Artemis II Lunar Science Passport

Vol. 1.2

Amber Turner & the Artemis II Lunar Science Team

Dear Artemis II Crew,

This booklet is a study aid for your Artemis II IVA lunar science objectives. We hope you find it useful and fun in between your classroom sessions with us.

Ex Luna, Scientia.

-Your Artemis II Lunar Science Team

This booklet was created by Amber Turner, with contributions from your Artemis II Lunar Science Team. Team members who developed your core science training curriculum or helped create visuals for this booklet are listed below. However, your entire Artemis II Lunar Science Team has contributed to your mission.

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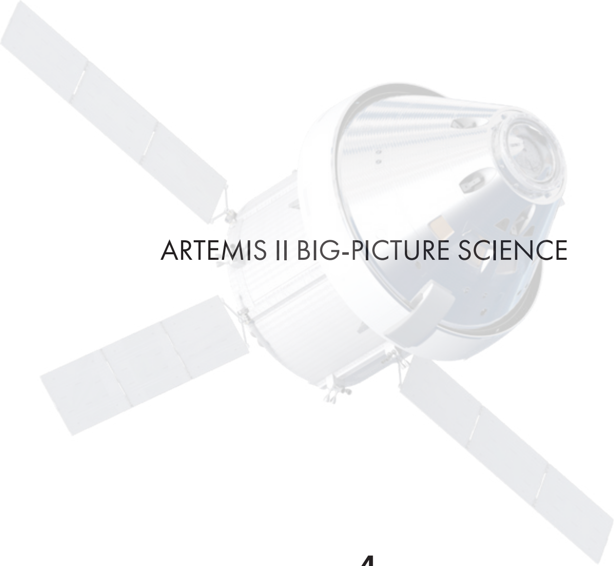
ARTEMIS II BIG-PICTURE SCIENCE



Artemis II Enables Focused Research

What crew describes

What the description tells the science team

Fundamental science question the observation helps answer

Crew observations during Artemis II will **directly contribute to science**. These focused observations will inform open science questions of interest to the scientific community and relate to fundamental lunar and planetary questions.

Human eye's ability to see subtle color variations contribute to science

Colors → Composition → Window to the interior of the Moon → Recent History and Evolution of the Moon

Color variations → Differences in color of volcanic terrain (pinks/oranges) → Composition and how recently the Moon was volcanically active

Seeing the 3-dimensional features of the Moon this perspective cannot be achieved by remote sensing satellites

Moon as a 3D object Morphology observations → Details of the shapes and surface properties → Clues to geologic processes and formation

Photometric observations of the lunar regolith - provide detail and context that complement LRO imagery (and that would take LRO months to years to accomplish

Images/obs. of lunar regolith under multiple illuminations → Properties of lunar regolith → Future science and exploration landing site selection implications

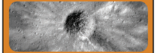
Looking for lofted dust

Apollo astronauts saw dust in the lunar environment that later spacecraft missions couldn't replicate → 4 more sets of eyes on the Moon to collect data → Implications for mission planning and safety; fundamental questions about lunar environment

ARTEMIS II LUNAR SCIENCE THEMES

COLOR/ALBEDO

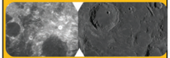
Color Provinces & Albedo Variation



Color differences may be connected to initial variations in crustal composition, or some evolutionary difference.

VIEW CHANGES

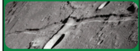
Photometric Changes



Physical and compositional properties of lunar regolith can be inferred by analyzing repeat images of the same location.

GEOLOGIC TARGETS

Tectonics

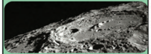


Crew observations of surfaces under low-sun angle lighting will augment mapping of tectonic features on the Moon.

Volcanic History

Identifying color differences within the mare basalts, and across several units may be related to age and/ or composition.

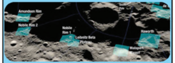
Impact History



Crew will image and describe multiple impact craters, starting with the largest visible features (basins) down to identifying the smallest observable feature.

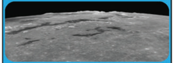
GEOGRAPHIC TARGETS

Landing Sites & Lunar Poles



Artemis II crewed observations and photography of the south polar region and future Artemis landing sites will benefit mission planning and serve as inspiration.

Terminator & Limb



Views of the sharp terminator or lunar limb will identify subtle morphologies highlighted in a contrast illumination.

TIME-CRITICAL EVENTS

Earth From Space

Crew observations of the Earth from deep space enable characterization of color, identification of surface features, and estimation of cloud cover.

Dust & Exosphere

Apollo crew member observations varied on what they saw in the lunar exosphere.

Impact Flashes

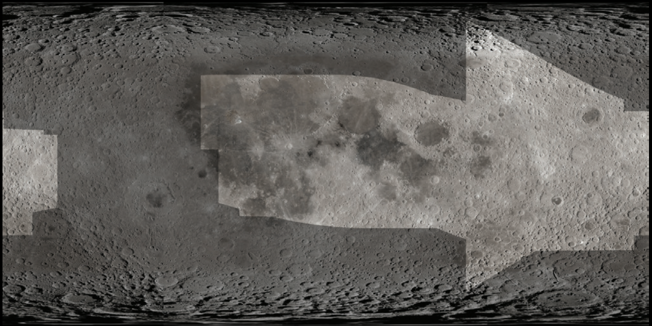
Crew members will observe any un-illuminated lunar surface to identify flashes on the surface (caused by micrometeorite bombardment).

FROM YOUR OBSERVATIONS WE GET...

Observations of...	Are clues to...	From YOUR observations we get...
Color and Albedo	Composition	Where to look for subtle differences in what the crust is made of
Photometric Changes	Physical & Compositional Properties	Differences in the regolith that are not easily observed with orbiters
Swirl Locations	Buried Magnetized Sources	Are swirls they as obvious and distinct to the eye as they are in images and if not, why and how should we explore them?
Geologic Features	Geologic History	Observations of key Solar System processes that may be too nuanced for orbiters
Impact Flashes	Meteorite Activity	Constrains the impact rate in the Earth-Moon system at a scale we can't measure on Earth
Lunar Sunset &Sunrise	Dust above the lunar surface	Is dust levitated above the surface due to static electricity or other processes
Terminator & Limb	Subtle Morphology	How do processes change the surface in recent history

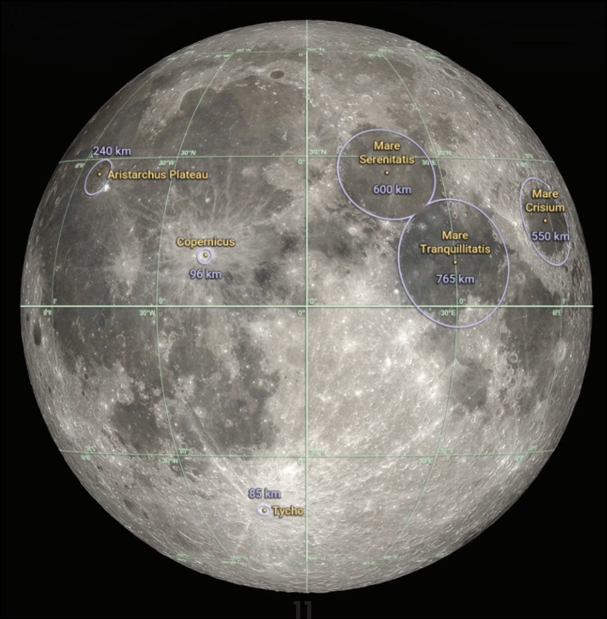
In addition to the content in this Passport, you can access online modules created by Megan Borel to explore the geography and geology of your Moon. Scan the QR code to access the E-Resources for Artemis (ERA) content.

REGIONAL CONTEXT MAPS

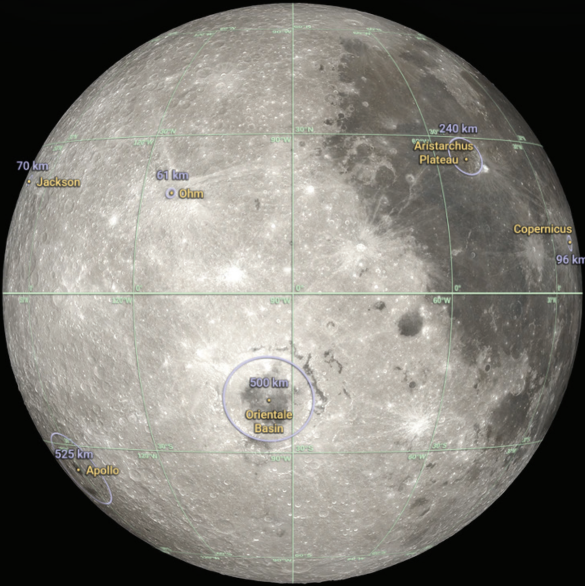


Some of your lunar observations will be the first direct human observations of features that were either not illuminated by the Sun or not viewed while in orbit during Apollo missions. The highlighted areas of the map depict sunlit regions that Apollo astronauts could see from orbit. The darkened regions were either never exposed to sunlight (such as the large gap that includes Orientale) or were beyond the spacecraft's horizon. The large cone shape represents part of Apollo 13's flyby.

