WHAT WILL LUNAR LANDINGS DO TO THE LUNAR SURFACE: A COSMOCHEMIST PERSPECTIVE

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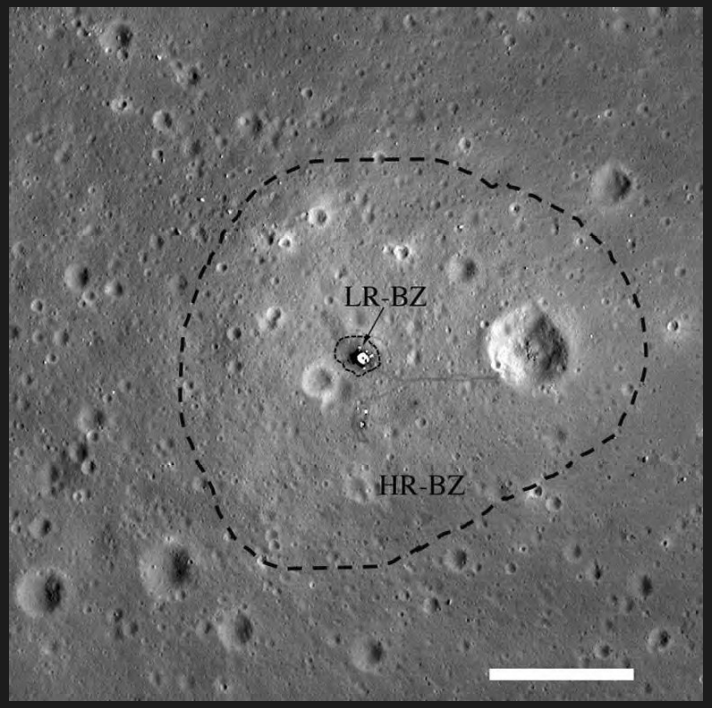
Buzz Aldrin deploys the Solar Wind Collector
AS11-40-5872

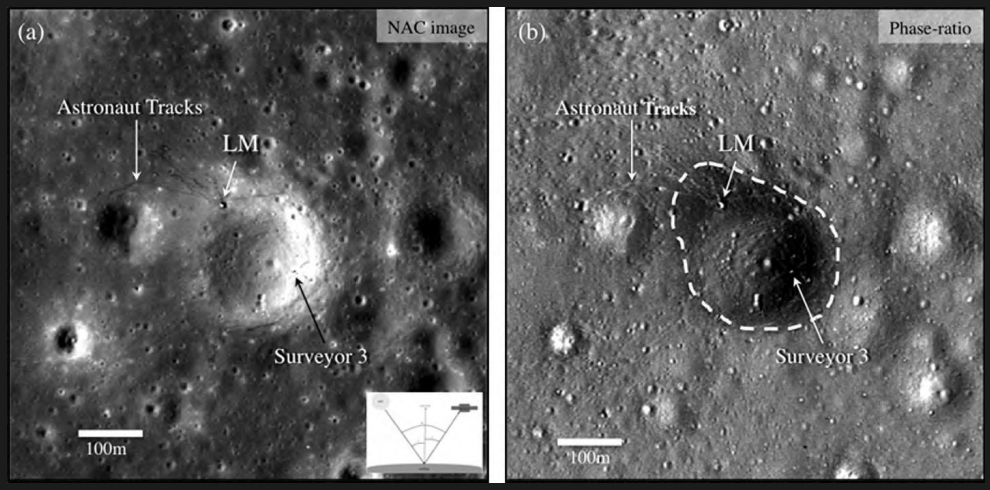
THOUGHT ORGANIZATION



Apollo 11 landing site as viewed by LROC NAC (M175124932, NASA/GSFC/ASU)

Figures from Clegg et al. (2014;Icarus)

- What do we know happened to the surface as a result of Apollo landings?
- What have studies of Apollo samples revealed?
- What is being done <u>now</u> to better understand the impact of landings?



