Headline Article

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Rock and Roll at the Apollo 17 Site

--- The latest orbital images and topographic data offer new insights to the geologic context of Apollo 17 impact melt breccias.

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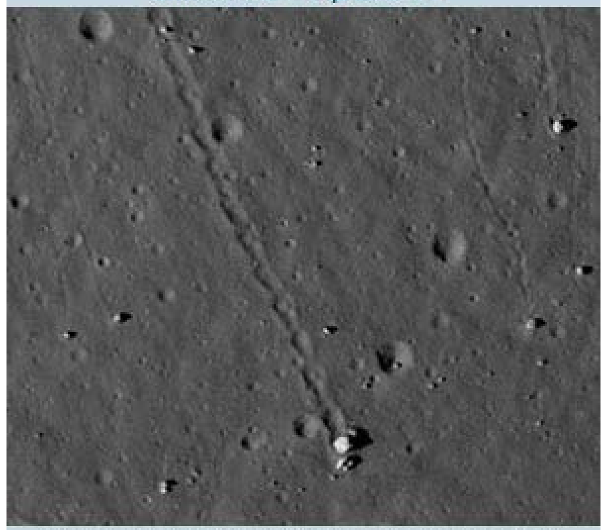
Boulders & Tracks • North Massif
Station 6 • Apollo 17



NASA LROC NAC M134991988R NASA/GSFC/ASU

Astronauts Eugene A. Cernan and Harrison H. (Jack) Schmitt collected 243 pounds (110 kg) of rock and **regolith** samples during 22 hours working on the lunar surface during the Apollo 17 mission in December 1972, while Astronaut Ronald Evans orbited in the command module. The field observations, audio descriptions, and photographs coupled with orbital data and detailed, laboratory analyses of Apollo samples provided unprecedented information about the Moon and its geologic history. The Apollo samples continue to inspire new questions and answers about the Moon. Debra Hurwitz and David Kring (Lunar and Planetary Institute and NASA Solar System Exploration Research Virtual Institute; Hurwitz now at NASA Goddard Space Flight Center) were particularly interested in solving the mystery of where the boulders came from at the base of the North Massif (station 6) and at the base of the South Massif (station 2) from which Apollo 17 astronauts collected samples of impact melt **breccias**. The breccias were unequivocally formed by impact processes, but forty years of analyses had not yet determined unambiguously which impact event was responsible. Was it the basin-forming event of the landing site's neighbor Serenitatis (possibly **Nectarian** age); the larger, nearby Imbrium basin (**Imbrian** age and one of the last large basins to form); a combination of these impacts or an impact event older or younger than all of the above. Tracking down the origin of the boulders would ideally unravel details of the formation age of the breccias and, ultimately, help with the historical record of basin formation on the Moon. Hurwitz and Kring verified the boulders rolled down from massif walls—Apollo 17 impact melt breccias originated in massif material, not from the Sculptured Hills, an overlying geologic unit. But the relative geologic context is easier to explain than the absolute age, at least until some discrepancies are resolved in existing Ar-Ar and U-Pb **radiometric** ages of the Apollo 17 impact melt breccias.

