

Hot Idea

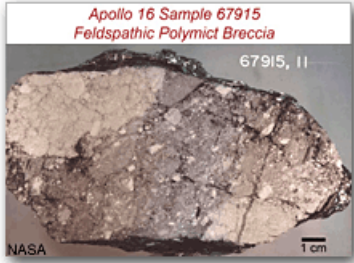
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Celebrated Moon Rocks

--- Overview and status of the Apollo lunar collection: A unique, but limited, resource of extraterrestrial material.

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The Need for Lunar Samples and Simulants: Where Engineering and Science Meet sums up one of the sessions attracting attention at the annual meeting of the Lunar Exploration Analysis Group (LEAG), held November 16-19, 2009 in Houston, Texas. Speakers addressed the question of how the Apollo lunar samples can be used to facilitate NASA's return to the Moon while preserving the collection for scientific investigation. Here is a summary of the LEAG presentations of Dr. Gary Lofgren, Lunar Curator at the NASA Johnson Space Center in Houston, Texas, and Dr. Meenakshi (Mini) Wadhwa, Professor at Arizona State University and Chair of NASA's advisory committee called CAPTEM (Curation and Analysis Planning Team for Extraterrestrial Materials). Lofgren gave a status report of the collection of rocks and regolith returned to Earth by the Apollo astronauts from six different landing sites on the Moon in 1969-1972. Wadhwa explained the role of CAPTEM in lunar sample allocation.

References:

- [Lunar Exploration Analysis Group \(LEAG\) Annual Meeting Agenda](#), November 16-19, 2009.
- [Lunar Sample Compendium](#).

The Collection of Lunar Samples from Apollo Missions

The six Apollo missions that landed astronauts on the Moon returned a collection of rock and soil samples weighing approximately 382 kilograms (842 pounds) and consisting of 2,196 separate samples. Today there are more than 110,000 individually numbered subsamples (split, chipped or sawed pieces) available to investigators for detailed studies. The collection also includes 16.5 meters (54 feet) of core samples pulled from the top of the lunar regolith. (The fine-grained, fragmental, loose material blanketing the Moon is most commonly referred to as soil but it has none of the organic sediment component as on Earth. The more precise term is [regolith](#).) The number of samples increased as the missions progressed, as shown in the table below. Click on the emblems for more information about the missions from NASA.

MISSION							TOTAL
	Apollo 11	Apollo 12	Apollo 14	Apollo 15	Apollo 16	Apollo 17	
Number of samples:	58	69	227	370	731	741	2196
Weight in kilograms:	21.8	34.3	42.3	77.3	95.7	110.5	381.7

These missions, the astronauts, the thousands of people who worked to make the missions possible, and the lunar samples brought back to Earth were celebrated worldwide.



Successful Returns: [LEFT] Seated on the back of the car from left to right, the Apollo 11 astronauts, Edwin Aldrin, Michael Collins, and Neil Armstrong, are celebrated at a ticker tape parade in New York City. [RIGHT] The first Apollo 11 sample return container, holding the collected lunar surface material, is shown just after it arrived on July 25, 1969 at the Manned Spacecraft Center, now known as the Johnson Space Center in Houston, Texas. The rock box had arrived only minutes earlier at Ellington Air Force Base by air from the Pacific recovery area.

Today NASA continues to take charge of the curation and allocation of the Apollo lunar samples. The specially-built Lunar Sample Laboratory Facility, 30 years old this year, is a class 10K clean room (no more than 10,000 particles 0.5-micron size per cubic foot of air inside the laboratory). It is housed in a special building at the Johnson Space Center in Houston, Texas. Workers wear clean coveralls, hats, gloves, and shoe covers to minimize contamination.



NASA is in charge of organizing and storing the Apollo lunar materials. [LEFT] Samples are transferred for processing or examination into these sealed, stainless-steel glove cabinets in the Lunar Sample Laboratory at the NASA Johnson Space Center in Houston, Texas. The cabinets are continuously purged by nitrogen, a relatively non-reactive gas, to create an environment with minimum chemical reactions with the samples. Gloves are fitted to holes in the sides of the cabinets, capped when not in use, so that workers can reach and handle the samples. The special airlock into the wall, on the right side of the cabinet, opens to the pristine corridor where the samples are transferred to and from the storage vault. [RIGHT] Here I am inside the laboratory examining an Apollo 15 lunar breccia with an optical microscope at one of the cabinet viewing stations; photo by Jeff Taylor.

