Moon

Lesson 1 – Flagstaff, AZ and the Moon: How are they Connected?

USGS science for a changing world
Astrogeology Research Program

Flagstaff, AZ and the Moon: How are They Connected?

Grade Level: All

Objectives:

- Knowledge of the relevance between Flagstaff, AZ and the Apollo Program

Arizona State Standards:

- **6SC-P1. PO2.** Describe the processes explained by prominent scientific theories of the origin of the solar system

Time Needed: 1 class period

Materials:

- Astronaut Training in Flagstaff video
- To the Moon, NOVA, WGBH video
- Overheads of Astronaut training

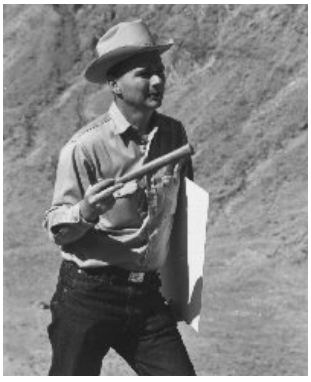
Procedure:

This section is included because Flagstaff is directly tied to early lunar exploration. This strong connection provides an opportunity to point out Flagstaff's role in the Apollo Program as well as our part in the development of planetary science as a new field of study.

Background:

"That's one small step for man, one giant leap for mankind," said Neil Armstrong, as he took man's first step onto the surface of the Moon. Thus started a series of moon landings that lasted from 1969 to 1972. Altogether, 12 men walked on the Moon and the Apollo Manned Lunar Missions would go down in history as one of humankind's greatest accomplishments.

The scientific data and samples brought back by the Apollo astronauts resulted in revolutionary changes in scientific theories regarding the origin and evolution of the Moon and the solar system itself.



The town of Flagstaff, Arizona played an important role in the Apollo project. Astrogeology, the geologic study of the moon and planets, was a brand new science and a natural extension of terrestrial geology. Eugene Shoemaker, a geologist with the U.S. Geological Survey (USGS) and the father of astrogeology, strongly believed science

should be part of lunar exploration. It was perfectly logical to him that if we were spending so much time and effort sending people to the moon we should make an effort to garner scientific information at the same time.

Brecciated dunite clast returned from Apollo 17.

Shoemaker began his career in the 1950s and devoted his work to studying impact features on Earth, on the Moon, and throughout the solar system. He conducted an in depth geologic study of Meteor Crater, Arizona and concluded that it most likely formed when a meteor struck the surface of the Earth. At the time, scientists hotly debated whether craters such as this one and those on the Moon were of volcanic origin or were caused by impacts of extraterrestrial bodies such as asteroids or comets. Gene used geologic evidence from Meteor Crater such as overturned rock layers, breccia, and other unique rock types to support the theory of impact origin. Eventually Gene's work would be supplemented by rock samples returned from the Moon, which offered even more evidence that these types of craters originated from meteor impacts.

The space race began in 1957 when Russia launched Sputnik, the first artificial space satellite. Soon after, the U.S. government established the National Aeronautics and Space Agency (NASA) and charged it with assuring that we would beat the Russian's in the attempt to conquer space, the final frontier. In 1960, Gene Shoemaker, head of the USGS Astrogeology Unit, received a NASA grant to begin geologic studies of the Moon and to work with NASA on a new project, the manned space program. The U.S. was determined to be the first nation in the world to put a man on the Moon. Meanwhile, Gene was determined to send a scientist to the moon.

During the early 1960's, Gene's group worked out of Menlo Park, CA. In 1963, Shoemaker relocated the fledgling Astrogeology Unit to Flagstaff, AZ. Northern Arizona was chosen because of its proximity to geologic features and formations similar to those on the Moon. Once in Flagstaff, the newly ordained Branch of Astrogeology got to work developing tools and techniques that would be used for lunar surface exploration.

Astronauts began arriving in Flagstaff as early as 1963 to undergo training in geologic field methods. A total of 54 Apollo astronauts participated in 45 geologic training exercises in northern Arizona between January 1963 and November 1972. Of these astronauts, 12 walked on the Moon. Geologists and astrogeologists from the USGS Flagstaff Field Center directed geologic field training exercises for the astronauts. Field exercises took place at several nearby locations including the Grand Canyon, Sunset Crater-Cinder Lake area, Merriam Crater, Meteor Crater, Hopi Buttes, Gray Mountain, and the Verde Valley. Training was also held at Lowell Observatory and Kitt Peak Observatory (Tucson, AZ).

