UPDATING THE GEOLOGIC MAPS OF THE APOLLO 15, 16, AND 17 LANDING SITES. W. B. Garry[1], S. C. Mest[2], R. A. Yingst[2], L. R. Ostrach[3], N. E. Petro[1], B. A. Cohen[1] [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, brent.garry@nasa.gov, [2]Planetary Science Institute, Tucson, AZ, 85719, [3]USGS Astrogeology Science Center, Flagstaff, AZ, 86001.

Introduction: 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. However, these maps have not been formally updated in nearly 40 years despite the wealth of information from the astronauts' observations, post-mission sample analyses, and data from recent orbital missions. Creating new geologic maps that merge surface observations and recent remote sensing data will complete the cycle of exploration **[1]** initially started by the creation of the pre-mission geologic maps. Our team is funded through NASA's Planetary Data Archiving, Restoration, and Tools (PDART) program to produce two new U.S. Geological Survey (USGS) Special Investigation Maps (SIM) for the Apollo 15, 16, and 17 missions: a regional map (1:200K) and a landing-site map (1:24K).

Project Overview: Our project is 3 years (2018 to 2021) and is comprised of three main tasks:

Task 1. Digitize the pre-mission geologic maps of the Apollo 15-16-17 landing sites. There are no digital GIS files of the pre-mission geologic maps of the Apollo landing sites. The pre-mission geologic maps are historical records of the early thoughts scientists had about the lunar surface. However, there is no efficient way to compare these original maps with new lunar data sets in a registered GIS space. In year 1, we will digitize 8 maps to new LROC basemaps: the Apollo 15, 16, 17 (1:250K and 1:50K) pre-mission maps **[2-7]** and the Apollo 17 post-mission maps (1:250K and 1:25K) **[8]**. The GIS-ready files will be archived in the PDS Cartography and Imaging Sciences (IMG) Node in year 2.

Task 2. Create 6 new USGS SIM geologic maps of the Apollo 15-16-17 landing sites. The original USGS geologic maps for the Apollo 15, 16, and 17 missions provide the pre-mission assessment of the landing sites, but they were never systematically updated as a new series of official maps after the missions. We will integrate observations and interpretations from the past 40 years of each mission to make complete and thorough new geologic maps for the Apollo 15, 16, and 17 mission sites. The new regional (1:200K) and new landing site (1:24K) maps will be mapped at higher map scales than the pre-mission maps (1:250K and 1:50K) to take advantage of the resolution of the Lunar Reconnaissance Orbiter Camera (LROC) basemaps. The new map boundaries cover a similar or broader area than the original pre-mission regional geologic maps. For the new landing site maps, we selected map boundaries that are consistent with the post-mission traverse maps (1:25K) which do not include any geologic units, rather than boundaries of the pre-mission geologic maps (1:50K) **(Figs. 1-3)**. Therefore, the new landing site maps will cover a much smaller area than the pre-mission maps, but allow us to capture details of the surface observations along the traverse in the NAC basemaps. Lead mappers are: Apollo 15 (Garry), Apollo 16 (Mest), and Apollo 17 (Yingst).

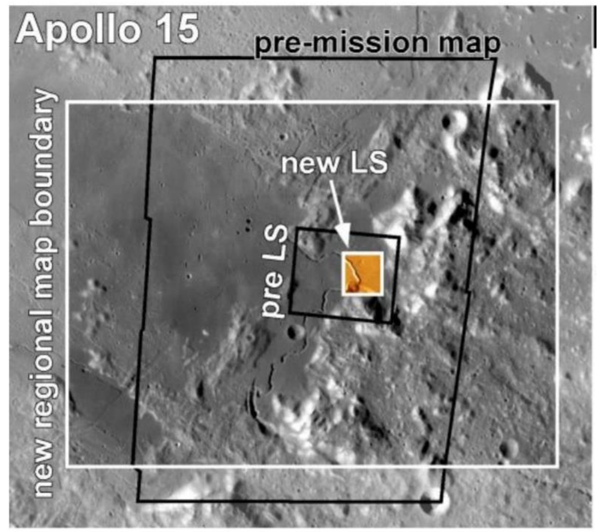

Figure 1. The new map boundaries for Apollo 15 (white boxes) are different than the pre-mission maps (black lines).