Meticulous facilities and strict handling procedures ensure the continued scientific integrity of the Apollo lunar samples for the needs of the research and engineering communities today and into the future. About 70% of the total weight of Apollo lunar samples is located in the Lunar Sample Laboratory's pristine sample vault. "Pristine" lunar samples (those continuously in NASA custody since return from the Moon) are stored in multiple layers of packaging in cabinets organized by mission. They are handled in stainless-steel glove cabinets purged by high-purity nitrogen gas, which is relatively non-reactive, in an environment monitored continuously for oxygen and moisture contents to minimize degradation of the samples or chemical reaction with air.

Approximately 8% of the total weight of the collection is stored in the returned sample vault. These are samples lent to authorized researchers and returned to NASA. They are re-inventoried as "returned" because these samples were exposed to air when they were located in the investigators' laboratories. The samples are individually bagged, tagged, and are made available again for other research projects when contamination is less of a concern.

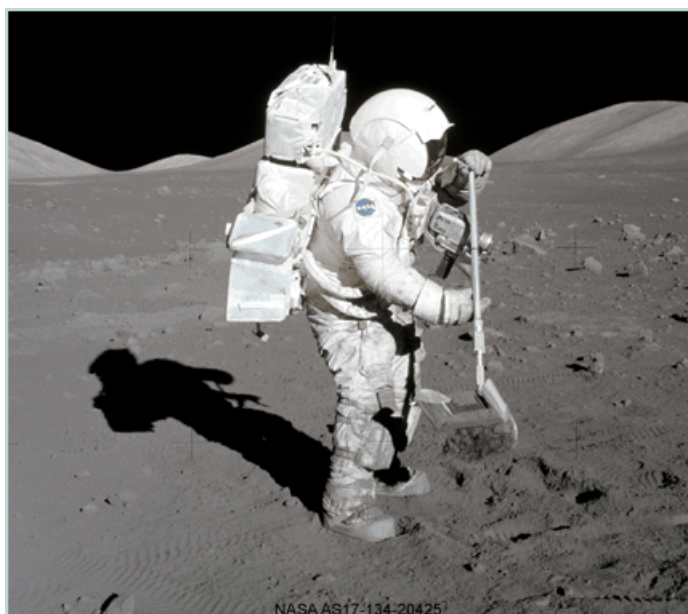
Another 13% of the total weight is stored in the Brooks Air Force Base remote storage facility, which was completed in 2002. This representative sampling of the collection is stored at the second location to ensure the entire collection would not be lost in the event of a

major hurricane or other catastrophe at Johnson Space Center.

The other 9% of the total weight of lunar samples is currently outside the custody of the Johnson Space Center. Some are on loan to scientists and educators for research and teaching projects; others samples are on loan to museums, planetariums, and public scientific expositions [see the list of international [Lunar Sample Display Locations](#)]; a small percentage has been destroyed during approved experimentation; and some pieces of Apollo 11 and Apollo 17 samples were given as official gift plaques to all the states of the United States, to Puerto Rico, and to 135 foreign nations. U.S. regulations prohibit private ownership of Apollo lunar samples.

Lunar Sample Allocation

The last container of lunar samples from the last Apollo mission was logged into the lunar laboratory on January 30, 1973. From their first arrival, the samples from the Apollo Missions have been under continuous investigation. They are, as you can imagine, highly sought after for scientific research in cosmochemistry, and for testing hypotheses of the origin of the Earth/Moon system, planetary formation, and solar system evolution. The renewed interest in robotic and human exploration of the Moon has spawned substantial interest in studying lunar materials among the engineering/resource utilization community. Their studies sometimes require lunar samples to validate development of tools and processes using simulants (soils made from Earth materials to mimic lunar properties). Because of the obviously limited supply of Apollo lunar samples, NASA has a robust allocation system that has been in place since the beginning of the collection. It distributes nearly 400 samples each year.