Two of these locations were crater fields constructed specifically to mimic lunar landing sites in order for astronauts to train in an environment that was more moon-like. One of the crater fields was just north of Flagstaff in the Sunset Crater-Cinder Lake area. Here, scientists used explosives to make a scale model of the Mare Tranquilitatis region of the Moon, proposed Apollo 11 landing site. Dynamite was used to recreate craters in the same size and position as they were on the Moon. Nearly all of the astronauts who walked on the Moon trained at this site. The other crater field was in the Verde Valley, south of Flagstaff, and also served as a training ground for many Apollo astronauts.

The geologic training that astronauts received consisted of teaching them how to do productive fieldwork using traditional geologic methods such as observation, mapping, and sample collecting. Geologists use specific tools when doing fieldwork and the astronauts were given training on using similar tools designed especially for use on the Moons surface. These tools included a modified rock hammer and an adjustable sampling scoop to break apart and gather lunar rocks and soil. Astronauts also used lunar rakes and tongs to gather samples and a camera to take pictures of geologic features and places where the lunar samples were collected. Additionally, the astronauts were trained in using drills so they could return core samples of the lunar surface regolith.

USGS geologist Harrison "Jack" Schmitt helped in the design and testing of the tools he himself would later be using on the surface of the Moon during the last mission, Apollo 17. Schmitt was the first and only geologist to ever walk on the Moon and represents the unyielding efforts of Gene Shoemaker to follow his dreams.

The following is an excerpt from the USGS Astrogeology website: *Jack Schmitt joined the Astrogeology team as a geologist at the Flagstaff Field Center in 1964, having recently earned a doctorate degree from Harvard University. In addition to assisting in the geologic mapping of the Moon, he led the Lunar Field Geological Methods project. When NASA announced a special recruitment for scientist-astronauts in late 1964, Schmitt applied. Out of more than 1,000 applicants, six were chosen. Of those six, Joe Kerwin, Owen Garriott, and Edward Gibson would fly in the Skylab missions in 1973 and 1974, and Schmitt would go to the Moon on the Apollo 17 mission.*

Just one year after joining the USGS, Schmitt was transferred to NASA and began his pilot training at Williams Air Force Base in Arizona. On December 7, 1972, Apollo 17 was launched, carrying Schmitt, Ronald Evans, and mission commander Eugene Cernan. On December 11, the lunar module, Challenger, landed at Taurus-Littrow on the Moon, and four hours later Cernan and Schmitt became the eleventh and twelfth men to walk on the Moon. The pair did a total of three EVAs (extravehicular activities) before their departure on December 14, collecting rock and soil samples, taking photographs, setting up equipment, and making observations. During the mission, Schmitt and Cernan discovered orange soil, a surprising find that created a great deal of excitement in the scientific community. Schmitt was the only geologist to go to the Moon. Apollo 17 was the final manned mission in a four-year exploration of the Moon. The crew of Apollo 17 left a plaque that reads:

> ***"Here man completed his first exploration of the Moon, December 1972 A.D. May the spirit of peace in which we came be reflected in the lives of all mankind."***

Jack Schmitt on a Moonwalk
Scientist-Astronaut Harrison H. Schmitt is photographed standing next to a huge, split boulder during the third Apollo 17 extravehicular activity (EVA-3) at the Taurus-Littrow landing site on the Moon.[1]

NASA photo AS17-140-21496
624 x 500, 201 kilobytes

Jack Schmitt with American Flag Planted on Lunar Surface
Scientist-Astronaut Harrison Schmitt, Apollo 17 lunar module pilot, is photographed next to the U.S. flag during extravehicular activity (EVA) of NASA's final lunar landing mission in the Apollo series. The photo was taken at the Taurus-Littrow landing site. The highest part of the flag appears to point toward Earth in the distant background.[1]