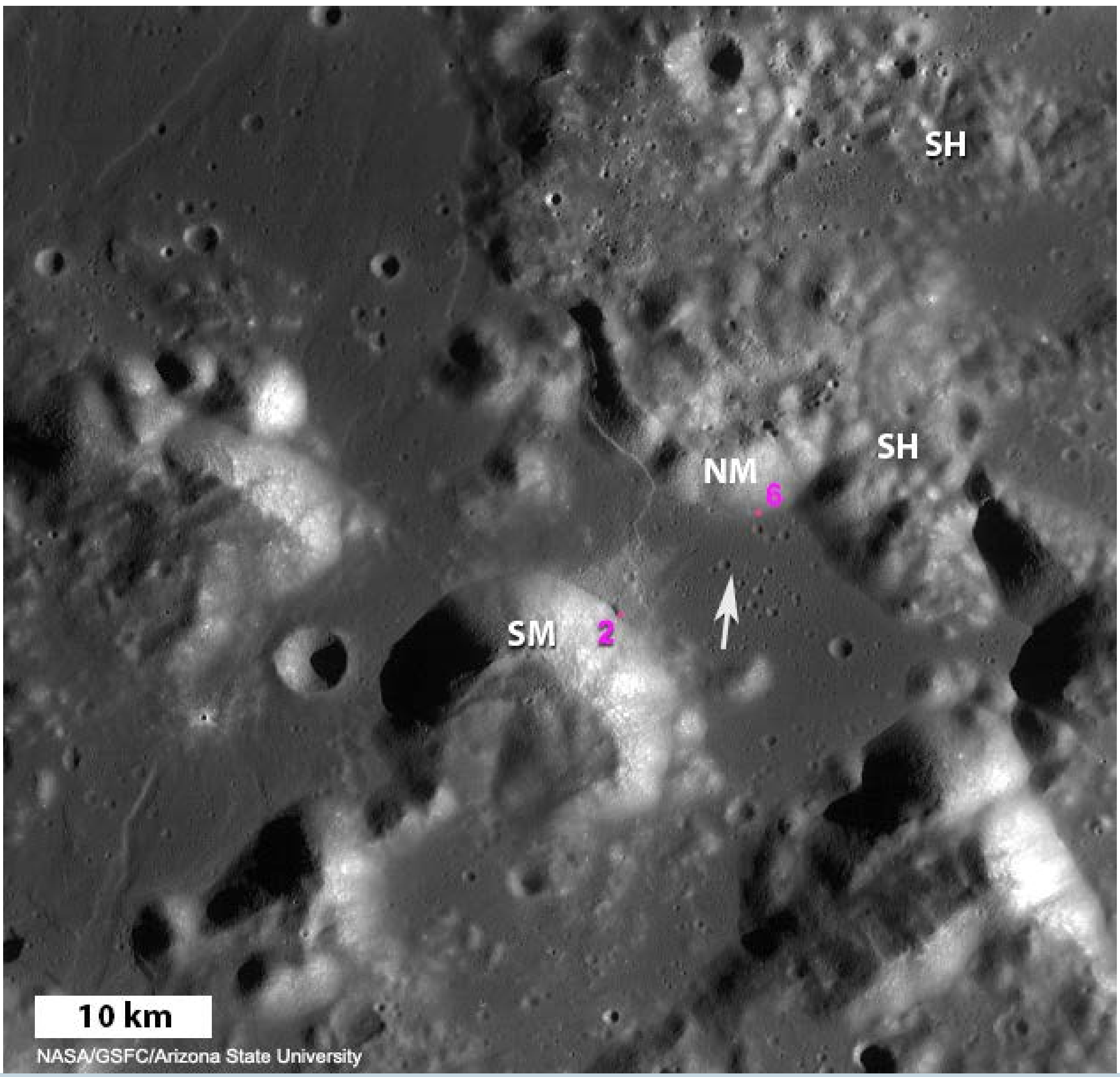
Reference:

- Hurwitz, D., and Kring, D. A. (2016) Identifying the Geologic Context of Apollo 17 Impact Melt Breccias, *Earth and Planetary Science Letters,* v. 436, p. 64-70, doi: 10.1016/j.epsl.2015.12.032. [**abstract**]

- **PSRDpresents:** Rock and Roll at the Apollo 17 Site --**Short Slide Summary** (with accompanying notes).

