UPDATING THE GEOLOGIC MAPS OF THE APOLLO 15-16-17 LANDING SITES. W. B. Garry[1], L. R. Ostrach[2], M. J. Jodhpurkar[3], R. A. Yingst[4] and S. C. Mest[4] [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [2]USGS Astrogeology Science Center, Flagstaff, AZ 86001, [3]Arizona State University, Tempe, AZ 85282, [4]Planetary Science Institute, Tucson, AZ 85719.

Introduction: Our team is funded by NASA PDART to produce updated geologic maps of the Apollo 15-16-17 landing sites at regional (1:200k) and landing site (1:24k) map scales (Goal 2, Table 1). As part of the project, we will map craters to determine crater-age models for newly defined map units (Goal 3) and renovate the original, pre-mission geologic maps of each landing site to Lunar Reconnaissance Orbiter Camera (LROC) base maps in a GIS (Goal 1). The pre-mission geologic maps of the Apollo landing sites preserve a unique moment in the history of human space exploration – the initial interpretations of the lunar surface prior to exploration by the Apollo astronauts. Our new maps will incorporate findings and interpretations from nearly 50 years of studies of the Apollo data, surface observations, sample analyses, recent remote sensing data, and improved crater model ages.

Table 1. Summary of Project Goals

Goal 1	Digitize pre-mission geologic maps
Goal 2	Create 6 new USGS SIM maps at 1:200k & 1:24k
Goal 3	Determine crater-derived ages for new units

1. Renovation of Pre-Mission Geologic Maps: We have completed digital renovation of the 1:250k and 1:50k pre-mission geologic maps to LROC Wide Angle Camera (WAC) (100 m/px) and Narrow Angle Camera (NAC) (~1.5 m/px) basemaps **[1]**. Currently, we are finalizing the GIS packages and support documents for submission to the PDS Cartography and Imaging Sciences Node in May-June, 2021. Six maps will be archived in the PDS: Apollo 15 (I-723) **[2, 3]**, Apollo 16 (I-748) **[4, 5]**, and Apollo 17 (I-800) **[6, 7]**.

2. Updated Geologic Maps for Apollo 15-16-17: Our team is working on six new special investigation maps that will be published by the USGS. Over the past year, we have only made incremental progress on the maps. Here, we discuss the current state of each map and provide a description of mapping units and features.

2.1 Apollo 15 (1:200k): The regional map (0°–6°E, 24°–28°N) is centered on Rima Hadley (~135 km-long) **[8]** and covers Mons Hadley and the Montes Apenninus east of the rille, Palus Putredinis on the western side of the map, and Lacus Mozart **[9]** in the southwestern map corner. The basemap is the Kaguya Terrain Camera (TC) mosaic (7 m/px).

Map Units and Geologic Contacts. The initial map unit groups we have defined are: mare materials, rille materials, the Apennine Bench Formation (ABF) **[10]**, massif materials, and crater materials. Geologic contacts are defined as certain, approximate, and buried.

Linear Features. The main linear features we have mapped to date are *rille margins* along Rima Hadley, *normal faults* for each wall of linear graben (>1 km wide) and *graben* for narrower (≤1 km wide) linear depression features. *Troughs* (enclosed elongate pits) and *scarps* (down drop/slope breaks in the terrain) are also mapped, primarily in the mare materials. *Crater rims* (≥500 m) are mapped as a well-defined *crest* or *buried*. Additional features mapped in the area include raised, linear *ridges* and possible mare *flow fronts*.

Point Features. We have mapped boulders (≥25 m wide) visible on the base map that are located within the rille, in the mare plains, and on the massifs.

2.2 Apollo 15 (1:24k): The landing site map (3.38°–3.88°E, 25.88°–26.35°N) is roughly centered on the Apollo 15 lunar module. The map covers mare plains, the north flank of Hadley Delta massif, St. George crater, a segment of Rima Hadley explored by the crew, plus the North complex and South complex **[8]**. The basemap is an LRO NAC mosaic (1.4 m/px).

Map Units and Geologic Contacts. The initial map units we have defined are: mare materials, rille materials, massif materials, and crater materials. We have identified at least six impact crater types defined by diameter, rim morphology, and the presence or lack of outcrops and boulders in and around the crater. Geologic contacts are defined as certain, approximate, and buried. We are analyzing the NAC DTM terrain data to constrain mare materials associated with possible overflow (levees?) from Rima Hadley **[11, 12]**.