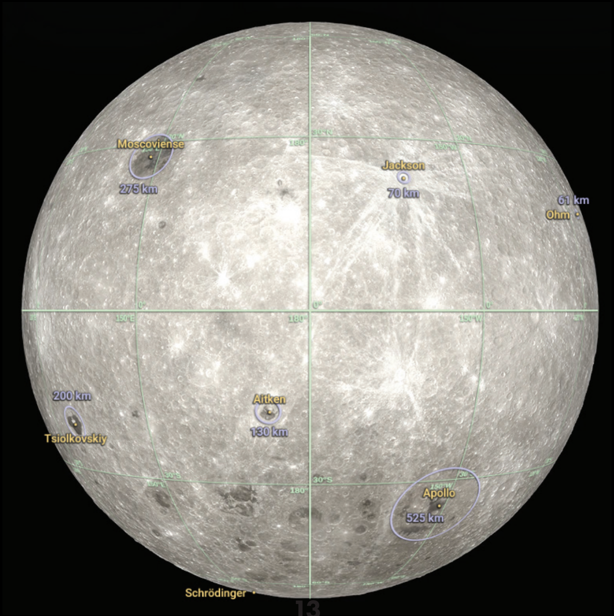
REGIONAL CONTEXT MAP - NEARSIDE



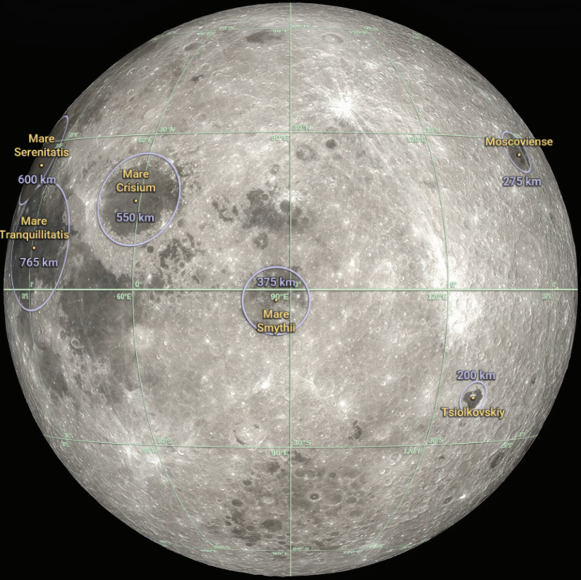
REGIONAL CONTEXT MAP - WEST LIMB

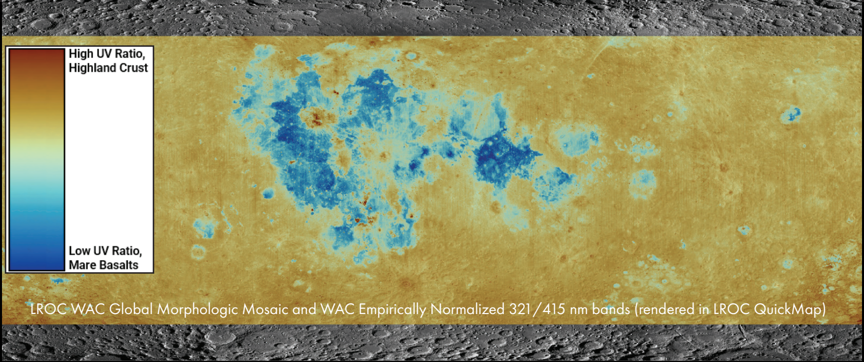


REGIONAL CONTEXT MAP - FARSIDE

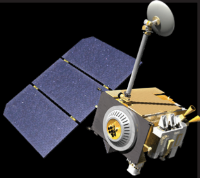


REGIONAL CONTEXT MAP - EAST LIMB





Multispectral data from the Lunar Reconnaissance Orbiter Wide Angle Camera (LROC WAC) can detect gradients in the Moon's surface composition. In your Passport, we present maps showing the ratio of two ultraviolet wavelengths (321 and 415 nanometers). This ratio maps the distribution of highland crust and mare basalts across the surface and highlights just how diverse the lunar surface is in its composition [34].



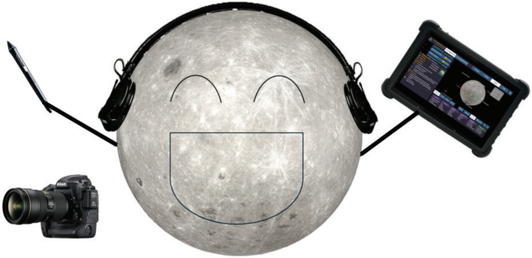
Variations in UV can mark transitions between different units and can hint at how sharp or gradational those boundaries are. Given the wide range of compositions on the lunar surface, any color or albedo changes visible to the human eye in areas where multispectral data have been collected could complement these datasets, which is incredibly valuable for science. Your vantage point during the Lunar Flyby will allow you to observe color and albedo transitions across large geographic areas, something not possible from the surface. When viewing your Big Fifteen up close in UV, you will notice where mare basalts and highland crust intermingle, which highlights the challenge of unraveling the Moon's geologic history.

For this Passport, we did not include numerical values for the UV ratio maps; instead, we focus on how the data are interpreted in terms of composition.

THE BIG FIFTEEN

The "Big Fifteen" refers to fifteen high-priority science targets for imaging and observations during the Lunar Flyby. They are diverse and complex in their geologic history, and observations of them could help answer big-picture science questions. They are also nearly evenly distributed across the lunar surface, allowing them to serve a complementary and critical function as navigational waypoints. This distribution is designed to help with orientation regardless of vehicle attitude.

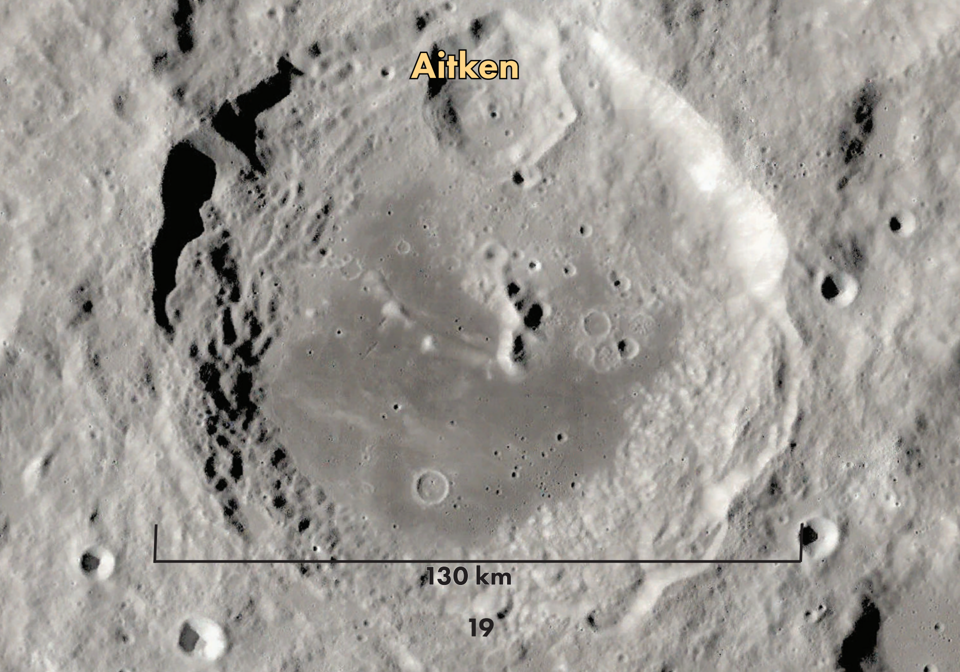
Annotation Challenge!



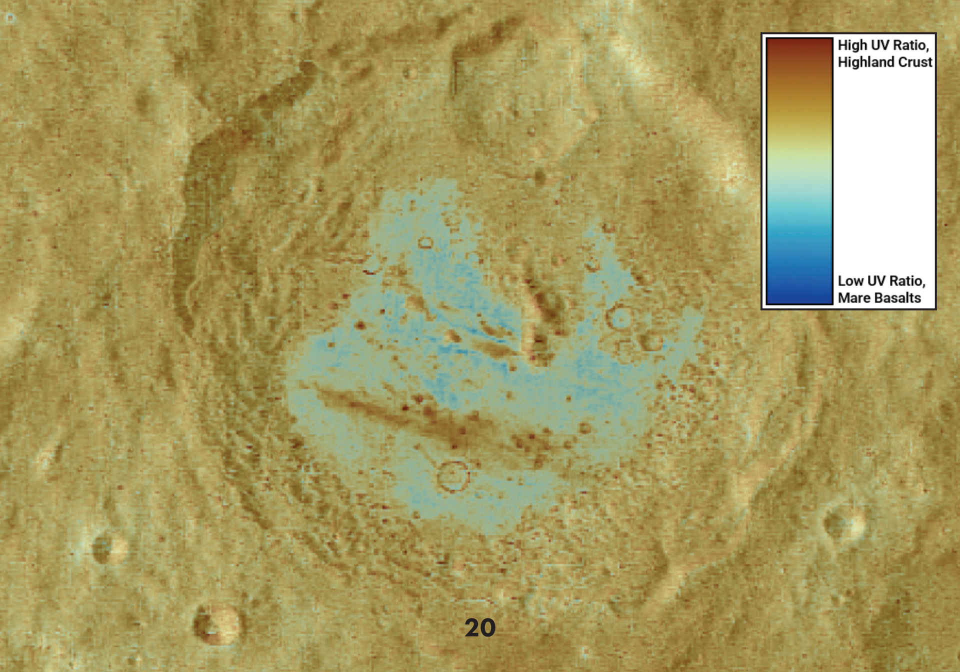
Annotate any resolvable features on the visuals in your Passport using as many helpful descriptors as possible.

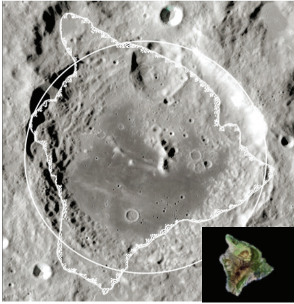
Examples:

- Color and albedo variations: swirls, mare basalt contacts
- Crater morphology: terraced rims, peak structures, hummocky ejecta blankets
- Tectonic features: wrinkle ridges, scarps



Aitken
130 km


High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts

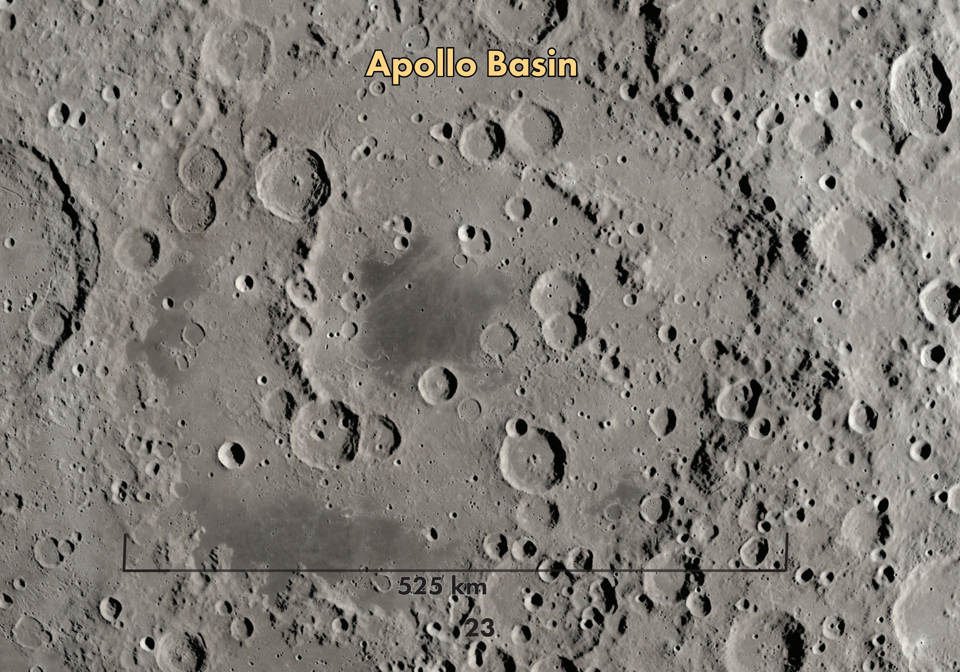


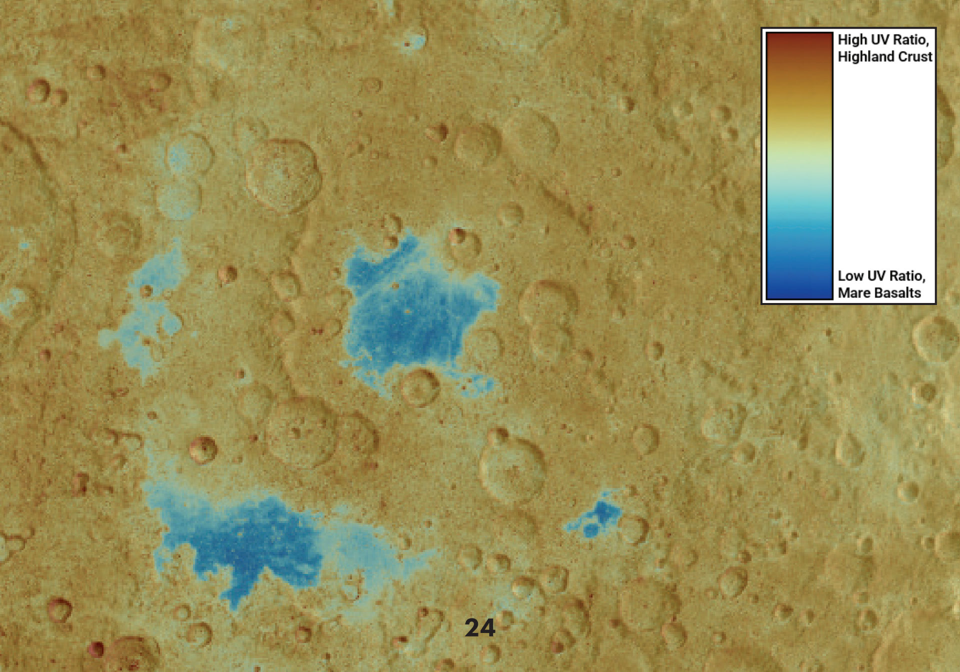
Aitken is a complex crater that lies along the northern rim of the South Pole–Aitken Basin. The central peak of Aitken crater towers approximately 1 kilometer above the crater floor [1]. Aitken dates to the Imbrian period (~3.85 to 3.2 billion years ago), which is characterized by extensive volcanism and the formation of mare, contributing to mare emplacement on its floor [1]. **With a diameter of 130 km, Aitken is roughly the size of Big Island, Hawai'i.**