NASA photo AS17-134-20384
500 x 500, 62 kilobytes

Jack Schmitt Working at Lunar Rover
A view of the lunarscape at Station 4 (Shorty Crater) showing Scientist-Astronaut Harrison H. Schmitt working at the lunar roving vehicle (LRV) during the second Apollo 17 extravehicular activity (EVA-2) at the Taurus-Littrow landing site. Shorty Crater is to the right. The peak in the center background is Family Mountain. Portion of South Massif is on the horizon at the left edge.[1]

NASA photo AS17-137-21011
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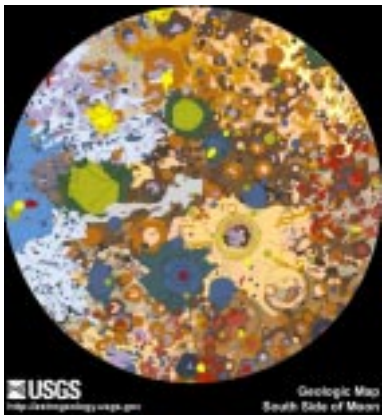
Reference: http://astrogeology.usgs.gov/About/AstroHistory/schmitt.html

Because astronauts were on a tight schedule, they only had a specific amount of time to dedicate to geologic exploration. Therefore, for Apollo's 15 through 17 a lunar roving vehicle was developed to help use exploration time most efficiently. The lunar rover was 10 feet long and six feet wide, weighed 460 pounds, and could travel a distance of 40 miles on the Moon. Scientists at the USGS Flagstaff Field Center built a model of the lunar rover for astronauts to use during training in northern Arizona. This

model rover is currently on display in the newly dedicated Shoemaker Center for Astrogeology at the Flagstaff Field Center.

Although the initial intent of the Apollo project was political in nature, a substantial amount of scientific data was collected throughout the project thanks to the efforts made by scientists, most importantly Eugene Shoemaker. The Apollo missions resulted in a change in scientific theories regarding the origin, evolution, and composition of the Moon. The USGS geologists who helped train astronauts to conduct scientifically sound geologic investigations played a major role in bringing about these new theories.

Today, USGS astrogeologists continue to map and make new discoveries about the Moon in an effort to learn more about our own planet, as well as the rest of the planetary objects in our solar system. Hopefully, their efforts, along with those of many other planetary scientists will lead to another manned mission to the Moon and maybe even to another planet in our solar system, Mars.



Additional Resources:

http://astrogeology.usgs.gov/About/AstroHistory/astronauts.html
http://www.hq.nasa.gov/office/pao/History/SP-350/ch-7-8.html
http://history.msfc.nasa.gov/apollo/photo.html
http://www.apolloexplorer.co.uk/bymission.htm
http://www.najaco.com/space/apollo/5.htm
http://www.lunarlegacies.com/mycollection-2.htm
http://aerospacescholars.jsc.nasa.gov/HAS/Cirr/SS/L2/Training.htm

