Digital Restoration of the Apollo 11 Landing Site Map

"That's one small step for a man." "One giant leap for Mankind."

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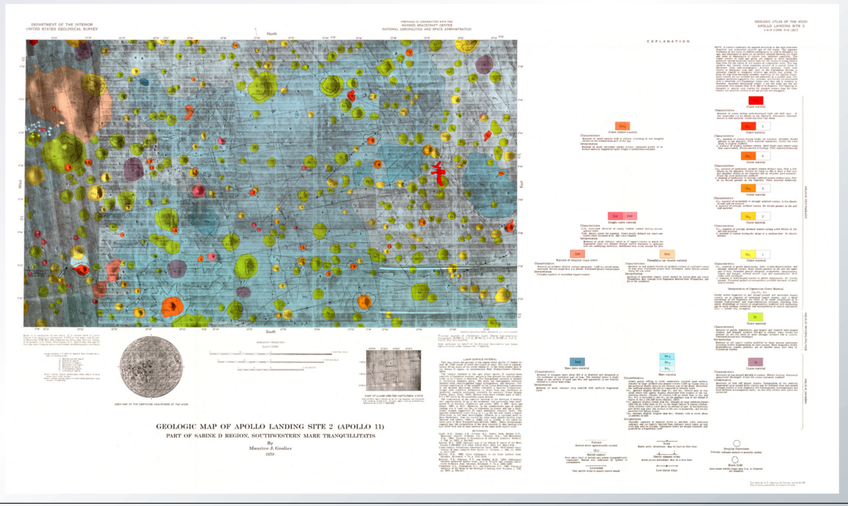
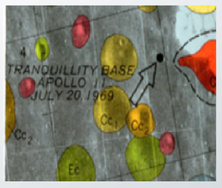


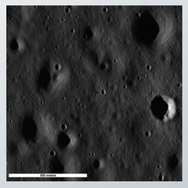
INTRODUCTION

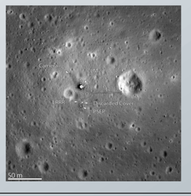
- **APOLLO 11 HISTORY**: [1]On July 16, 1969, one of the most significant events in the scientific realm and US history took off. Apollo 11 had launched. This would revolutionize history as we know it - redefining America and the world's scientific capabilities. On board was commander Neil Armstrong, lunar module pilot Buzz Aldrin, and command module pilot Michael Collins. On July 20, four days after launch was initiated, the lunar module Eagle would land on the Moon, and Neil Armstrong would be the very first man to step foot on another planetary body. With such a feat achieved Neil Armstrong commented the world renown statement: "That's one small step for a man." "One giant leap for Mankind."

- **APOLLO 11 LANDING SITE MAP**: In order to safely and successfully land on the moon the Apollo team used careful precision in cultivating a suitable landing spot. Such effective methodology was achieved from using images taken by the Lunar Reconnaissance Orbiter Camera (LROC) onboard of LRO, and applying understandings about surface features here on Earth in the study of Geology. A pre-mission geologic map was created for the mission to deduce where the best landing spot would be. It was determined that Mare Tranquilitatis would be the overall safest landing site. Although this location is high in crater density, Mare Traquilitatis is smooth and level, making the terrain optimal for landing. The landing site was also an appropriate choice for its position during the time of landing, to reduce distance and thus travel time. The geologic map of the Apollo 11 landing site[2], created by Maurice J. Grolier in 1970 can be found to the left.

- **MY PROJECT**: With this event being a groundbreaking moment in history, coupled with the innate tendencies of human nature to yearn for furthering pre-existing knowledge, it is only fathomable that as a society we will venture to the moon, again. For such future ventures, this project was intended to digitally restore the geologic map of the Apollo 11 landing site. Digital use is a look into our past and an application to our future. This reconstructive map will not only serve as a tool for future journeys but to also preserve the importance of the geology and history of its past-mission. By using newer ArcGIS mapping software, and high-resolution images from LROC-NAC the quality of the digitally restored map will be significantly improved. This map will join the other Apollo mission maps, and many other geologic maps in the field of planetary science in a USGS archive.