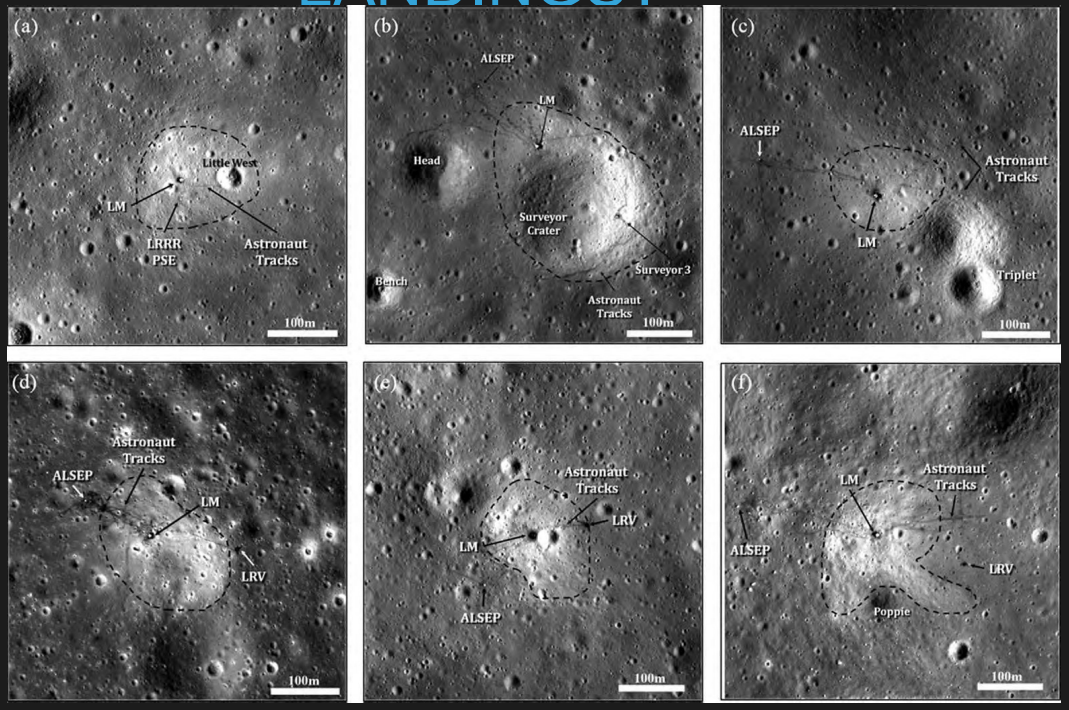
Apollo 12 landing site as viewed by LROC NAC, phase ratio image at right (M1114333947R/M1114319742R). By Apollo 12 crew members walked outside of the visible blast zone [NASA/GSFC/ASU]

WHAT DO WE KNOW HAPPENED TO THE SURFACE AS A RESULT OF APOLLO LANDINGS?

Apollo 11 landing gear, engine bell, and jett bag (AS11-40-5892)

- During Apollo the regolith was scoured by lander exhaust during descent/ascent, residual LM descent propellant was vented, LM cabin atmosphere was vented (filtered too), crew members interacted with the regolith, excess mass was left on the surface
- Did these activities contaminate the samples?
  - Decontamination of Apollo equipment and the handling/curation of the samples is worth a separate discussion

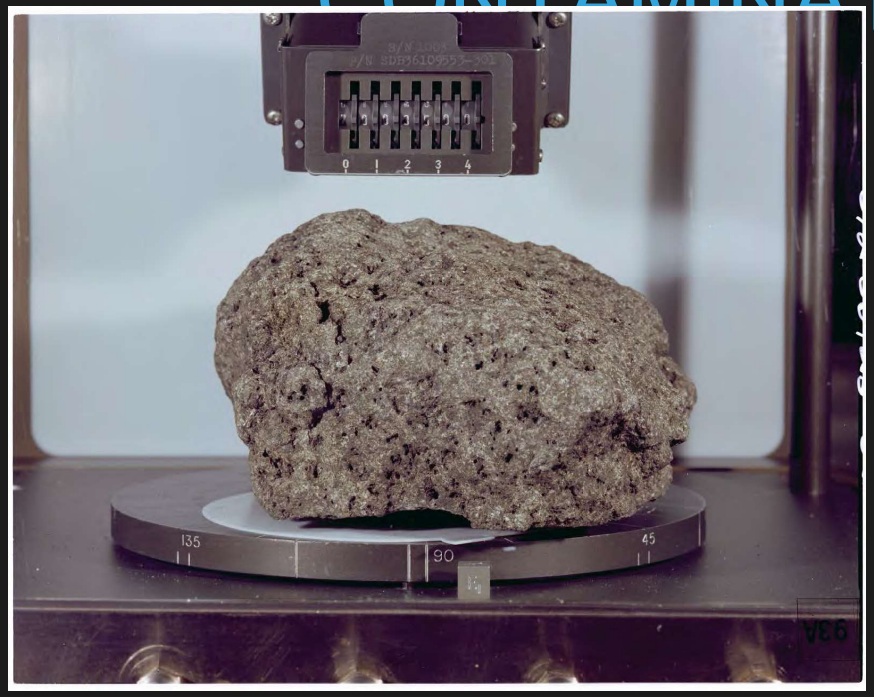
WHAT DO WE KNOW HAPPENED TO THE SURFACE AS A RESULT OF APOLLO LANDINGS?