Field Work at Stations 2 and 6

The Apollo 17 landing site is situated at 20°9'55"N, 30°45'57" E in Taurus-Littrow Valley, nestled among the mountains on the southeastern margin of Mare Serenitatis. The valley's regolith-covered basaltic floor material is pockmarked by impact craters, thought to be secondaries from Tycho crater–2000 kilometers away. Obtaining samples of the South and North Massifs (the southern and northern valley walls rising to heights of ~2000 meters) was of particular interest to the mission planners. These rocks, if associated with the formation of the Serenitatis basin as predicted, would include impact melt that could be radiometrically dated to establish when the basin formed. The boulders at the bases of the massifs, at collection stations 2 and 6, were therefore prime sampling goals of the mission. Regolith samples were also important as they contained materials from the Sculptured Hills, the domed/hummocky unit superimposed on the massifs at stations 2 and 6 (see image mosaic, below).



Lunar Reconnaissance Orbiter Wide Angle Camera (LROC WAC) mosaic looking down at the Taurus Littrow valley area. White arrow shows the Apollo 17 landing site. Locations of stations 2 and 6 are shown in pink. SM = South Massif, NM = North

Massif, SH = Sculptured Hills. The Sculptured Hills unit has a distinctive surface morphology compared to the massifs, indicating a separate origin, though not necessarily a different age. North is up. Sun is shining from the East.

A group of five boulders at the base of North Massif are the scattered pieces of one larger boulder that broke apart after rolling down the ~25^{o} slope from an outcrop on the North Massif.

Boulders at Station 6 – Apollo 17

NASA photos AS17-141-21589 to 21598 taken by Astronaut Eugene Cernan of Astronaut Harrison Schmitt; image mosaic by David Harland. https://www.hq.nasa.gov/alsj/a17/a17.sta6.html

Taken during the Station 6 traverse, this view shows the boulders where samples of impact melt breccias were collected. Hurwitz and Kring's project aimed to identify the geologic context of the breccias.

Astronauts Cernan and Schmitt hammered samples off the boulders. The following lines are time-stamped quotes from the **Apollo 17 Lunar Surface Journal—Geology Station 6**:

> **"164:53:11 Schmitt:** And this boulder's got its own little track! Right up the hill, cross contour."
>
> **"165:02:13 Schmitt:** Hey, I'm standing on a boulder track. (To Gene) How does that make you feel?"
>
> **"165:02:17 Cernan:** That makes me feel like I'm coming over to do some sampling. (Pause) Think how it would have been if you were standing there before that boulder came by."
>
> **"165:02:33 Schmitt:** I'd rather not think about it."

See the beautiful photo below for another view of the size of the boulders.