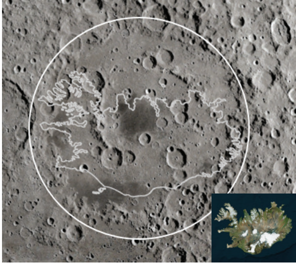
Aitken's mare patch contains high albedo swirls in its southern area [2]. High albedo material / spots in the peak complex, may be either a landslide made of local soil or debris from a small, nearby impact [1]. Faults in the northeast indicate geologically recent contraction of the region.

Descriptions of mare color and albedo in Aitken will reveal the interior composition and possible buried magnetized sources. Of particular interest are the swirl boundaries—are they sharp or gradational, and do they follow topography?

Morphology and stratigraphy of crater rims, along with the color and albedo of material on crater peaks and floors, will inform impact mechanics, material transport, and crustal layering.


Apollo Basin
525 km


High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts



Apollo Basin is a double-ringed impact basin located in the northern region of South Pole-Aitken Basin. It is characterized by blocky and mountainous terrain. **Measuring ~525 km in diameter, Apollo Basin spans about the same east-west distance as Iceland.** Volcanic resurfacing postdated impact formation, which is evident by mare infill on its floor. The impact that formed the basin was powerful enough to excavate layers from the Moon's upper mantle, deposited earlier by the SPA Basin impact.

Spectral instruments have detected mafic signatures consistent with South Pole–Aitken (SPA) Basin ejecta, indicating that SPA-derived materials may be present in Apollo Basin and making it a compelling target for future scientific exploration [3].

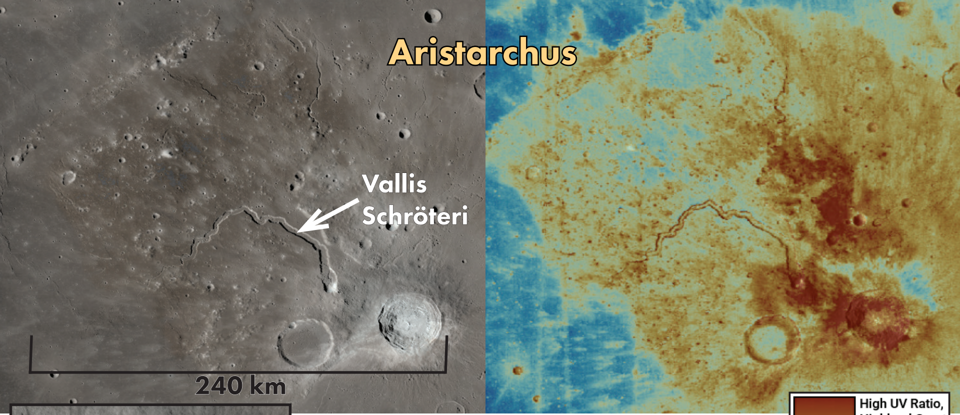
Apollo Basin's rim and surrounding ejecta include these mantle derived materials—providing constraints on how deep the mantle layer was before excavation [3].

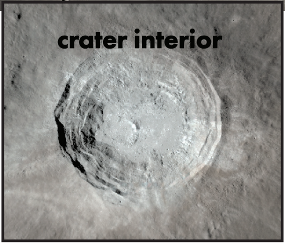
Descriptions of mare color and albedo can help piece together its volcanic history, specifically where resurfacing buried older crustal or mantle materials.

Descriptions of ring stratigraphy, and color and albedo differences, help constrain excavation depth, crustal composition, and thermal conditions of basin formation.

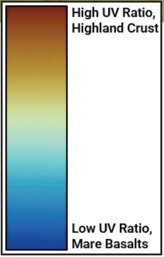
The big picture science questions for Apollo Basin are:

- **Is there a correlation between basin ring formation and mare deposits?**
- **How do Apollo Basin's mare deposits compare to others across SPA Basin?**

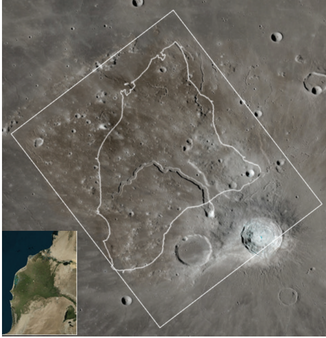




Aristarchus is a young, bright impact crater on the Nearside. The crater is approximately 42 km in diameter and sits on the Aristarchus Plateau.



Measured along its longest axis, from north-east to southwest, the plateau is very close in size to the Nile River Delta, which extends about 240 km along the Mediterranean coastline.



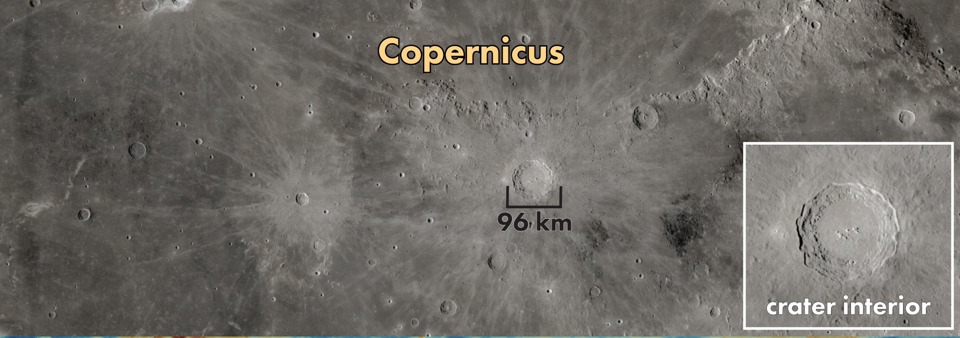
Its geologic diversity makes it one of the Moon's most scientifically valuable regions and a potential target for future lunar resource exploration.

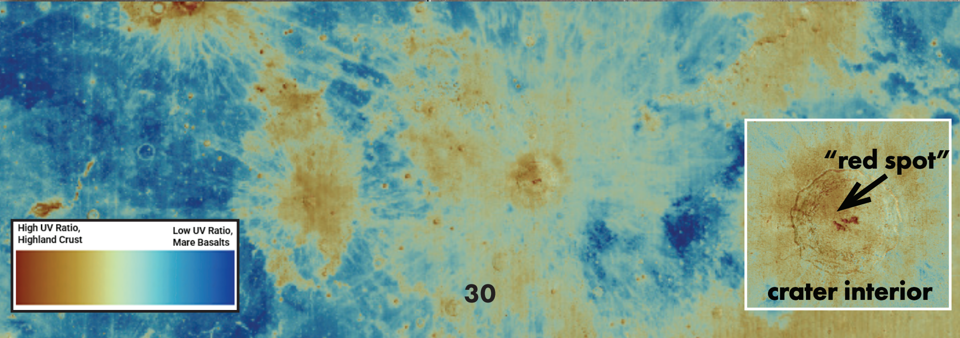
The crater has terraced walls, a central peak, and impact melt deposits, exposing both mare and highland materials [6]

The plateau is an elevated crustal block that preserves a mix of ancient volcanic and tectonic features. It contains extensive pyroclastic deposits rich in volcanic glass, including the largest and thickest known deposit of volcanic glass on the Moon's surface [5]. It also includes **Vallis Schröteri**, the largest sinuous rille on the Moon, formed by ancient lava flows [4]. This rille is part of a wider system, with some segments created by collapsed lava tubes.

Descriptions of color and albedo variations across the Aristarchus region will help constrain the origin of its various landforms. Within the crater, the exposure of both mare and highland materials within a single crater is also of high interest.

- **What color(s) are the pyroclastic deposits on the plateau?**
- **What can you tell us about the system of rilles?**


Copernicus
96 km
crater interior


"red spot"
crater interior
High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts

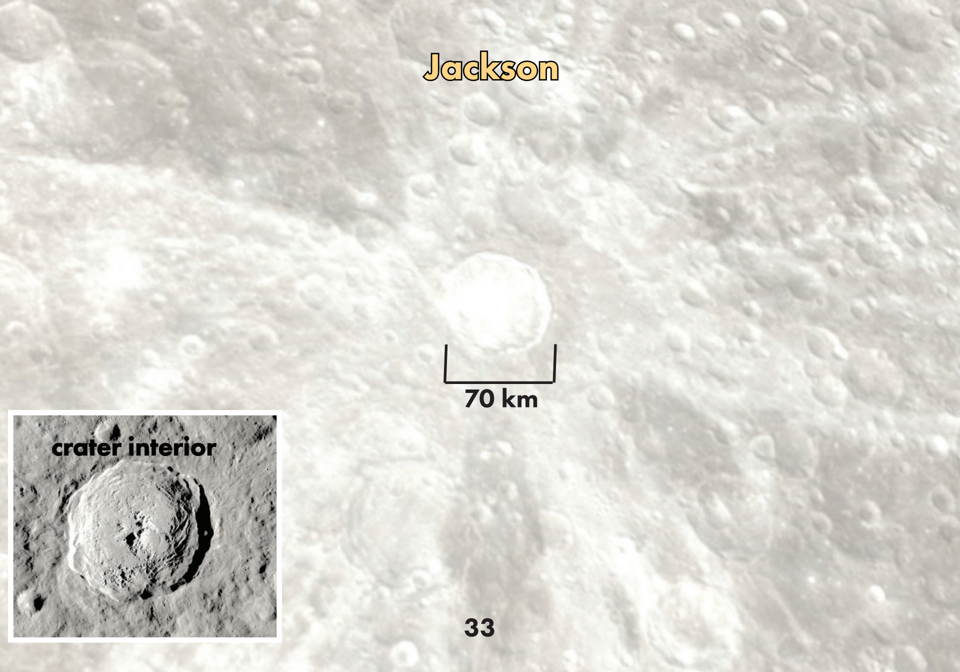
Copernicus is a 96-km-diameter, rayed crater featuring multiple central peaks. It formed during the Copernican period, which spans from about 1.1 billion years ago to the present. **Copernicus is comparable in size to Popigai —an ancient, 100-km-wide impact crater in northern Siberia, Russia.**