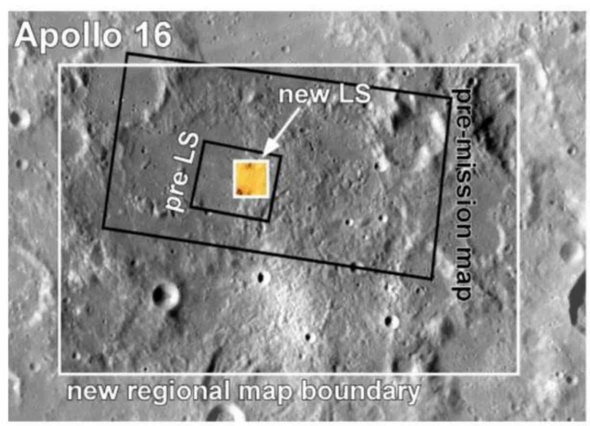

Figure 2. The new regional map boundary for Apollo 16 site covers a broader area than the pre-mission map. Boundaries for the new landing site (LS) map allow features along the traverse and distinct craters (e.g., South ray crater) to be mapped in more detail.

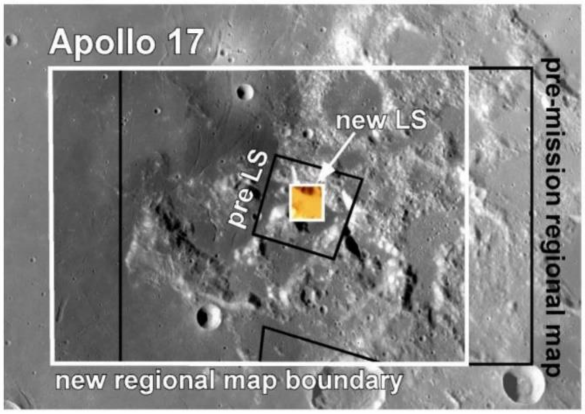

Figure 3. For Apollo 17, the new regional map boundary will cover a similar area as the original pre-mission map, but shifted to the west to cover volcanic units in southeastern Mare Serenitatis. The pre-mission landing site (LS) (black box) and new LS boundary (orange square) are shown in the center.

<u>Task 3. Determine crater-derived ages for the new map units.</u> Relative and absolute model ages of the geologic units mapped for each site will be determined by evaluation of stratigraphic relationships (superposition, embayment, and crosscutting) and through evaluation of crater size–frequency distributions. This task will be led by Co-I Ostrach. Our results will be compared to previously reported ages (crater densities and absolute model ages) **[9-12]**. We expect any discrepancies with earlier age estimates (i.e., based on pre-LRO images) to result from limitations in image resolution and illumination, which can strongly affect crater measurements **[13]**, in addition to differences in defined count areas **[11]**. Co-I Ostrach will generate crater size–frequency distribution plots and calculate crater density to characterize crater populations. Crater plots and estimates of absolute model ages will be produced in the CraterStats2 software using standard cumulative and differential fit functions **[14]** in addition to incorporating newer error analysis **[15]**.

Defining Map Units: The main types of geologic units we expect in the map areas are mare materials, highlands/massif materials, and crater materials. These general units are based on previous mapping and the common types of materials that were sampled during Apollo. Geologic units will be defined and characterized on the basis of morphology, albedo and surface textures, and topography.

Mare Materials. Contacts between mare materials will be drawn based on differences in albedo, color boundaries, textures, and crater density. Volcanic features such as sinuous rilles, domes, cones, and pyroclastic material will also be mapped as discrete geologic units or marked with linear attributes depending on the size and scale of the feature.

Highland Materials. Massifs in the mapping regions will be subdivided based on differences in morphologies, elevations, and compositions. Additional highland units will include talus/debris/mantling materials at the base of the mountains and landslides.

Crater Materials. For the 1:200K-scale regional maps, we will map craters down to 500 m. For the 1:24K-scale landing site maps, we will map craters down to 50 m.

Anticipated Results: Creating new maps will update original interpretations about the landing sites that were revised after the missions (e.g., initial interpretation of volcanic domes at the Apollo 16 site) **[16]**. While some interpretations of the pre-mission maps won't change, we anticipate the following changes in the new maps including the removal and/or addition of geologic units, and improvement in the location of contacts.

<u>Apollo 15.</u> We will use the LROC WAC high sun and the Clementine UV-VIS color-ratio mosaics to identify the distribution of ejecta from geologically fresh craters and subdivide the mare unit. These two data sets can also be used to define freshly disturbed areas on the massifs. On the new landing site map, we anticipate detailed mapping of Hadley Rille to include outcrops, contact of talus, and boulder tracks **[17]**.

<u>Apollo 16.</u> A 1:200K-scale post-mission map **[18]** will serve as a foundation for our regional map. Several unit boundaries will change to reflect the new understanding of mounds initially interpreted to be volcanic domes that are now interpreted as ejecta deposits from Imbrium basin **[16]** and mapped as 'rugged terra material' on the post-mission geologic map **[18]**.

<u>Apollo 17.</u> The updated regional map covers a smaller area than the original **[6]** regional map and changes several contacts and names of the geologic units. For example, three units (Cd, Imp, Im) in the original map located to the south of the Apollo 17 landing site were mapped as a single unit (Ib2) in **[8]**.

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