Selected Apollo Missions to the Moon

Mission	Crew	Training Locations in Northern Arizona	Date and duration of mission	Landing site	Rocks brought back	Notes
Apollo 11	• Neil Armstrong • Edwin "Buzz" Aldrin • Michael Collins - Command Module pilot	Meteor Crater, Grand Canyon, Flagstaff, Lowell Observatory, Sunset Crater (also Kitt Peak)	July 16-24, 1969	Sea of Tranquility	48.5 lbs of basalt; oldest dated at 3.7 billion years (by).	Armstrong overshot planned landing site but landed safely.
Apollo 12	• Alan Bean • Pete Conrad • Richard Gordon - Command Module pilot	Meteor Crater, Grand Canyon, Cinder Lake Crater Field, Sunset Crater, San Francisco Volcanic Field, Coconino Point (also Chocolate Mountains in southern AZ)	November 14-24, 1969	Ocean of Storms on a ray of Crater Copernicus	75 lbs of basalt; oldest dated at 3.7 billion years.	
Apollo 13	• Jim Lovell • Fred Haise • John Swigert	Meteor Crater, Grand Canyon, Cinder Lake Crater Field, Sunset Crater, Black Canyon Crater Field in Verde Valley, Hopi Buttes, Merriam Crater (also Kitt Peak)	April 11-17, 1970	***Intended*** spot was Fra Mauro Highlands	_____	Explosion of oxygen tank resulted in no lunar landing. They were returned safely to Earth.
Apollo 14	• Alan Shepard • Ed Mitchell • Stuart Roosa - Command Module pilot	Grand Canyon, Cinder Lake Crater Field, Sunset Crater, Black Canyon Crater Field in Verde Valley (also Kitt Peak)	January 31-February 9, 1971	Fra Mauro Highlands	96 lbs. Most were breccias formed as a result of impacts. Dated at 3.9 billion years.	
Apollo 15	• Dave Scott • Jim Irwin • Al Worden - Command Module pilot	Meteor Crater, Grand Canyon, Cinder Lake Crater Field, Sunset Crater, San Francisco Volcanic Field, Coconino Point, Merriam Crater (also Chocolate Mountains in southern AZ)	July 26-August 7, 1971	Hadley-Appenine Front on the southeast edge of Mare Imbrium; also called Palus Putredinis (Marsh of Decay)	170 lbs of rocks and soil. Genesis Rock was anorthosite dated at 4.5 billion years old.	First mission to use the Lunar Roving Vehicle.
Apollo 16	• Charlie Duke • John Young • Ken Mattingly - Command Module pilot	Meteor Crater, Grand Canyon, Cinder Lake Crater Field, Sunset Crater, Hopi Buttes, Black Canyon Crater Field in Verde Valley	April 16-27, 1972	Descartes Highlands, Cayley Plains	213 lbs of breccias.	2nd Lunar Rover used.
Apollo 17	• Gene Cernan • Harrison "Jack" Schmitt • Ron Evans - Command Module pilot	Meteor Crater, Grand Canyon, Hopi Buttes, San Francisco Volcanic Field, Cinder Lake Crater Field, Sunset Crater, Coconino Point, Merriam Crater	December 7-19, 1972	Taurus-Littrow	243 lbs including orange beads that were 3.7 billion years old & plagioclase that was 4.3 billion years.	3rd Lunar Rover used. Jack Schmitt was the 1st geologist to walk on the Moon.

Questions for Discussion

1. What might have Flagstaff, AZ been chosen as an astronaut training site?

2. Why do you think the Cinder lake Crater Field was created?

3. What were some of the geologic field techniques that astronauts learned to help them explore the lunar surface?

4. Why was it important that astronauts learn these geologic techniques?

5. Why do you think the lunar tools used by the astronauts had long handles?

6. How might have the USGS built electronic lunar rover simulator helped the astronauts during training? Why was it electric?

7. Astronauts brought back hundreds of pounds of moon rocks, the oldest being 4.5 billion years old. What might the age of this rock say about the origin of the moon?

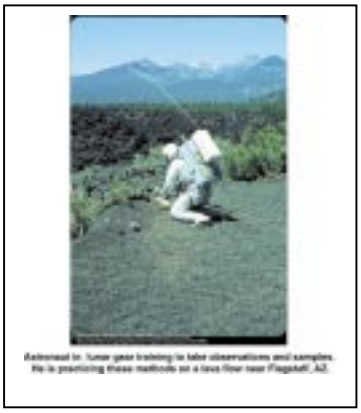
8. Even though conditions under which astronauts trained were similar in many ways to lunar conditions, can you think of some differences?

9. How was Harrison “Jack” Schmitt different from all the other astronauts that walked on the moon?

10. Why do you think there has not been a manned mission to the moon since the Apollo missions?

OVERHEADS

Overhead 1. Gene Shoemaker, astrogeologist and director of the Branch of Astrogeology of the USGS, leads astronauts on a geologic tour of Meteor Crater, AZ.

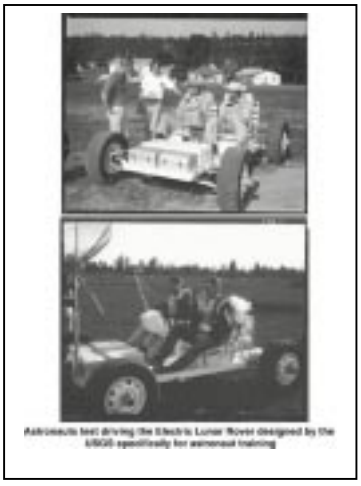


Overhead 2. Astronaut in lunar gear training to take observations and samples. He is practicing these methods on a lava flow near Flagstaff, AZ. Astronaut in lunar gear training to take observations and samples. He is practicing these methods on a lava flow near Flagstaff, AZ.