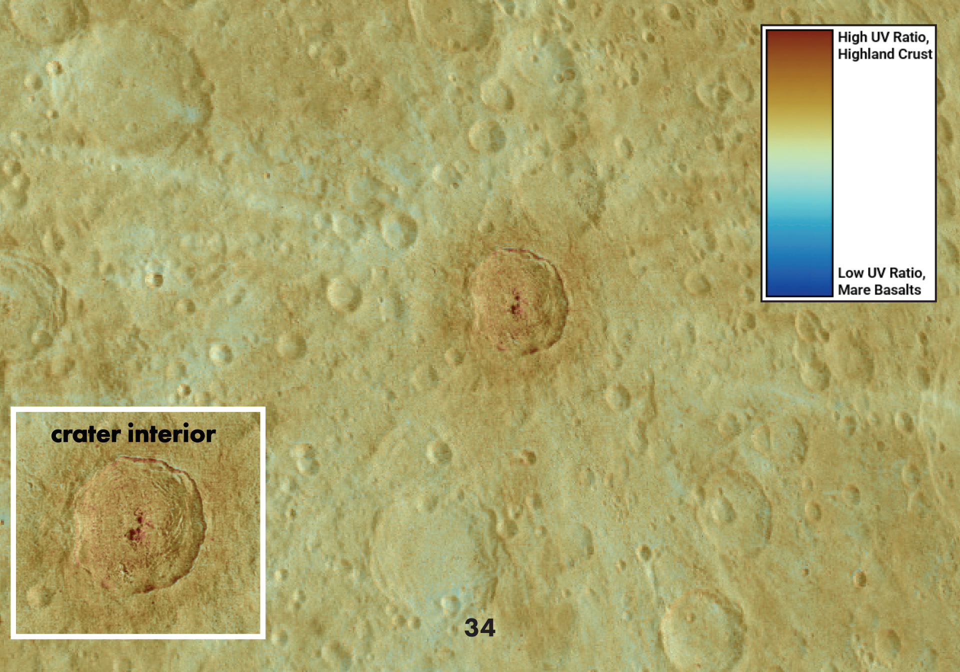
Copernicus is surrounded by a hummocky ejecta blanket, created by the uneven dispersal of material during the impact. This lunar crater provides clues to how the crust responds to an impact to produce a central peak formation and extensive ejecta system.

Orbital spectral data has revealed a "red spot" which is a potential rhyolite (silica-rich volcanic rock) extrusion in the crater's northwest region [8]. **Descriptions of color and albedo variations across Copernicus, especially in its northwest quadrant, help determine the composition and provenance of materials within the crater's interior. While spectral data reveal the red spot, what color and albedo differences can you observe?**

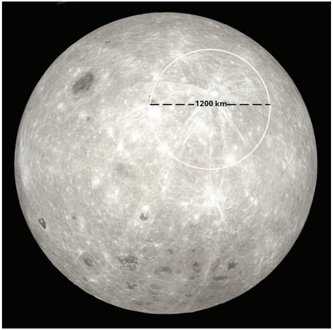
The Apollo 12 landing site in Oceanus Procellarum lies on a ray from Copernicus crater, approximately 350 km away from the crater rim. This provided scientists with an opportunity to establish chronological boundaries between the mare basalts of Oceanus Procellarum and the ejecta material from Copernicus. [7]. **Descriptions of the crater's interior morphology, ray system, and their crosscutting relationships with surrounding terrain aids in refining lunar stratigraphy and crater chronology studies.**

Jackson




High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts
crater interior

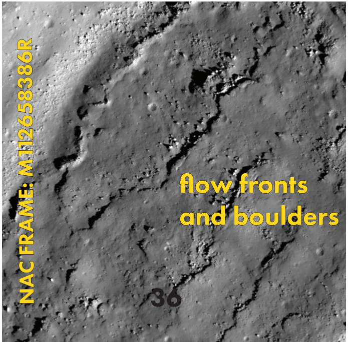
Jackson is a complex crater on the Farside, marked by prominent rays that indicate its young age. You can think of Jackson as Tycho's twin in terms of its extensive ray system and crater morphology. The impact that formed Jackson exposed deep material, and the central peak brings up rock from several kilometers below the surface.

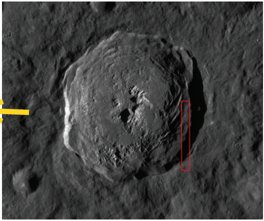


Although its crater is not large (~70 km), Jackson's ray system is vast, measuring over 1,200 km in diameter. **The diameter of the ray system is close in size to the island of Madagascar (~1,600 km from north to south).**

Thin sheets of impact melt cover terraces and crater walls, often fractured into brittle, puzzle-like pieces [9]. Flow fronts appear frozen in motion, and boulders, some weathered out of the melt, line the slopes and crater floor [9]. These boulders will eventually slump downslope and become buried, while small impacts gradually erode and soften Jackson's sharp features [9].

"Remember that Jackson is the crunchy one." — Ernie



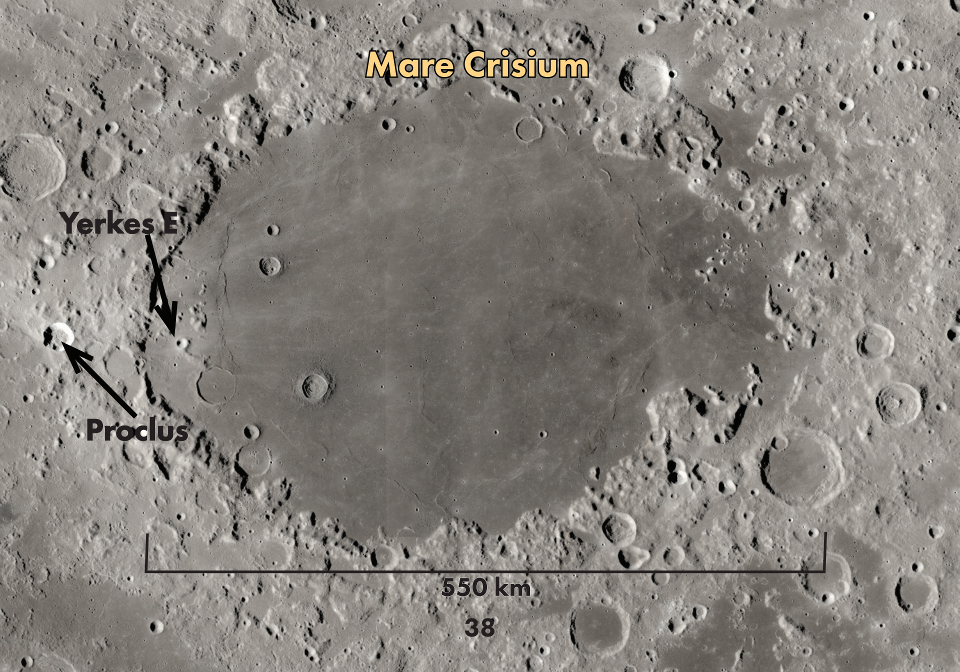


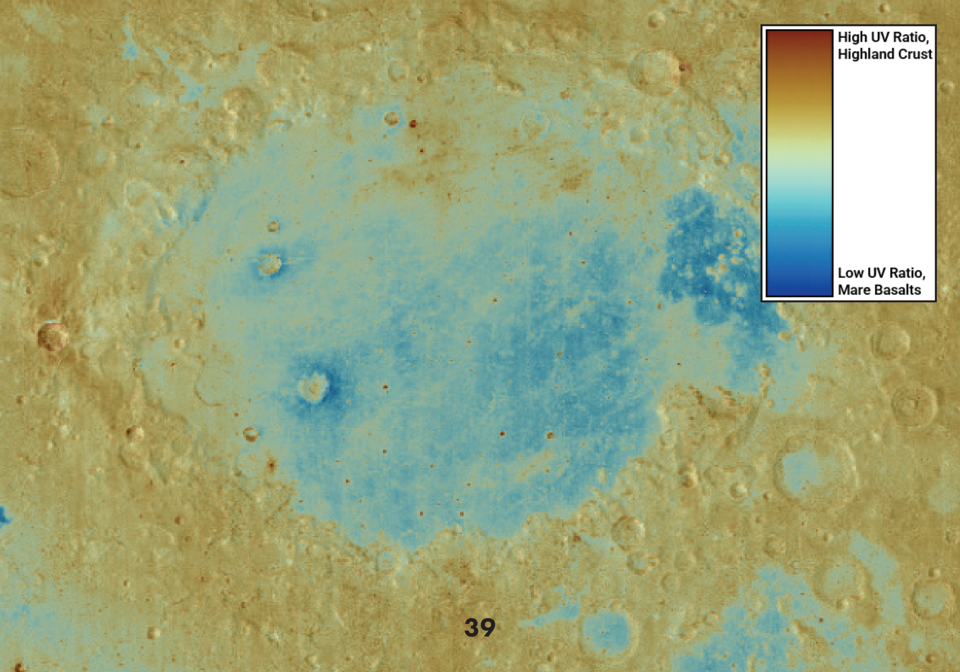
NAC image depicting location of some flow fronts and boulders [9]

Descriptions of the morphology of these features give insight into how complex craters form and how impacts deliver, modify, redistribute, and mix material on the lunar surface. Jackson also serves as a target for understanding ray systems on the Moon. Observations of its rays (color, albedo, extent, and crosscutting relationships) help reveal clues to material transport and space weathering.

Our big picture science questions for Jackson are:

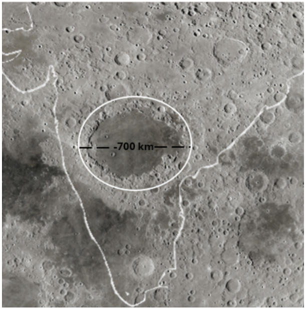
- **How does the brightness of surface features change with age?**
- **What does the morphology of crater ejecta and rays tell us about the dynamics of impact formation?**


Mare Crisium
Yerkes E
Proclus
550 km


High UV Ratio,
Highland Crust
Low UV Ratio,
Mare Basalts

Mare Crisium is a lunar mare formed by basaltic lava flows that filled the ancient Crisium Basin and provides clues about the effects of large impact events on lunar mare formation. **Crisium Basin (~700 km in diameter, with Mare Crisium at ~555 km in diameter) could fit within India's Deccan Plateau.**

The mare basalts vary in composition, with some enriched in elements such as titanium and calcium [10]. Constraining the various lithologies of the mare basalts in Crisium Basin is a current focus of research [10][11].