The left pictures depict where the landing site of Apollo 11 is on the original geologic map. The picture then takes a closer look to the landing site using images developed from LROC[3,4]. This is a promising way to visualize the size of the Lunar module compared to the map. Additionally shown, is the Lunar module[3], in actuality the lunar module itself is immense in size but for a 1:25,000 scale in the geologic map, it appears deceivingly small.

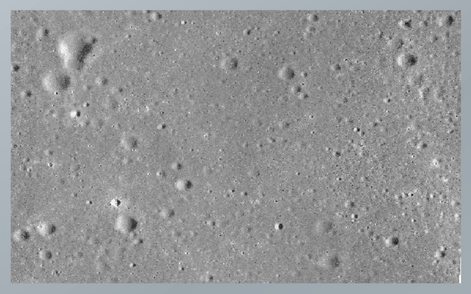
Apollo 11 Lunar Landing Mission Crew

Commander Neil A. Armstrong [left], command module pilot Michael Collins [middle], and lunar module pilot Edwin "Buzz" E. Aldrin Jr. [right][5].

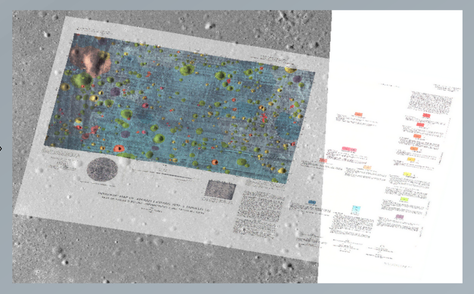
METHODS

1. Using the Planetary Image Locator Tool (PILOT) on the USGS astrogeology website[6], images from LROC-NACL and LROC-NACR were retrieved for the targeted area. Several raw images in high resolution of this site were chosen to make a basemap for the new digitized map.

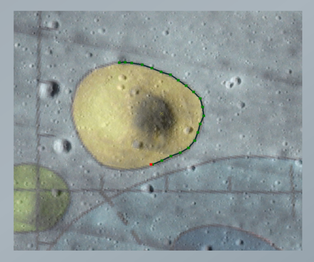
2. After finding the high-resolution images that appeared most appealing, they were imported into ArcMap, where they effectively matched coordinates together. The images were edited through touch-ups of contrast and brightness to match each other to improve appearance. Once satisfied, the new basemap of high resolution can be registered.



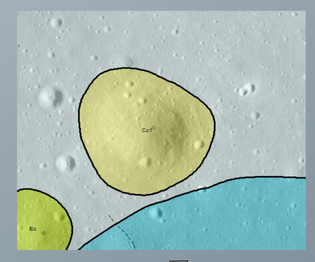
3. The 1970 original geologic map was then imported into ArcMap. Using control points as a georeferencing tool, the craters and other surface features of the original geologic map were matched with the new registered basemap. Once everything is positioned correctly, mapping can begin.



4. Next is to recreate the map features using these applications in ArcMap: geologic contacts, linear features, and map units. Using these features, the craters and other geologic indications were traced over, recreating the line work done from the original map.

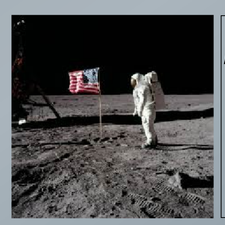


5. Once recreated, the geologic contacts are converted to polygons, and joined with the map units, so that they can be colored in with the appropriate colors from the original map. This would create the new digital version of the original map that can be seen on the right. The map is then digitally restored!



WHY DIGITIZE?

After the digital restoring process is done, this map will be preserved in a digital archive with other Apollo mission geologic maps by the U.S. Geological Survey. They can be accessible by the public and science community for research use of the geologic features on planetary objects and applied to future comparisons in the field. These can provide keys to understanding how our solar system formed, and be used for future missions. The Apollo 11 map gives us an advantage to look back at one of the major accomplishments in US History. These maps of the Apollo missions will leave a historical and enduring mark, providing an everlasting trace back through time at one of the most important events in history.



Astronaut Buzz Aldrin posing with the United States flag during EVA. Astronaut Neil A. Armstrong took this picture with a 70mm Hasselblad lunar surface camera[7].