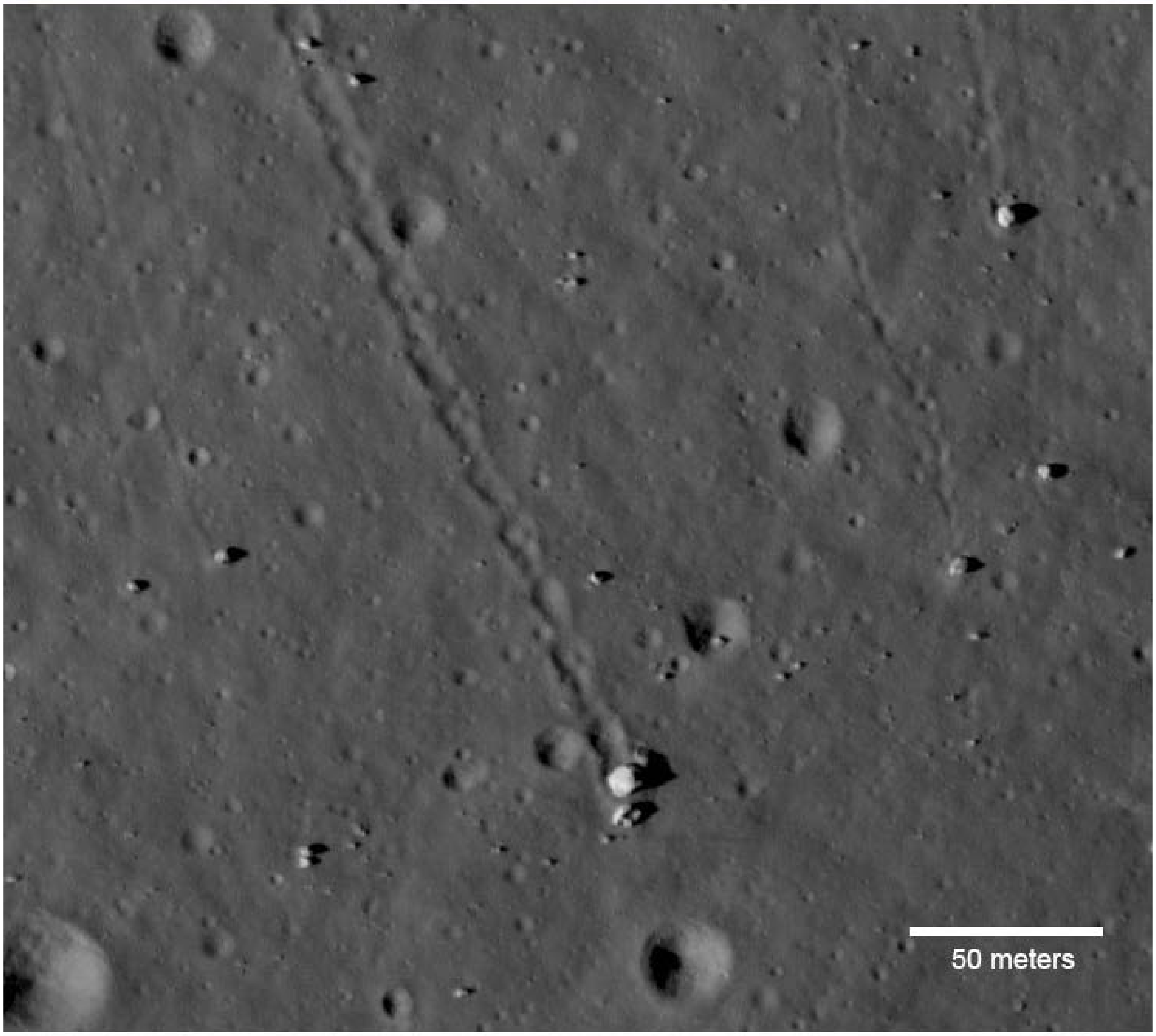
This iconic photograph from Apollo 17 shows Astronaut Schmitt next to two boulders at Station 6 where he and Astronaut Cernan collected rock and regolith samples. Apollo image AS17-140-21496.

Using LOLA and LROC NAC

To find the origin of the boulders, and corroborate the field observations, Debra Hurwitz and David Kring poured over Lunar Orbiter Laser Altimetry (LOLA) topographic data and Lunar Reconnaissance Orbiter Narrow Angle Camera (LROC NAC) images (so exquisitely detailed that you sense your own feet making historic boot prints). These data sets are invaluable when making connections between the landing site and the broader geologic setting. While re-mapping the geology of the Apollo 17 landing site Hurwitz and Kring identified 93 tracks in the North and South Massif walls to boulders at the massif bases. The source outcrop for the Station 6 boulders is about 500 meters up the North Massif slope—confirming what Astronauts Schmitt and Cernan observed but could not climb to.

Their mapping also confirmed that the Sculptured Hills is a separate geologic unit that occurs on the other side of the crests of the massifs from the Apollo 17 landing site. Hurwitz and Kring did not find any evidence of Sculptured Hills material on the massif walls.