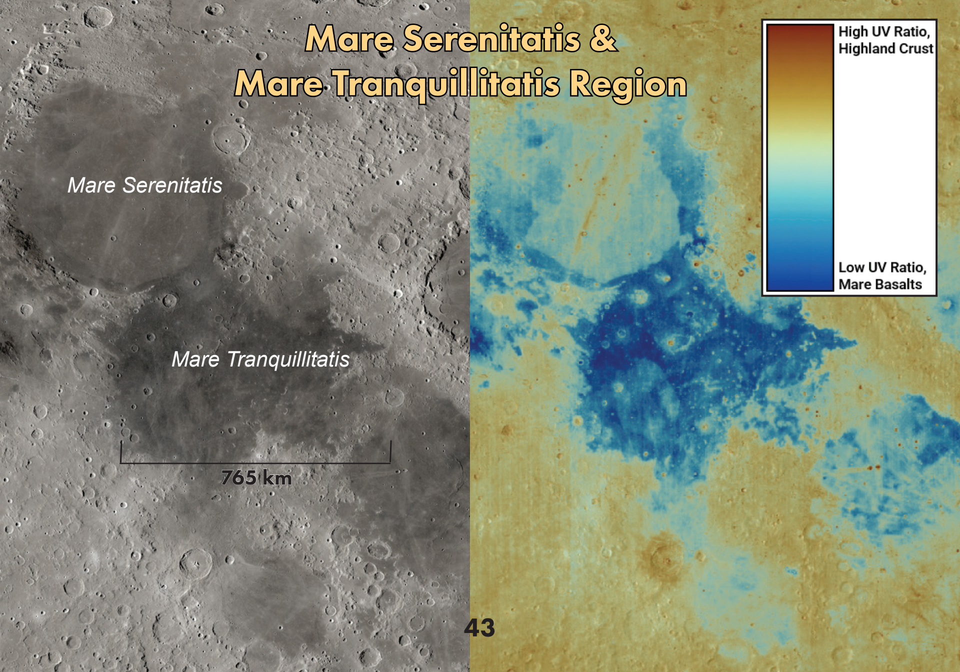


LRO spectral data show that in western Crisium Basin, the mare basalts are mixed with feldspathic ejecta from craters like Proclus, making it hard to distinguish between mature highland materials and mixed mare basalts [11]. Feldspathic materials in and around the inner ring of Crisium Basin are identified by their albedo, with the highest values linked to fresh craters like Yerkes E and Proclus or to steep slopes. Variations in the albedo of these materials may be due to space weathering rather than composition [11].

Mare Crisium also has wrinkle ridges, which may be linked to thrust faulting. There may also be volcanic cones and pyroclastic deposits; the presence of both has been debated [12].

Descriptions of color and albedo variations across the mare basalts and their boundary preservation can help constrain their composition and therefore their volcanic histories, including the eruption styles and rates with which they were formed.

Observing the morphology of wrinkle ridges, particularly where they cross-cut different mare basalts, supports interpretations of structural relationships and the timing of crustal deformation.


Mare Serenitatis &
Mare Tranquillitatis Region
Mare Serenitatis
Mare Tranquillitatis
765 km
High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts

Mare Serenitatis is a large multi-ring impact basin formed during the late Nectarian period (~3.92 - 3.85 billion years ago) [13]. Its structure includes at least three concentric rings, partially preserved in surface ridge patterns and supported by gravity data, which together help reconstruct the basin's formation and the lunar crust's response to massive impacts [13]. Following the basin-forming impact, multiple volcanic episodes flooded the basin with basaltic lavas and subsequent tectonic deformation produced the wrinkle ridges seen today.

Mare Tranquillitatis is a basaltic lava plain with a wide diversity of volcanic landforms including lunar pits, mare domes, rilles, and distinctive wrinkle ridges.

The Alps (from Nice, France to Vienna, Austria) span approximately 1200 km, about the same distance from the north-west region of Mare Serenitatis to the lower central region of Mare Tranquillitatis.

Mare Serenitatis contains one of the Moon's most prominent mass concentrations (a gravitational anomaly created by mantle uplift and dense basaltic infill) [13]. Although mascons are not visible to the naked eye, understanding them is helpful for geologic context and for interpreting morphologic terrain expressions on the surface. Other notable features include rilles, wrinkle ridges, high-albedo rays that overprint portions of the mare, and lunar pits.

Descriptions of color and albedo variations of mare basalts provide insight into compositional differences across the region, help determine the relative ages of lava flows, and improve our understanding of regional volcanic evolution and material mixing. Together, these observations show that this mare-filled region provides important clues into the rates, timing, and style of lunar volcanism.

Characterizing the system of wrinkle ridges (such as their size, extent, and crosscutting relationships) supports studies of lithospheric response to mascon-related tectonic uplift.

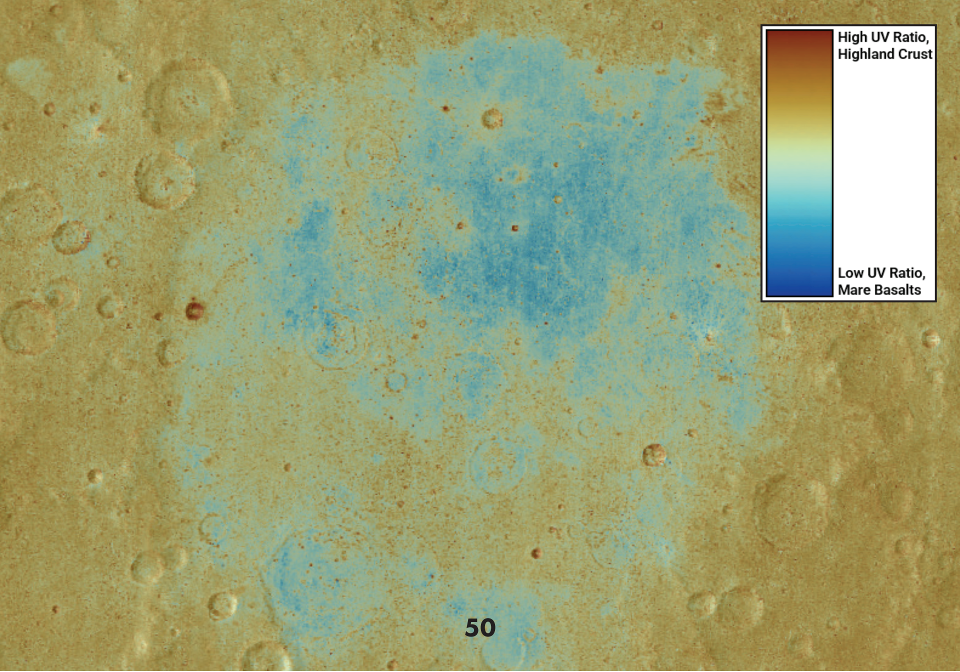
In **Mare Tranquillitatis**, the presence of over 200 mare domes (small shield volcanoes) offers opportunities for volcanic history observations [15]. Mare Tranquillitatis and other young mare differ in age and volcanic source. Apollo 11 landed in Mare Tranquillitatis, where they collected samples indicating that these mare basalts are rich in titanium in comparison to terrestrial basalts [15].

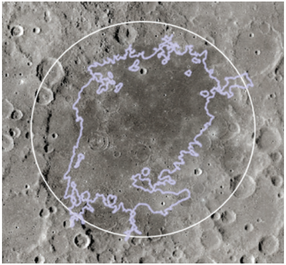
The complex geologic history of Mare Tranquillitatis reflects multiple phases of tectonism, including early subsidence and basin loading, a later global stress field, and more recent global contraction [14]. These three phases have been studied by comparing newer, distinct features with older, degraded ones such as wrinkle ridges [14]. Lobate scarps are other notable tectonic features in this region.

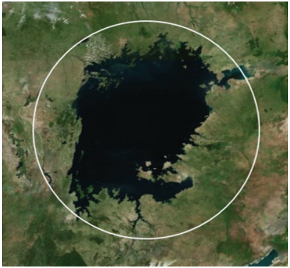
Descriptions of any differences in the color, albedo, and morphology of mare domes in Mare Tranquillitatis help constrain variability in their formation processes and volcanic history. What can you discern about their relationships with the surrounding terrain (i.e., overprinting on mare)?

Descriptions of the distribution and structure of wrinkle ridges and other tectonic features help determine the timing and origin of compressional tectonism in the region.


Mare Smythii
375 km


High UV Ratio,
Highland Crust
Low UV Ratio,
Mare Basalts





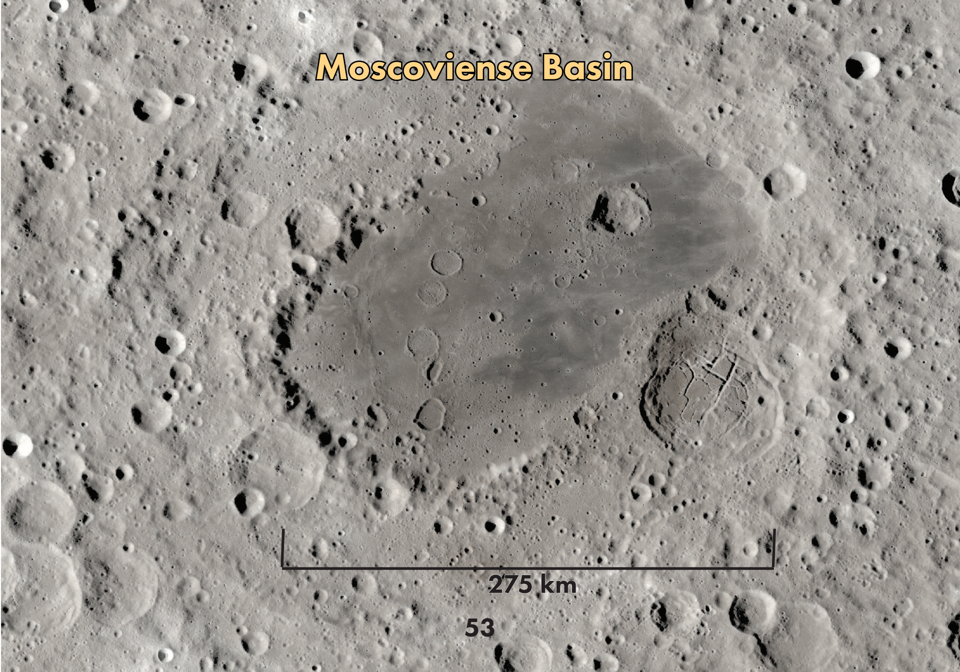
Smythii Basin (infilled by **Mare Smythii**), the fifth-oldest impact structure on the Moon formed early in its history, has inner and outer rings composed of massifs, a scarp within the inner ring, and several large craters on the basin floor that have been modified by intrusions [16]. **East Africa's Lake Victoria (about 337 km across) is almost the same size.**

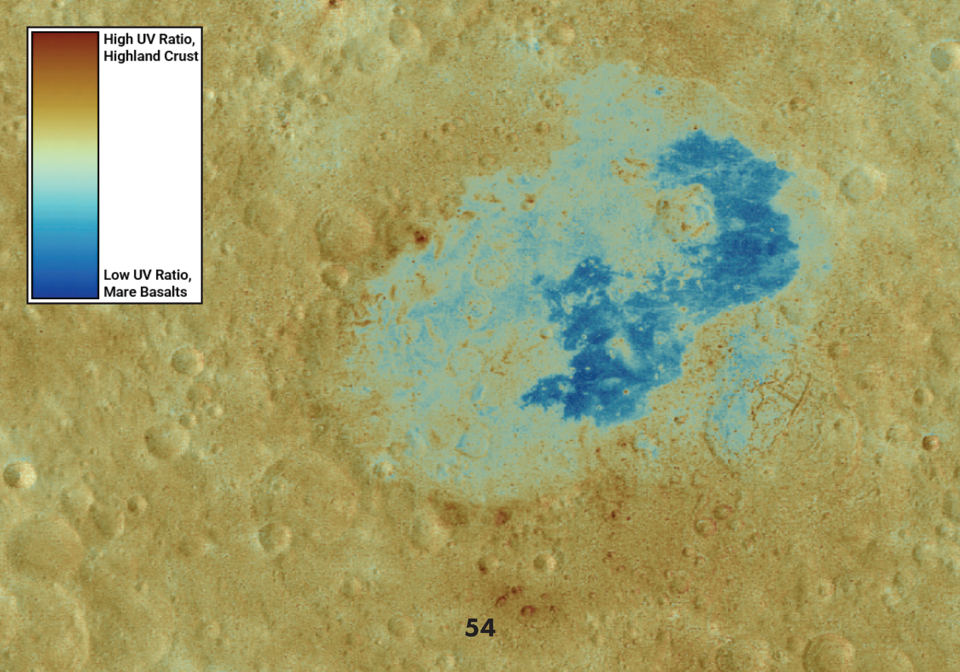
Mare Smythii contains an ancient cryptomare deposit along its eastern margin, as well as mare basalts overlain by pyroclastic eruptions. Together, these features provide evidence of the basin's age and complex geological history [16].