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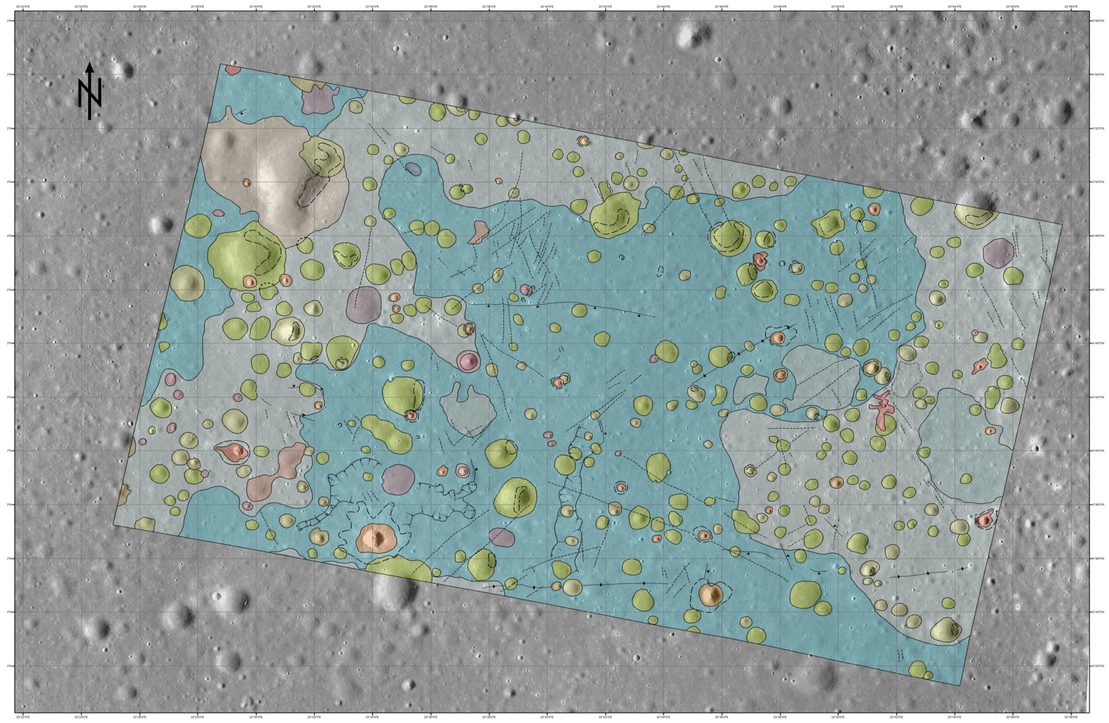

Scale 1:25,000

GEOLOGIC MAP OF APOLLO LANDING SITE 2 (APOLLO 11)

PART OF SABINE D REGION, SOUTHWESTERN MARE TRANQUILLITATIS

Base is a composite of two parts: 1) a narrow band of Lunar Orbiter high-resolution photograph V-H72 on the west, and 2) part of Photomap OIB II-6 (25) prepared by Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. 20315 over the rest of the map area. Irregular spots and streaks are photographic artifacts.

Large numbers 1-7 refer to regions that include early Apollo lading sites:
1. Maskelyne DA region
2. Sabine D region
3. Oppolzer A region
4. Wichmann CA region
5. Maestlin G region
6. Flamsteed K region
7. Lansberg P region

Small number above quadrangle name refers to lunar base chart (LAC series); Small number below refers to published geologic map (scale 1:1,000,000)

Principal sources of information: Lunar Orbiter high-resolution photographs: II-H84 (2, 3 of 3), II-H85 (2, 3 of 3), II-H86 (2, 3 of 3), V-H71, H72, H75 and H76

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LUNAR SURFACE MATERIAL

This map shows the geology of the region where Apollo 11 landed on July 20, 1969 (arrow in lower left corner of map). The site is approximately 20 km south of the crater Sabine D, in the west-central part of the Sabine D region, in the southern western Mare Tranquillitatis (Grolier, 1970).

The surface material at the spot where Apollo 11 touched down consists of fragmental material, generally fine grained but with abundant rocks up to 1 meter in diameter. The fine-grained material is notable in containing abundant glass. The rocks are fine-grained vesicular basaltic lavas, medium-grained vuggy microgabbros, and breccias. Preliminary examination of the samples at the Lunar Receiving Laboratory of the Manned Spacecraft Center indicates a basaltic composition, though with numerous differences in detail from any terrestrial or meteoritic samples previously available for analysis (Lunar Sample Prelim. Exam. Team, 1969). Several rocks have yielded ages of 3.0± 0.7 x 109 years by the potassium-argon method.