Boulder Tracks Down the North Massif Wall at Station 6 -- Apollo 17



NASA LROC NAC image M134991988R, NASA/GSFC/Arizona State University, http://lroc.sese.asu.edu/images

In this LROC NAC image of the North Massif wall, up slope is to the top. A long track shows where a boulder rolled down the hill and broke into the cluster of boulders at the base of the North Massif at station 6 of the Apollo 17 traverse. **Cosmic-ray exposure ages** of the boulder cluster are about 20 million years—we are looking at a ~20-million-year-old boulder tract! Astronauts Cernan and Schmitt explored the site in December 1972. Additional, smaller boulders and their tracks as well as small impact craters are also visible. Sun is shining from the left.

A Sampling of Apollo 17 Impact Melt Breccias

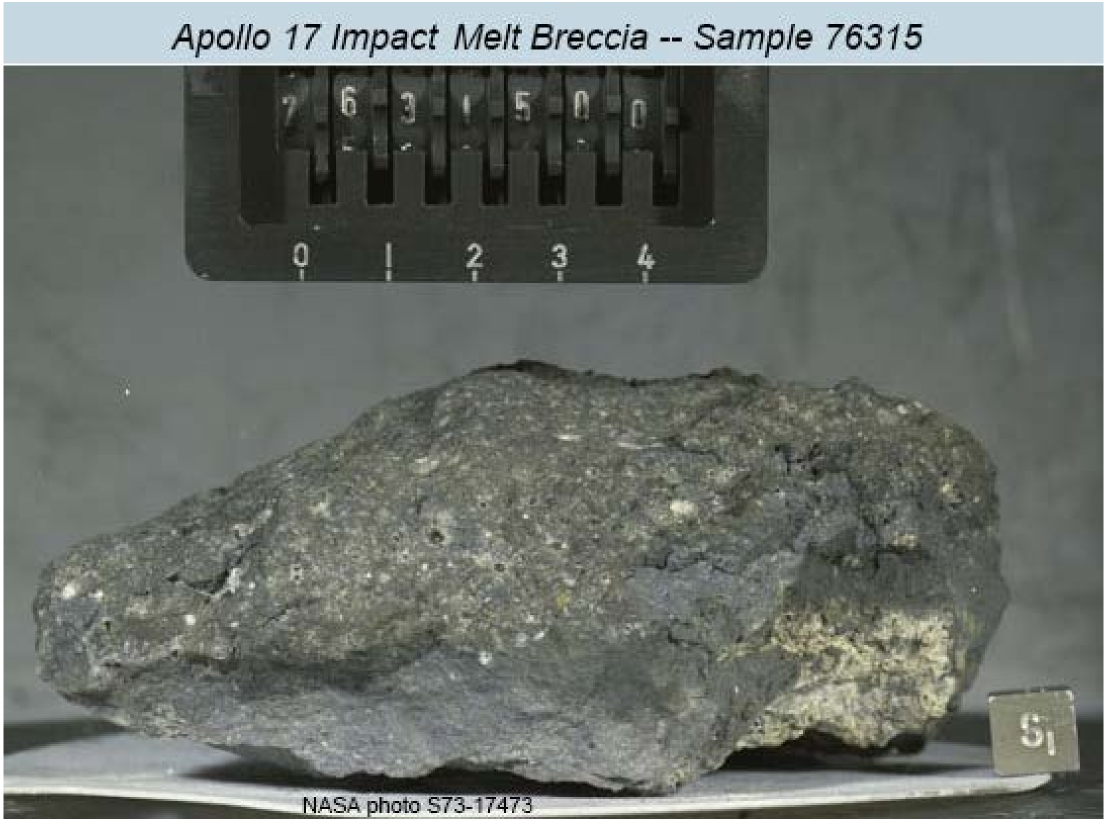
This photo shows how the treasured lunar samples were packaged for return to Earth. The description from the 1972 NASA document EP-101 written by Gene Simmons says, "Made of aluminum, this box is used to return Lunar samples to Earth. It is about the size of a small suitcase but is many times stronger. The Apollo Lunar Sample Return Container has changed very little since it was first used on Apollo 11. It is affectionately nicknamed the "rock box."