Apollo landing sites and blast zones surrounding the LMs (Clegg et al. 2014)

- Clegg et al. investigated optical effects around Apollo and robotic landing sites.
- After Apollo 11, samples were collected both within and exterior to the High Reflectance Blast Zone
- Measured albedo changes are likely caused by smoothing of the regolith and removing the fine-scale roughness of the regolith.
- “(N)o chemical differences between Apollo samples collected in the BZ and undisturbed regions have been reported.” -Clegg et al. 2014

APOLLO SAMPLES AND CONTAMINATION STUDIES



Apollo sample 70035 in the curation facility.

- Every effort was made to mitigate contamination of Apollo samples, both during collection, storage, and curation
- Despite this, *some* samples were “contaminated”:
  - ”In the LM after EVA 1, the astronauts reopened SCB 2, removed rock 70035, held it with bare hands, and examined it with a hand lens to check the accuracy of their observations during the EVA.” - 70035 has resulted in dozens of publications!
  - http://apollo17.org?t=128:08:06
  - “After splashdown and loading of the command module on the recovery ship, the sample return containers were unstowed. The BSLSS bag, stowed in a Beta cloth bag (pressure garment assembly bag) on the floor of the command module, was wet through as it lay for 10 hours in 1/4 inch of water (either condensation or sea water). In an isolated work area with filtered air, the decontamination bags were removed from the SCB's and all of the return containers were individually bagged in two Teflon bags and one polyethylene bag, all heat sealed. The containers were transported to the LRL in this configuration in padded crates.” - Apollo 17 Sample Catalogue

PRELIMINARY EXAMINATION OF 11 SAMPLES

Delivery of the first rock box containing Apollo 11 samples to the Lunar Receiving Lab, 4 days after they left the lunar surface.

- "The rock samples were apparently kept free from inorganic contamination from either the rock box or the LM. Niobium, present in the skirt of the descent engine exhaust (88 percent), was not detected (detection limit 50 ppm) and indium, which forms the seal of the rock box, was not present (detection limit 1ppm)." *Apollo 11 Preliminary Science Report*

EXAMINATION OF APOLLO 17 SAMPLES

Sample context for 70011 under the LM (AS17-143-21930).

- Lunar landers used hydrazine and N_2O_4 as rocket fuel.
- On Apollo 15/17 samples were collected from beneath the LM to attempt to measure any effects from LM exhaust on the abundance of amino acids in the samples
- Sample 70011 was collected in an “special environmental sample container” and compared to a soil collected 6.5 km from the LM (72501) by Elslia et al., (2016; GCA).
  - No correlation of amino acid content with proximity to the Apollo 17 LM was observed
  - LM exhaust was not a primary source of amino acid in the samples

WHAT IS BEING DONE

Sample context for 76240 under the Station 6 boulder and in “permanent shadow” (AS17-140-21408).

- The Apollo Next Generation Sample Analysis (ANGSA) program is funding study of sealed “pristine” samples
- The “Astrobiology Analytical Lab at NASA Goddard” will “help to clarify the sources and formation pathways of these amino acids.”

