is trapped inside the mineral content of these rocks. Studies have shown that water might be accumulating near the poles of the moon through impact events that are evidenced in these samples.

"If humans are going to further explore the moon, and one day Mars, we need to figure out ways to fuel ourselves and survive beyond Earth, instead of constantly supplying everything from the Earth's surface, which is very difficult and very, very expensive.

"Understanding the composition of these rocks, where hydrogen atoms are, how they're stored and transported, really helps us understand the moon over its history and up to its present day, and how we might use that information to travel even further."



On the left, neutron imaging data from moon rocks collected during the NASA Apollo missions highlight variations in color based on how different parts of the sample, including different minerals, absorb neutrons. On the right, more details of the sample interior can be seen, including regions highlighted in magenta, which can help researchers determine where to make physical slices to extract only the elements of interest and preserves the rare moon rocks for further studies. Credit: Yuxuan Zhang/ORNL, U.S. Dept. of Energy

The Apollo mission samples Needham is studying include impact breccias, which are made up of dust, rock fragments and melted particulates mixed together after meteorites are pulled into gravity wells and bombard the moon's surface. Needham explained that when the meteorites struck roughly 4 billion years ago, the impacts combined with and stirred up mixtures of materials from the moon's surface as well as its deeper interior layers. In essence, he said, even one moon rock can contain a plethora of information from multiple astronomical events.

Neutrons are ideally suited to studying the chemical composition of the Apollo moon rocks: They can pass through almost any material, but light elements such as hydrogen will block or deflect them upon contact.

Using the MARS instrument, which specializes in creating radiographic images similar to clinical X-rays, Needham loaded the samples into containers stationed on a rotating platform that allows measurements to be taken of the rocks in 360 degrees. Regions where hydrogen atoms are likely to be found are highlighted within the rocks as the neutron beam passes through the sample.

In the neutron images, the hydrogen atoms show up as brightly colored spots in contrast to the rest of the sample. The more difficult it is for a neutron to pass through an element, the brighter that element will appear, creating a color scale that corresponds to different elements. The 360-degree measurements can then be used to create 3D models of the rocks that can in turn be compared with results from other research techniques, such as X-rays and electron microscopy.

Additional neutron measurements of the moon rocks were taken at HFIR's sister facility, the Spallation Neutron Source, or SNS, which is powered by the world-leading 1.55 megawatt pulsed-beam accelerator. The SNAP instrument at SNS specializes in studying materials under high pressures, but it also currently serves as a testbed for VENUS, a new state-of-the-art imaging instrument at SNS that will finish construction in 2024. Together, MARS and VENUS will provide researchers with the world's most complete set of imaging capabilities offered at one institution.

"These are precious samples, so we can't go slicing and dicing as much as we want," said Needham. "Neutrons help us see inside the samples so that we can make the most precise slices to expose only the areas of interest. And it's really only neutron imaging that makes hydrogen atoms visually pop out, letting you know that, 'Ooh! That's something I want to look at.'"

A month after conducting his experiments at the MARS instrument, Needham started a new position: research scientist at NASA Goddard Space Flight Center as the contamination control scientist for the agency's Artemis program. Artemis represents the next step in human space exploration. Its goal is to establish a sustainable presence on the moon as a step toward sending the first astronauts to Mars.

"Apollo only landed in a few select areas of the moon," Needham said. "The Artemis missions are going to be bringing back samples from many different regions, samples that are likely to be rich in hydrogen and other important minerals. Part of my job will be to ensure those samples are as perfectly preserved as possible for future research, just like the scientists who had the foresight 50 years to do the same for the samples that we're studying today.

"The sorts of analyses available at Oak Ridge will be really important for Artemis. It's part of a long-term plan to bring next-generation techniques to the next generation of samples that we're going to be bringing back."

Provided by Oak Ridge National Laboratory