This rock box was transferred from NASA's Johnson Space Center to the National Air and Space Museum in Washington, DC, where it is on display. Photo NASM-SI-2009-4738. Click for more information from the Smithsonian National Air and Space Museum.

Samples 76295 and 76315 (shown below) are representative of the impact melt breccias collected at Station 6. Previous studies found that both samples have similar mineral contents of 50% plagioclase, 40% pyroxene (mostly low-Ca), and minor amounts of olivine, ilmenite, and other minerals.

Apollo 17 Impact Melt Breccia -- Sample 76295

Sample 76295 has an **aphanitic** (fine-grained) matrix of mostly plagioclase and pyroxene, many clasts (fragments) of different types including breccia and **anorthosite**. No vesicles. Scale cube is 1 centimeter. NASA photo # S73-19312.



Sample 76315 has a matrix with micro-**poikilitic** texture of mostly plagioclase and low-Ca pyroxene; many plagioclase-rich clasts (including the large crumbly, light-colored clast on the bottom right); and vesicles. Scale cube is 1 centimeter. NASA photo # S73-19312.

Beyond Boulder Tracks to Basin Chronology

Hurwitz and Kring confirmed the impact melt breccias collected from the Apollo 17 boulders originated from massif material solely, with no mixing of Sculptured Hills material. As for when the breccias formed, previous work determined **radiometric** ages from bulk Ar-Ar analyses of multiple samples and found the weighted mean age of 3893 ± 9 million years. Interestingly, U-Pb analyses yield ages about 25 to 55 million years older. Hurwitz and Kring point out that the difference may be a consequence of incorrect Ar-Ar calibration, which will have to be corrected. The more interesting question still is: which basin-forming event or events are these ages pointing to? Hurwitz and Kring say the geologic context of the impact melt breccias implies the massifs formed from Serenitatis, before Imbrium ejecta surged across the lunar landscape to deposit the Sculptured Hills. Or maybe the massifs were made of preexisting material and simply exposed by the Serenitatis basin-forming event. Or maybe the massifs and Sculptured Hills are both products of the Imbrium impact, an interpretation suggested in 2011 by Paul Spudis, Don Wilhelms, and Mark Robinson on the basis of LROC data. The boulder tracks are clearer than the ejecta-strewn path to answering this question!

This work ties into larger issues about lunar basin chronology, which is a complicated subject involving age-dating rocks from multiple locations, geologic mapping, and computer modeling of impact dynamics. The complexity is shown in several **PSRD** articles, such as **New Lunar Meteorite Provides its Lunar Address and Some Clues about Early Bombardment of the Moon** and **The Crazy Mixed-Up Lunar Crust**. The study by Hurwitz and Kring shows that we need to have detailed geologic observations at many scales, ranging from the sampling stations at the Apollo 17 site, the entire area explored by astronauts, the surrounding massifs and other deposits, to the entire Imbrium-Serenitatis region. Determining the ages of lunar impact basins requires broad geologic studies.

If the Apollo 17 impact melt breccias indeed came from the Serenitatis basin impact, then their age dates the basin-forming event and is consistent with the global **lunar cataclysm** theory, which holds that the inner Solar System was affected by a sharp increase in impact bombardment rate between ~3920 and 3850 million years ago. But if the cataclysm is a chronologic illusion stemming from the pervasive effects that the Imbrium impact had on the lunar nearside, the cataclysm might be a sampling problem, not an event. In fact, older ages of big impacts are beginning to be reported, such as a 4200 million year age for a lunar rock that appears to have crystallized in a deep sea of impact melt (see **PSRD** article: **A Sample from an Ancient Sea of Impact Melt**). It's no wonder that testing the lunar cataclysm hypothesis by determining the timing of formation of lunar basins is the highest-priority recommendation of the National Research Council for return missions to the Moon. Hurwitz and Kring are keen to explore Schrödinger, the best preserved basin of its size on the Moon, to examine and collect samples of impact melt that are linked unambiguously to a specific basin-forming event.