Higher-albedo patterns in the mare could potentially be swirls [17]. The relatively young basaltic lava flows and fractures provide clues into the diversity and longevity of lunar volcanism and how it influences tectonics.

Mare Smythii also preserves exposed impact melt deposits on its floor, which are relatively rare on the Moon and valuable for dating ancient impact events. The impact melts are overlain by younger mare basalts, showing that the basin was resurfaced by multiple lava flooding events after the initial impact [17].

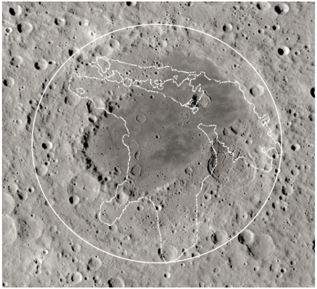
Descriptions of swirl color, albedo, boundary sharpness, crater infill, and thickness help determine the provenance of cryptomare and volcanic deposits. Descriptions of morphology and terrain expression on different sides aid in reconstructing the impact history.


Moscoviense Basin
275 km


High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts

Moscoviense Basin is a multiringed impact structure located on the Farside, within the Feldspathic Highlands Terrane (FHT), which contains remnants of the Moon's oldest crust. **Moscoviense Basin measures about 450 km in diameter, just large enough to encompass Lake Huron.**

The basin is filled by Mare Moscoviense (~275 km in diameter), which is the largest mare deposit on the Farside.



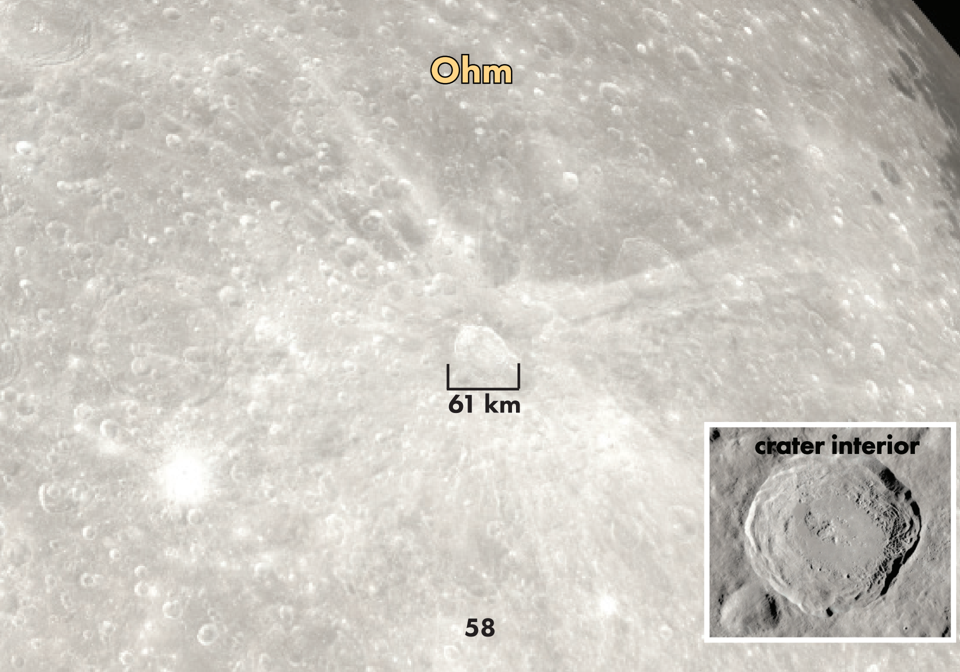
Heavily degraded and dating to the Nectarian period (~3.92 - 3.85 billion years ago), it contains craters of various ages and morphologies, reflecting a long and complex history of impacts and volcanic resurfacing [18].

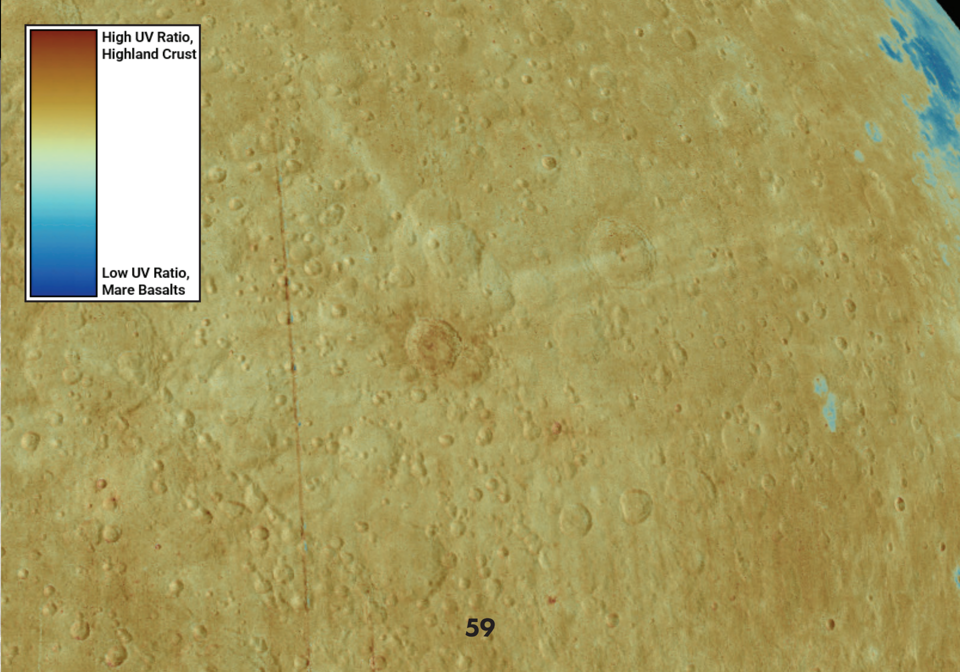
The mare likely formed through multiple basaltic eruptions, as indicated by their various color and albedo variations and craters nearly buried by younger flows. Variations in mare shade and peak ring morphology provide insight into early crustal differentiation on the Farside [18].

Swirls have been detected by orbital spectral instruments, but are they distinguishable to the human eye? If so, do they follow a topographic trend?

Your observations of the color and albedo of the swirls—including whether their boundaries appear sharp or gradational—contribute to future landing site selection, as swirls are of high interest for lunar science exploration.

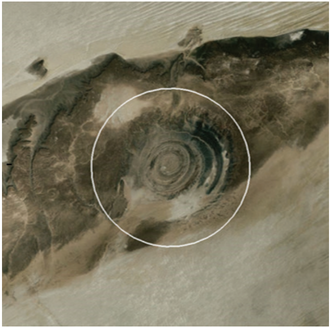
Descriptions of Moscoviense Basin's ring stratigraphy and color and albedo differences help constrain excavation depth, crustal composition, and thermal conditions during basin formation, and support models for the origin of pink spinel anorthosite excavated from the mantle [19]. This basin therefore provides important clues about the Moon's deep interior.


Ohm
61 km
crater interior


High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts

Ohm is a young (Copernican-aged) crater that shows evidence of extensive impact melting. **The Richat Structure, also known as the "Eye of the Sahara," is ~40 km in diameter and could fit within Ohm's interior.**

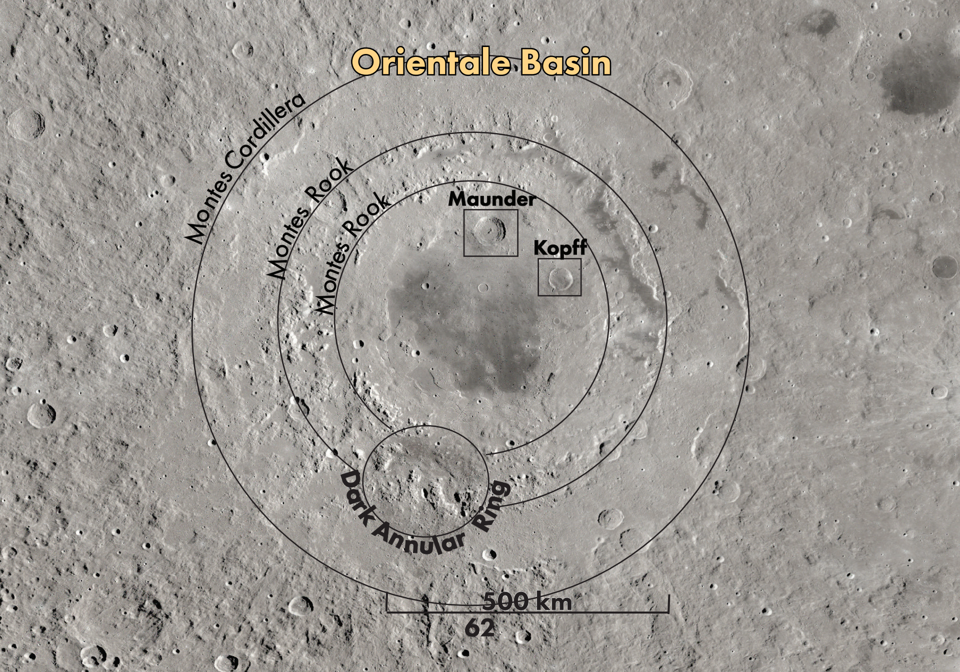
Its central peak appears to be surrounded by impact melt deposits. Geologic features on the crater floor include lava channels, lava ponds, and dome-like structures [20].