Linear Features. Layered outcrops exposed in the wall of Hadley Rille are mapped with two different line thicknesses for 'thin' and 'thick' exposures, similar to **[13]**. Boulder tracks are mapped on the rille walls. Crater rims (≥100 m diameter) are mapped as *buried* or well-defined *crest*. In addition, traverse routes are mapped based on tracks visible in LROC NAC images **[14]**.

Location Features. Surface assets from the Apollo 15 mission (lunar module, lunar rover vehicle, science packages) and traverse stations have been marked. Boulders (≥10 m wide) in the rille, on the mare plains, and on the massifs are mapped as individual points.

2.3 Apollo 16 (1:200k): The regional map (13°–19°E, 7.5°–11.5°S) covers portions of the Cayley plains and the Descartes highlands **[15]**. The basemap is a Kaguya TC morning mosaic (7 m/px).

Map Units and Geologic Contacts. We have only defined initial map units as plains materials, massif materials, and crater materials **[16]**. We have started preliminary mapping of geologic contacts between the plains and mountainous ridges and massifs, plus crater materials as certain, approximate, or buried.

Linear Features. We have mapped crater rims as well-defined *crests* or subdued-*buried* features.

2.4 Apollo 16 (1:24k): The landing site map (15.30°–17.72°E, 8.77°–9.22°S) is centered on the Apollo 16 landing site. The map covers the plains explored by the crew, North Ray and South Ray craters, and portions of Smoky and Stone Mountains. The basemap is an LROC NAC mosaic (0.90 m/px).

Map Units and Geologic Contacts. We have started to map the geologic contacts between the relatively flat, lower-elevation plains and mountainous massifs, plus the extent of ejecta from South Ray crater.

Linear Features. Boulder tracks and scours/furrows from South Ray crater ejecta debris are mapped. Crater rims (≥100m diameter) are mapped as *buried* or well-defined *crest*. In addition, the route of each traverse is mapped based tracks visible in LROC NAC images.

Location Features. Surface assets from the Apollo 16 mission (lunar module, lunar rover vehicle, science packages) and traverse stations have been marked. Boulders (≥10 m wide) from South Ray crater and other locations are mapped as individual points.

2.5 Apollo 17 (1:200k): The regional map (27°–33°E, 18°–22°N) is centered on South Massif and the Taurus-Littrow valley. The map covers highland material to the east, impact craters Littrow and Fabbroni, plus mare volcanic structures (Osiris, Isis, Abetti) in southeastern Mare Serenitatis on the western side of the map. The basemap is a Kaguya TC mosaic.

Map Units and Geologic Contacts. We defined a set of fundamental map units as mare materials, massif materials, and crater materials. We have started preliminary linework of geologic contacts between the lower-elevation mare plains and massifs, plus crater materials defined as certain, approximate, or buried.

Linear Features. We have mapped crater rims as well-defined *crests* or *buried*. *Normal faults*, *rille margins*, and *troughs* are various depression features that have been mapped in this area.

2.6 Apollo 17 (1:24k): The landing site map (30.46°–30.92°E, 19.97°–20.43°N) is centered on the Apollo 17 landing site. The map area includes volcanic plains of the Taurus-Littrow valley, the Lee-Lincoln scarp, portions of the flanks of North Massif and South Massif, and landslide material from the South Massif. The basemap is an LROC NAC mosaic (1.35 m/px).

Map Units and Geologic Contacts. The linework for geologic contacts has been completed. Initial geologic map units are based on previous map units **[7]** plus at least two new units. Geologic contacts are defined as certain, approximate, or buried.

Linear Features. The trace for the Lee-Lincoln scarp is mapped as a *scarp*. Crater rims (≥100 m diameter) are mapped as *buried* or with a well-defined *crest*. In addition, the route of each traverse is mapped based on tracks visible in LROC NAC images.

Location Features. Surface assets from the Apollo 17 mission (lunar module, lunar rover vehicle, science packages) and traverse stations have been marked. Boulders (and boulder tracks) have also been mapped.

3. Crater Model Ages: A crater catalog has been created for each map area **[17]**. Standard practices for crater measurements were employed. We used the CraterTools extension **[18]** in ArcMap 10.7.1 to measure the impact craters. For 1:200k maps, craters ≥500 m are mapped on LROC WAC mosaics. For the 1:24k maps, craters ≥10 m are mapped on LROC NAC mosaics. For Apollo 15, ~640 craters were mapped on the 1:200k map and 8,250 craters on the 1:24k map. For Apollo 16, ~900 craters are mapped on the 1:200k map and 6,480 craters on the 1:24k map. For Apollo 17, ~900 craters were mapped on the 1:200k map and 6,480 craters on the 1:24k map. This catalog will be used to determine geologic ages for defined map units.

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