Additional Resources

Links open in a new window.

- **PSRDpresents:** Rock and Roll at the Apollo 17 Site --**Short Slide Summary** (with accompanying notes).

- **Apollo 17 Lunar Surface Journal—Geology Station 2**, from NASA. Corrected Transcript and Commentary by Eric M. Jones.
- **Apollo 17 Lunar Surface Journal—Geology Station 6**, from NASA. Corrected Transcript and Commentary by Eric M. Jones.
- Fassett, C. I., Head, J. W., Kadish, S. J., Mazarico, E., Neumann, G. A., Smith, D. E., and Zuber, M. T. (2012) Lunar Impact Basins: Stratigraphy, Sequence and Ages from Superposed Impact Crater Populations Measured from Lunar Orbiter Laser Altimeter (LOLA) Data, *Journal of Geophysical Research,* v. 117, E00H06, doi: 10.1029/2011JE003951. [**abstract**]
- Hurwitz, D., and Kring, D. A. (2016) Identifying the Geologic Context of Apollo 17 Impact Melt Breccias, *Earth and Planetary Science Letters,* v. 436, p. 64-70, doi: 10.1016/j.epsl.2015.12.032. [**abstract**]
- Martel, L. M. V. (Jan. 2009) The Crazy Mixed-Up Lunar Crust. *Planetary Science Research Discoveries*. **http://www.psrd.hawaii.edu/Jan09/lunarBasins.html**.
- Martel, L. M. V. (Dec. 2009) Celebrated Moon Rocks. *Planetary Science Research Discoveries*. **http://www.psrd.hawaii.edu/Dec09/Apollo-lunar-samples.html**.
- Neumann, G. A. and 21 others (2015) Lunar Impact Basins Revealed by Gravity Recovery and Interior Laboratory Measurements, *Sciences Advances,* v. 1(9), e1500852, doi: 10.1126/sciadv.1500852. [**abstract**]
- Schmitt, H. H. (1973) Apollo 17 Report on the Valley of Taurus-Littrow, *Science,* v. 182, p. 681-690, doi: 10.1126/science.182.4113.681. [**abstract**]
- Simmons, G. (1972) On the Moon with Apollo 17: A Guidebook to Taurus-Littrow, NASA Document **EP-101**.
- Spudis, P. S., Wilhelms, D. E., and Robinson, M. S. (2011) The Sculptured Hills of the Taurus Highlands: Implications for the Relative Age of Serenitatis, Basin Chronologies and the Cratering History of the Moon, *Journal of Geophysical Research,* v. 116, E00H03, doi: 10.1029/2011JE003903. [**abstract**]

- Taylor, G. J. (June 2016) A Sample from an Ancient Sea of Impact Melt. *Planetary Science Research Discoveries*. **http://www.psrd.hawaii.edu/June16/Lunar-impact-melt.html**.
- Taylor, G. J. (Oct. 2004) New Lunar Meteorite Provides its Lunar Address and Some Clues about Early Bombardment of the Moon. *Planetary Science Research Discoveries*. **http://www.psrd.hawaii.edu/Oct04/SaU169.html**.
- The Lunar Sample Compendium **http://curator.jsc.nasa.gov/Lunar/lsc/index.cfm**.
- The Scientific Context for Exploration of the Moon: Final Report (2007) Committee on the Scientific Context for Exploration of the Moon, *National Research Council,* ISBN: 0-309-10920-5, 120 pages. [**download link**]
- **Videos** of lunar image mosaics, including the Apollo 17 site by the LROC Team, Arizona State University.
- **Video** flyover of Schrödinger volcanic vent and impact peak ring using LROC and LOLA data by Hurwitz, Blackwell, and Kring, Lunar and Planetary Institute.

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