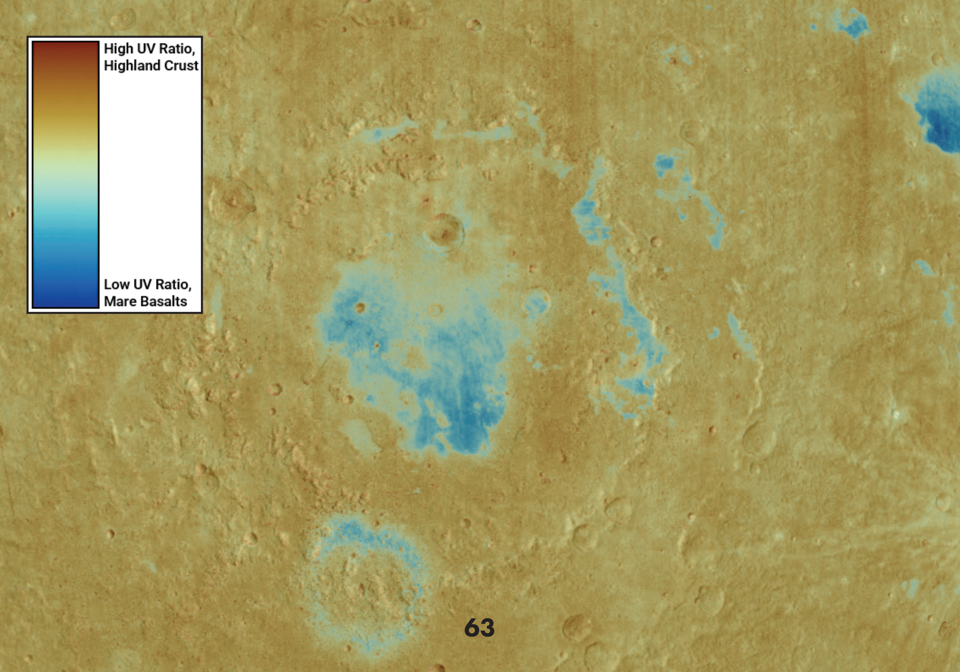


Ohm's bright ejecta tells us about material transport (how rock and debris were ejected and redistributed during the impact), and its wall terraces show mass wasting (the slow, long-term downslope movement of material after the impact).

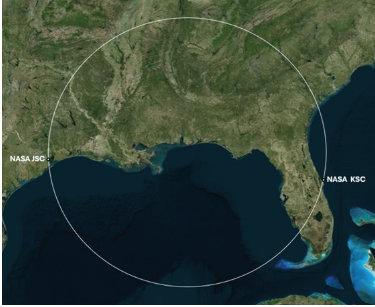
Severely fractured solidified impact melt near the crater wall likely indicates that the impact melt pond was either not thick enough or not uniformly thick enough to completely cover the underlying crater floor feature [21].

Ohm is a proxy for studying small and young impact crater ray systems, particularly their extent, which is of high interest. Descriptions of ray visibility, including their color, albedo, and reach, along with detailed observations of the crater's walls and central mounds, can provide valuable insight into impact processes.


Orientale Basin
Montes Cordillera
Montes Rook
Montes Rook
Maunder
Kopff
Dark Annular Ring
500 km


High UV Ratio,
Highland Crust
Low UV Ratio,
Mare Basalts

Orientale Basin, known as the **"Grand Canyon of the Moon,"** is a three-ringed impact basin. It's the Moon's best example of large impact basin formation and has **never been seen in sunlight by human eyes.** Its nickname is based on how well preserved its stratigraphy is. **Orientale Basin and its surrounding ejecta could fit within the straight-line distance from NASA's Johnson Space Center to Kennedy Space Center, which is just over 1,400 km.** Orientale's two inner rings are referred to as "Montes Rook," and its outer ring is referred to as "Montes Cordillera".



In order of geologic processes, this region formed through an impact basin event (complemented by impact melt), and then mare volcanism.

The basalts of Mare Orientale, which partially infill the central depression of the basin, may preserve buried impact melt deposits, effectively making it a time capsule that records impact melt thickness, differentiation, and stratigraphy of the lunar interior.

The basin's rings and features like Maunder Crater provide a window to the Moon's crustal composition and preserve stratigraphic relationships [22]. Regional wrinkle ridges, circumferential fractures, and fractures in nested craters like Kopff further highlight the structural complexity of the basin.

Descriptions of stratigraphic relationships within the rings and craters provide valuable insight into the processes of formation of large basins across the Solar System.

Comparisons of color and albedo variations in mare basalts within Montes Rook and Montes Cordillera provide insight into compositional differences that piece together volcanic history and basalt distribution across the basin.

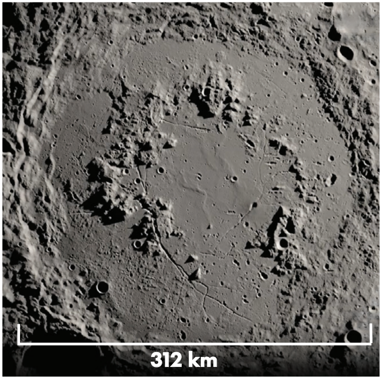
Orientale's Dark Annular Ring, with its distinctive "kiss" shape, is of particular interest, as spectral data show that it has a different mineral signature than the mare patches in the rest of the basin, suggesting that it was formed by different volcanic processes than the other mare basalts. **Observations of its boundaries, stratigraphy, and uniformity could yield important clues about its formation [23].**

Other big-picture science investigations / questions:

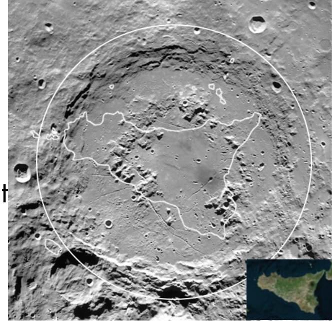
- **How does the sharpness of surface morphology change with the age of the feature?**
- **What is the series of geologic events that are preserved across the Moon's youngest basin?**

Schrödinger Basin

Schrödinger Basin is the second youngest impact basin on the Moon [11]. Its peak ring spans roughly 150 km in diameter and stands between 1 and 2.5 km above the basin floor. **Spanning approximately 285 km, the island of Sicily can lie within the floor of Schrödinger Basin.**



The Schrödinger Basin impact excavated deep crustal material, including potential melt from the earlier South Pole–Aitken Basin (SPA) impact. Science investigations at Schrödinger could help assess the Late Heavy Bombardment hypothesis and constrain the timing of basin formation by determining the age of SPA [25] [28]. **Spanning ~285 km, the island of Sicily can lie within the floor of Schrödinger Basin.**

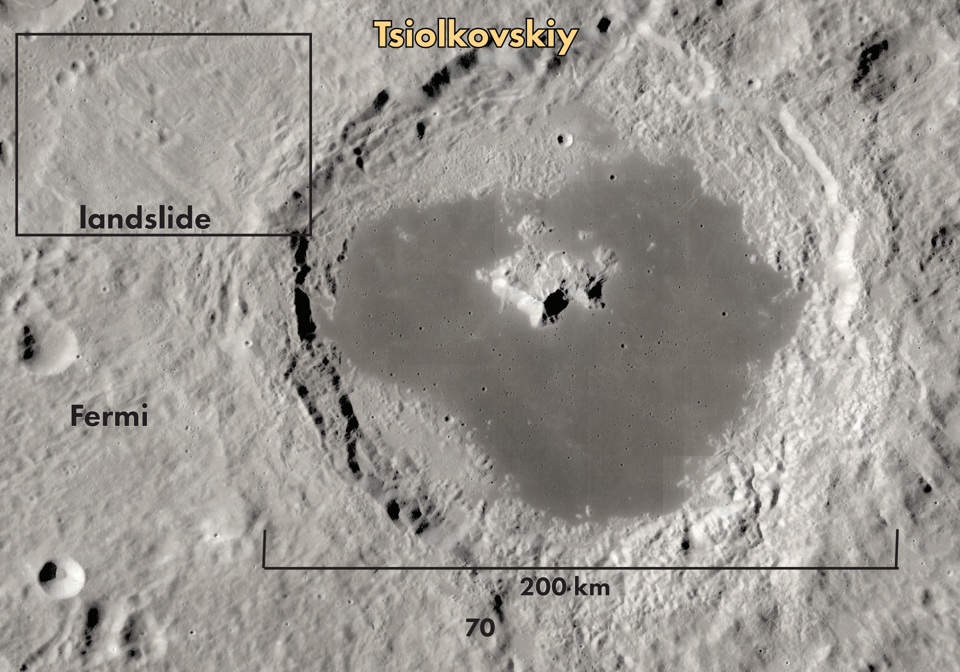


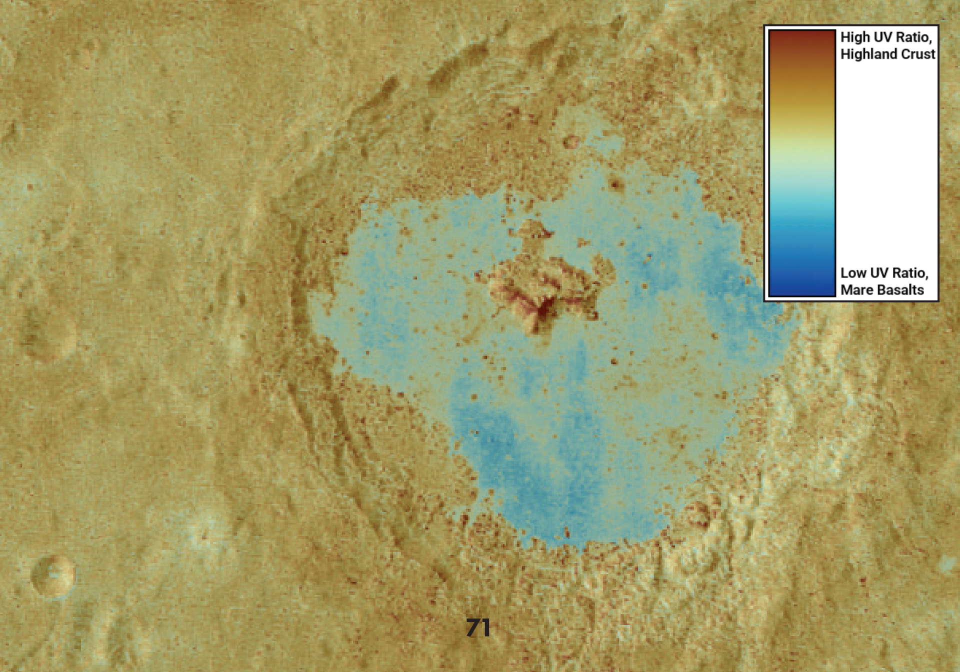
The basin hosts volcanic and tectonic features on its floor, including mare, a pyroclastic vent, and a system of extensional grabens [25]. As one of the Moon's youngest giant impact basins, its fractured floors provide insights into how impact stresses influence volcanic responses. The inner peak-ring floor may also contain impact melt and uplifted peak-ring lithologies, as well as secondary crater fields [28].

Spectral data of Schrödinger Basin are not provided in your Passport; however, referenced studies show the presence of mafic minerals [24], as well as SPA impact melt, particularly along Schrödinger Basin's southern wall [27].

Descriptions of any discernible color and albedo variations and thus potentially composition might help reconstruct the history of geologic surface processes and possibly the excavation depth of materials.