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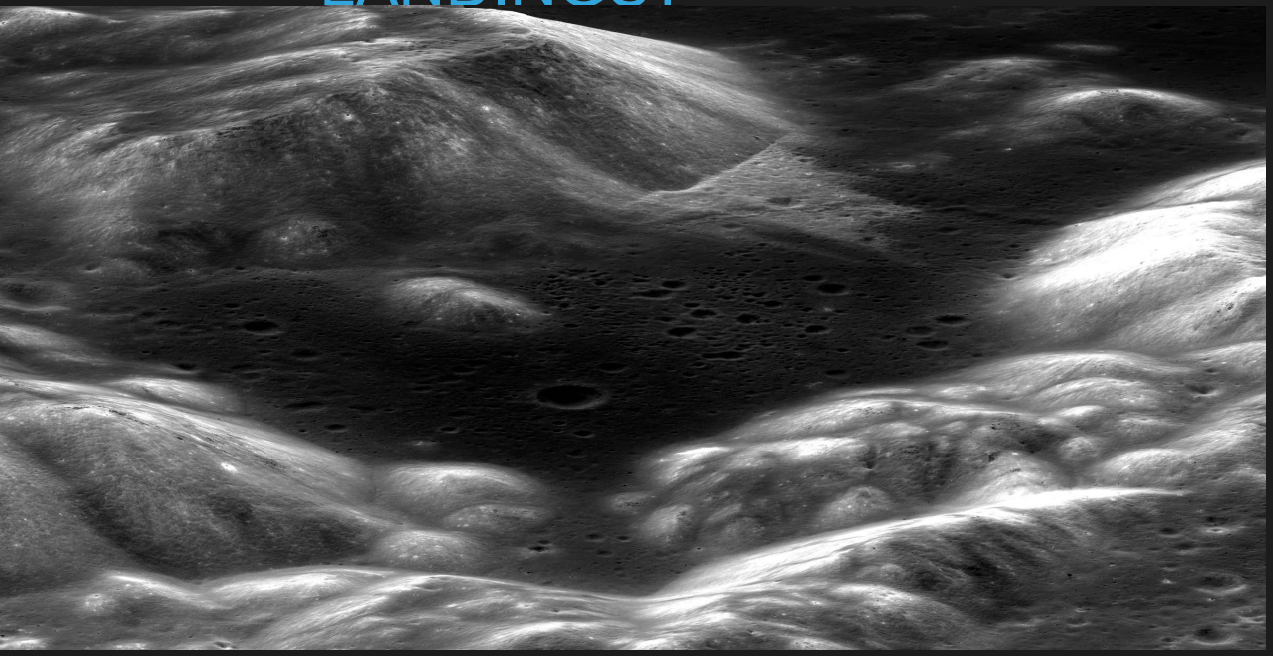

- Despite landing a LM, venting cabin atmosphere, venting fuel, etc… there is no concrete evidence of contamination of the Apollo samples (certainly compared to other possible sources of contamination).
- Ability to traverse outside of the Blast Zone (>100m) enables collection of “more-pristine” regolith samples
- Artemis allows us to test hypothesis of regolith modification from landings (scoop samples within the Blast Zone, characterization of the regolith at μ-scales)

Apollo 17 landing site viewed from the LROC NAC under high-sun conditions. M1266939757 (NASA/GSFC/ASU)

IMPLICATIONS OF HUMAN/ROBOTIC EXPLORATION OF THE LUNAR POLES

- Thus far three missions have impacted near the lunar South Pole (Lunar Prospector, ISRO's MIP experiment, and LCROSS)
- Future exploration near the lunar South Pole will enable unprecedented access to a unique environment. Landers should have well-characterized fuel, but based on Apollo experience, contamination of most areas of compositional interest is of little concern for most geochemical studies.
- The impact to volatiles by *in situ* exploration however suggests that any volatile studies should be done carefully, looking for the fingerprints of contamination, and for areas that may be untouched by such contamination (below the immediate surface, beneath boulders, etc…). Monitoring from orbit can be key for this! LRO/LCROSS experience shows we can observe exospheric events!
- Sampling in PSR's is an opportunity to understand how material transports across the Moon (Do we see evidence of Apollo/other contamination in PSR's?). The Prem et al. (2020) result presents a compelling hypothesis that we should test!

Shackleton Crater Oblique (M1195011983 NASA/GSFC/ASU)