Overhead 3. Mobile Geologic Laboratory built by the USGS and used during Astronaut training exercises.

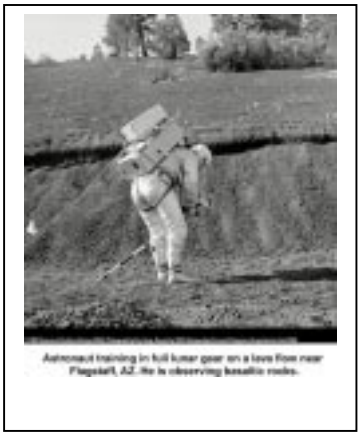
Overhead 4. Testing experimental lunar tools.

Overhead 5. Apollo Camera that astronauts carried with them during their lunar surface excursions.



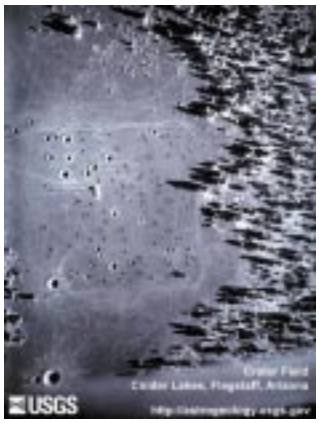
Overhead 6. Astronauts test driving the Electric Lunar Rover designed by the USGS specifically for astronaut training.

Overhead 7. Astronaut training using propulsion pack.



Overhead 8. Astronaut training in full lunar gear on a lava flow near Flagstaff, AZ. He is observing basaltic rocks.

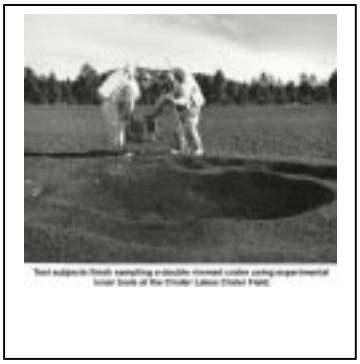
OVERHEADS (cont.)



Overhead 9. Aerial view of Cinder Lakes Crater Field, Flagstaff, AZ.

Overhead 10. Underground explosions were used to create the Cinder Lakes Crater Field. This field is a re-creation of a lunar surface found in the region Mare Tranquilitatis, where Apollo 11 lunar module landed.

Overhead 11. High resolution or close up view of Cinder Lakes Crater Field.



Overhead 12. Test subjects finish sampling a double-rimmed crater using experimental lunar tools at the Cinder Lakes Crater Field.

Overhead 13. Apollo 15 astronauts training on the lunar rover at Cinder Lakes Crater Field, Flagstaff, AZ.

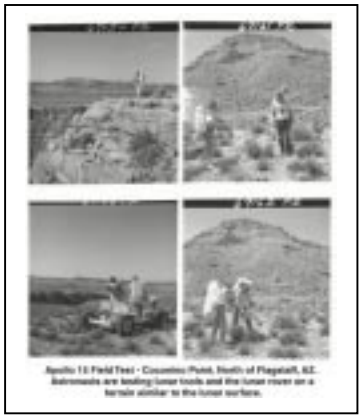
Overhead 14. Oblique aerial view of Cinder Lakes Crater Field.

Overhead 15. Astronauts performing a suited test at the Cinder Lakes Crater Field Training Area.

Overhead 16. Astronauts also trained at Merriam Crater in the San Francisco Volcanic Field near Flagstaff, AZ. Can you see similarities between this landscape and the lunar landscape?

OVERHEADS (cont.)

Overhead 17. Apollo 14 Crew members Alan Shepard and Ed Mitchell use lunar tools during training exercises at Black Canyon Crater Field in the Verde Valley, AZ.



Overhead 18. Apollo 15 Field Test - Coconino Point, North of Flagstaff, AZ. Astronauts are testing lunar tools and the lunar rover on a terrain similar to the lunar surface.

Overhead 19. Apollo 16 Field Test - Coconino Point, North of Flagstaff, AZ. Astronauts are testing lunar tools and simulating lunar exploration on a terrain similar to the lunar surface.

Overhead 20. Harrison "Jack" Schmitt was the first and only geologist to walk on the moon. He was a geologist with the U.S. Geological Survey before he became an Apollo astronaut.