The composition of the surficial material at the Surveyor V landing site, approximately 25 km to the northwest, had previously been interpreted to be basaltic (Turkevich and others, 1967, p. 637; Gault and others, 1967, p. 641). Moreover, in the southwestern part of Apollo landing site 2, mare unit Im_2 is hummocky in places and has a multilobate outline suggestive of some terrestrial volcanic flows. The spectral-reflectivity curve (0.4 µ to 1.1 µ) for the site shows a higher reflectivity in the blue wavelengths, relative to a standard point in Mare Serenitatis, than the curves for other early Apollo landing sites (McCord and others, 1969, p. 4386) and is similar to the curve for other parts of Mare Tranquillitatis (McCord, 1969). These observations suggest that the composition of the mare material in this landing site may differ from that of mare material in the other early Apollo sites.

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Cog

Crater Material

Characteristics
Material of crater having well-developed light and dark rays. A few resolvable (>2 m) blocks in rim deposits. Concentric structure occurs in wall material. Crater rim crest very sharp

Cog 5

Crater Material

Characteristics
C_5, material of craters having bright ray material. Abundant blocks present in rim deposits. Floor material hummocky. Crater rim crest sharp to slightly subdued
5, material of slightly subdued craters. Short bright rays extend away from some craters. Blocks are few or lacking. Floor material hummocky.

Cog 4

Crater Material

Characteristics
C_4, material of moderately subdued craters without rays. Only a few blocks in rim deposits. Crater as large as 400 m have a few rays and abundant blocks in rim deposits and on adjacent mare material. Crater rim crest moderately subdued
4, material of moderately to strongly subdued carters without rays. Few or no blocks present in rim deposits. Floor material hummocky

Cog 3

Crater Material

Characteristics
C_{C3}, material of moderately to strongly subdued craters. A few blocks in wall and rim material
3, material of strongly subdued craters. No blocks present in rim and wall material

Cog 2

Crater Material

Characteristics
C_{C2}, material of strongly subdued craters having a few blocks in rim and wall material
2, material of craters having the shape of a shallow bowl. No blocks present

Cc1 1

Crater Material

Characteristics
C_{C1}, material of gentle depressions, bowl- or pan-shaped craters, and strongly subdued craters. Some blocks present in rim and the upper part of wall. Patterned ground (irregular, subparallel, anastomosing ridges and troughs, several meters high and approximately 10 m wide) well developed
1, material of bowl-shaped craters or gentle depressions. No blocks present. Patterned ground not conspicuous probably because of small size of craters

Interpretation of Copernican Crater Material
C_{CG}-C_{C1}; 5-1

Poorly sorted fragments in and around primary and secondary impact craters; as in deposits of terrestrial impact craters, only a small percentage of the fragments are likely to be shock compressed or to contain high-pressure and high-temperature minerals resulting from shock. Morphology of craters is progressively modified with increasing age by mass wasting, tectonism, and superposition of craters and ejecta (C_{C1}, 1, oldest; C_{CG}, youngest)

Ec

Crater Material

Characteristics
Material of gentle depressions, pan-shaped and shallow bowl-shaped craters, and strongly subdued 125-400 m craters. Some blocks are present on the rim crest of some strongly subdued 350 m craters. Patterned ground well developed

Interpretation
Material of old impact craters modified by lunar erosion processes including further fragmentation by later impact. Rock fragments within Eratosthenian craters probably are of smaller mean size than in Copernican craters

Ic

Crater Material

Characteristics
Materials of pan-shaped 400-600 m craters. Blocks lacking. Patterned ground well developed. Crater rim crests extremely subdued

Interpretation
Materials of very old impact craters. Composition of the surficial fragmental layer around these craters may be different from that around younger craters if rock fragments are lithologically heterogeneous and have different disintegration rates, so that only certain rock types are preserved.