Apollo 17 scientist-astronaut Harrison H. Schmitt collects lunar rake samples at the Taurus-Littrow landing site. This rake was used to collect samples ranging in size from 1.3 centimeters to 2.5 centimeters.

Lunar Curator, Dr. Gary Lofgren, works with Dr. Meenakshi (Mini) Wadhwa and CAPTEM (Curation and Analysis Planning Team for Extraterrestrial Materials), a NASA advisory committee, to meet the needs of scientists and engineers who wish to obtain the most appropriate materials from the collection for their studies. Requests are considered for both basic research in planetary science and for applied studies including lunar materials beneficiation, resource utilization, toxicity, or hazards assessment. NASA provides access to the Apollo rocks, soils, and regolith core samples for destructive and non-destructive analyses.

The checklist for requestors of Apollo lunar samples looks something like this:

1. The investigator must demonstrate favorable peer review of proposed work involving lunar samples by (1) a formal research proposal approved for funding through a NASA program, or an equivalent scientific peer-review panel, within the past three years, or (2) peer-reviewed articles in professional journals that are pertinent to the specific sample request.
2. The investigator must submit a written request to the Lunar Sample Curator specifying the numbers, types, and quantities of lunar samples, and the planned investigations to be conducted on these. A resume is additionally required for new investigators.

For planetary science studies, the request is submitted to the Lunar Sample Curator, Dr. Gary Lofgren, at NASA Johnson Space Center. For engineering/resource utilization studies, the request is submitted to the Lunar Simulant Curator, Dr. Carlton Allen, also at NASA Johnson Space Center, who verifies that all necessary tests with lunar simulants have been completed satisfactorily, and determines whether the request warrants use of lunar samples, in which case it is forwarded to the Lunar Sample Curator.

The Lunar Sample Curator evaluates the submitted request and supporting materials, and makes a curatorial allocation if the request is from an investigator who has been approved previously for sample allocation by CAPTEM, and the request is for thin sections, "returned" lunar samples, or less than one gram of other lunar samples with no pristinity issues. The Curator otherwise forwards the request to CAPTEM for evaluation if the request is from a new investigator, and/or the request involves larger than one gram of material, or any

samples with pristinity issues. Furthermore, with very few exceptions, no lunar sample will be allocated that reduces the remaining pristine sample below 50% by weight.

The lunar sample requests forwarded to CAPTEM are evaluated by this standing committee. A positive recommendation by CAPTEM, followed by approval by NASA Headquarters, constitutes formal approval of the request. The Lunar Sample Curator prepares a Lunar Sample Loan Agreement (including a security plan) to be signed by the investigator. Finally, samples less than 10 grams are shipped within the U.S. by U.S. registered mail, outside the U.S. by U.S. diplomatic pouch mail to the American embassy nearest the investigator's location. Samples larger than 10 grams must be hand carried by the investigator or his/her representative.



The Apollo lunar samples are a unique, but limited, resource of extraterrestrial rocks and regolith. Rest assured these treasured samples are in good hands. The planetary science community has a long heritage of developing sample-handling protocols and instrumentation for maximizing science while minimizing the amount of sample consumed. This approach is a good one and a necessary one for assuring that these lunar materials will be available for the ongoing testing of hypotheses, old and new, and development of new instruments, tools, and technologies as we plan and realize humanity's return to the Moon.

Additional Resources

LINKS OPEN IN A NEW WINDOW.

- [Curation and Analysis Planning Team for Extraterrestrial Materials \(CAPTEM\).](#)
- [Lunar Exploration Analysis Group \(LEAG\) Annual Meeting Agenda, November 16-19, 2009.](#)
- [Lunar Petrographic Educational Thin Section Set.](#)
- [Lunar Sample Atlas.](#)
- [Lunar Sample Compendium.](#)
- [Moon Archive](#) articles from Planetary Science Research Discoveries.
- [Rocks and Soils from the Moon](#), website from Astromaterials Curation, NASA Johnson Space Center.



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