The basin's combination of rings, grabens, mare, and pyroclastic deposits records a history of impact, tectonic, and volcanic processes. **Observing the diversity of these features and their crosscutting relationships helps reconstruct the sequence of events that shaped the basin. Schrödinger's complex geologic history makes it a strong candidate for future lunar science exploration.**


Tsiolkovskiy
landslide
Fermi
200 km
70


High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts

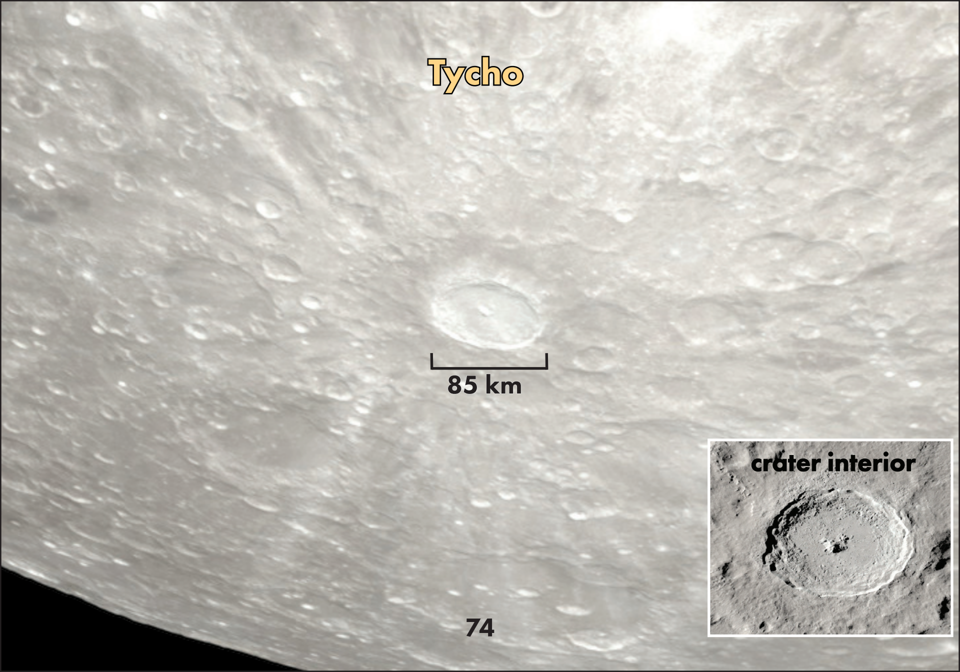
Tsiolkovskiy is a large, complex crater with a dark, flat, partially mare-filled floor, and a central peak. **The diameter of Tsiolkovskiy (~200 km) is just slightly larger than the straight-line distance from Dublin to Galway, Ireland (~187 km).**

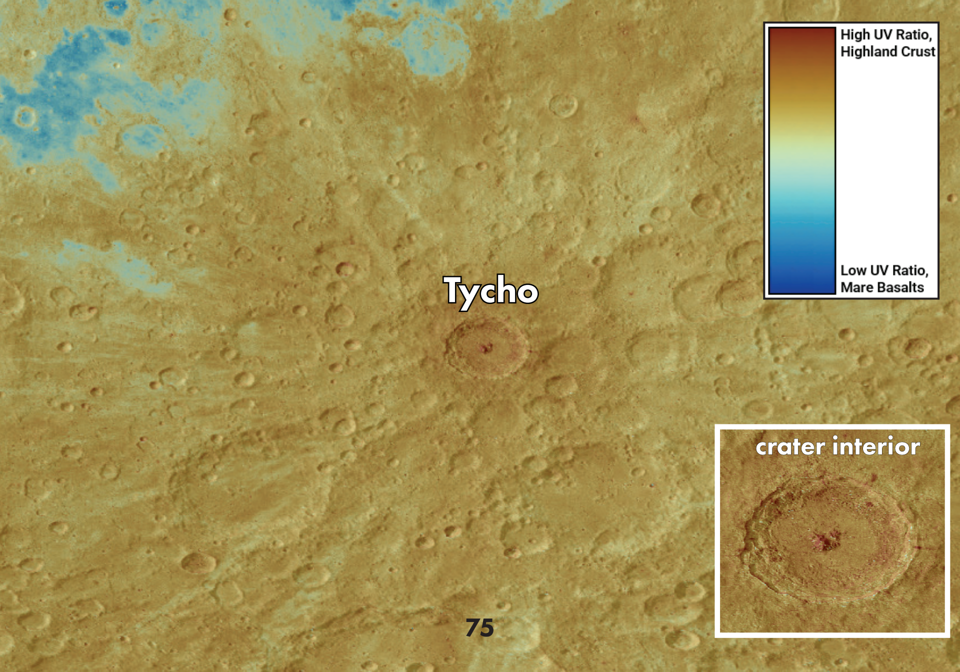
Its rim is characterized by impact melt and ejecta deposits. On the northwest side is a runout landslide, which originated from the northwest rim and flowed into the floor of Fermi crater (west), likely triggered by an oblique impact. This landslide is the largest of its kind on the Moon and on a dry, rocky, airless body in general, making it a feature of interest for studying the mechanics of rapid mass-wasting events [29].

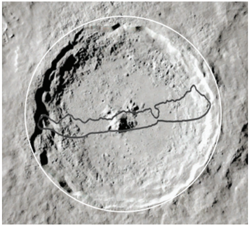
LRO observations show that Tsiolkovskiy has a distinctively rocky surface and a thin regolith layer, most notably in the southeastern region where an impact melt deposit appears to be preserved [30].

Observations of:

- **Morphology of the landslide helps reveal how impacts modify, redistribute, and mix surface materials.**
- **Crater rim morphology and stratigraphy, textures of crater floors, walls, and central peak provide clues to the composition and structure of the lunar crust.**
- **Color and albedo of the mare basalts give insight into their provenance and stratigraphy.**


Tycho
85 km
crater interior


High UV Ratio, Highland Crust
Low UV Ratio, Mare Basalts
Tycho
crater interior



Tycho, an 85-km diameter rayed crater, has a central peak, flow fractures, and impact melt deposits. **Hungary's Lake Balaton, which is approximately 78 kilometers across at its longest point, could comfortably fit within the rim of Tycho.** This fresh and well-preserved crater provides important information about the most recent period of geologic history on the Moon.

Tycho is famous for its extensive ray system, which reaches the Moon's South Pole and intersects future Artemis III Candidate Landing Regions [31]. Future sampling of material from Tycho's rays could be monumental for lunar science.

The central peak has steep slopes, and debris accumulation on these slopes indicates ongoing mass wasting [32]. Tycho's peak also has patches of impact melt, distinguished by their darker color and characteristic cooling fractures. Some of this impact melt has fractured and slid down, now resting on the slopes below [32].

Descriptions of the color and albedo of the ray system and its crosscutting relationships with the surrounding terrain aid in building out the stratigraphy of the Moon.

Descriptions of Tycho's interior (crater walls, floor, peak), specifically of any discernible color and albedo differences and morphological patterns, support studies that focus on the spatial distribution of impact melt within Tycho, and the broader impact formation processes of craters of this scale.

As a reminder, illumination plays a key role in science observations. Under low illumination conditions, surface morphology becomes accentuated, especially near the terminator where long shadows are cast on the surface. Higher illumination is ideal for observing color and albedo variations, as changes in hue and reflectance across the surface become more apparent when there's less obstruction by shadows.

Example Observations...

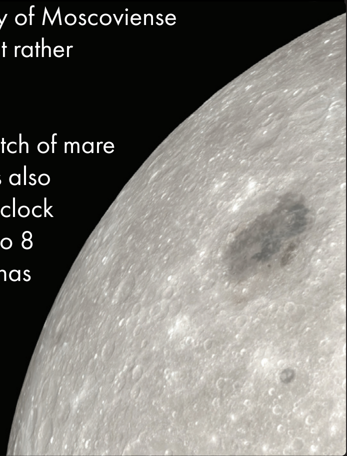
This section gives you three example observations, written by members of your training team.

These descriptions do not follow any sort of template and are merely to show you how descriptions can sound from different voices and perspectives - all of which are valuable. Diversity in your descriptions is what we want as we want them to be genuine to your experience during your Lunar Flyby.

Observation by: Juliane Gross

"I'm looking at Moscoviense Basin at an oblique angle through my camera lens and it is in the center of my field of view. It is the largest feature in my view; it looks really impressive. From large to small I can barely make out two circular mountain ranges; one that forms the boundary of Moscoviense and one inner peak ring, and they are not circular, but rather concentric, somewhat distorted rings.

The inner peak ring is completely filled with a dark patch of mare that varies in albedo and color hue. The mare patch is also elongated in shape with the long axis going from 2 o'clock to 8 o'clock or NE to SW, if 12 o'clock is north. At 7 to 8 o'clock the mare infill is much lighter in albedo and it has a more reddish-pinkish hue to it.



In general, the mare patch seems smooth compared to the rest of the terrain. The inner and outer ring seem very degraded, and it is hard to really see them with these illumination conditions. Nonetheless, they seem to be the most degraded between 12 o'clock to 2 o'clock, almost nonexistent, compared to the other directions.

Outside of and around the outer ring of Moscoviense at 11 o'clock, 2, 4, 6, 7, and 8 o'clock, are some really bright small craters, almost like pearls on a necklace surrounding the basin. Darker albedo terrain exists in between the basin and the brighter craters but not as dark as the mare patches. Above the basin, the terrain appears as a brighter streak going from east to northwest, it is brighter than some of the highlands in the other directions from Moscoviense, maybe a ray? To the south-east the highlands appear exceptionally bright too but that might be an effect of the sun angle."

Observation by: Ariel Deutsch

"The time is 19:04. I'm looking at Tycho crater from the Targeting Plan using my naked eyes. It is in the bottom portion of my view of the Moon, where north is up. The crater appears nearly circular and is similar in size to a mare-filled crater northward of it, along the highlands-mare boundary. I can make out the outer walls, especially the southeast facing portion of the crater wall in this illumination. The walls appear to be crisp and well-preserved. I can also just make out the central peak of the crater.

Tycho's most prominent characteristic is its relatively high albedo – it appears to be brighter than the surrounding bright highlands materials, probably because it is a relatively young crater. I can see bright rays emanating from the crater, the longest of which stretches up to the 10′ or 11′ o clock mark towards Kepler, across highlands then mare. The rays clearly overly the surrounding surfaces."

Observation by: Jacob Richardson

"Looking at Apollo basin, I'm seeing about a 500 km wide basin in the southwest view of my Moon. From large to small, I see two circular mountain ranges; one that forms the boundary of Apollo and one inner peak ring. Within the inner peak ring I see a dark patch of mare that is shaped a bit like a rounded star. Immediately north is a small bright fresh crater within one of the nooks of the star. More mare patches are visible and hug the inside of the outer rim at 9 o'clock and 6 o'clock, with 12 being north. South of Apollo, the terrain looks dark, but not as dark as the mare inside Apollo. The darker the area in this region both in and outside Apollo basin, the smoother and less cratered it looks. To the east of Apollo, the terrain appears brighter than some of the highlands in the other directions from Apollo. This bright area looks to be about the same size as Apollo itself. To the west of Apollo, the terrain looks way more cratered, but that might be an effect of the long terminator shadows."

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Artemis II Lunar Science Team members are **bolded.**

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(Note: follow hyperlinks at the bottom of this page to learn about melt fractures, waves, etc.)

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LROC WAC Multispectral Data & Interpretation

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Rendered Moon Visuals

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