COPERNICAN SYSTEM

ERATOSTHENIAN SYSTEM

NOLAN SYSTEM

NOTE: A crater's materials are mapped according to the size (rim-crest diameter) and interpreted relative age of the crater. The apparent freshness of the crater on Orbiter photographs is used to determine its age, and allowance is made for an inverse relation between the sizes and rates of degradation of craters (see enclosed pamphlet). The larger craters in each age group are mapped in color (mappable craters extend relatively farther from the rim crests of young craters than from the rim crests of old craters of comparable size). The map symbols that identify these materials consist of a capital letter to designate lunar time-stratigraphic division (system), lower case letters to designate rock unit, and, and, in the Copernican System, a subscript number to designate relative age within that system. To keep the map from becoming crowded, materials of the smaller Copernicus craters are not outlined but are indicated by a number only. For example, materials mapped as C_{C1}, outlined, and colored are associated with a relatively old Copernican crater more than 100 m (meters) in diameter; materials designated simply 1 are the same age but are associated with craters from 75 to 100 m in diameter. The mapping is extended to smaller size craters for younger craters than for older craters; the smallest craters in all age groups are unmapped.

Ccg

Crater cluster material

Characteristics
Material of small rayless 3-30 m craters, occurring in one irregular cluster in the northwestern part of the map
Interpretation
Material of small secondary impact craters; composed mainly of re-worked surficial fragmental layer. Origin of projectiles unknown

Ccd Ccdr

Dimple crater material

Characteristics
Ccd, undivided. Material of nearly rimless craters having convex upward walls
Ccdr, dimple crater rim material. Forms poorly defined rim about one fourth crater diameter wide. Rim crest rounded

Interpretation
Material of small volcanic vents or of impact craters in which the fragment layer has drained through narrow fractures or openings into the underlying substrate. Sublimates may occur around the rims

Crch

Material of irregular chain crater

Characters
Material of subdued shallow craters (generally >125 m) aligned north-eastward. Blocks larger than 2 m absent. Patterned ground conspicuous

Interpretation
Probably material of secondary impact craters

Crct

Theophilus ray cluster material

Characteristics
Material in and around the cluster of subdued carters in northwest corner of map area. Patterned ground well developed. Some blocks present along the rim crest

Interpretation
Material of secondary impact crater formed by ejecta from the crater Theophilus. May contain rock fragments derived from Theophilus, 320 km to the southeast

Im_3
Im_2
Im_1

Mare Material

Im_2

Mare dome material

Characteristics
Material of elongate dome about 200 m in diameter and elongated to the northwest in northwest part of map. The material forms a slight bulge in the surface of mare unit Im_2 and apparently is not directly related to a linear mare ridge

Interpretation
Material of small volcanic plug mantled with surficial fragmental layer

Characteristics
Forms gently rolling to level, moderately cratered mare surface. Density of large subdued pan-shaped craters (>500 m) higher than in the potential Apollo sites in the western part of the Moon. Relatively few subdued craters (50-125 m) compared to western sites
Im_3, appears slightly darker than Im_1 and Im_2. Occurs only in four small areas that appear slightly depressed with respect to the surrounding terrain. Density of craters (>50 m) lower than in Im_1 and Im_2. Im_3 is included in unit Im_2 on the geological map of the Sabine D region at the 1:100,000 scale (Grolier, 1970)
Im_2, appears slightly darker the Im_1. Density of the large subdued craters (500-700 m) lower than on Im_1 in the larger Sabine D region (Grolier, 1970). Craters >125 m cover about 10 percent of unit. In southwestern part of the map area, the surface of the unit is hummocky, and locally includes low lobate scarps
Im_1, appears slightly brighter than Im_2. Craters >125 m cover about 15 percent of unit

Interpretation
Probably consists of basaltic flows or ash-flow tuffs; vesicular volcanic ash (or lapilli) derived from volcanic vents (such as unit Ccd) may also be present. Uppermost flows are deeply cratered, and mantled by fragmental layer

Contact
Dashed where approximately located

Buried contact
Dots show a limit of buried unit where topographically expressed. Buried unit indicated by symbol in parentheses

Lineament
Very gentle scarp or gentle narrow trough

Scarp
Barbs point downslope. May be fault or flow front

Gentle sinuous scarp
Arrow points downslope. May be a flow front

Low linear Ridge

Irregular Depression
Probably collapse feature or possibly graben

Block Field
Area where blocks larger than 2 m. in diameter are abundant.