COMPLETED DIGITAL RENOVATION OF THE 1:5,000,000 LUNAR GEOLOGIC MAP SERIES. C. M. Fortezzo and T. M. Hare, U.S. Geologic Survey, Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, Arizona (cfortezzo@usgs.gov).

Introduction: In continuing support of a NASA Planetary Geology and Geophysics-funded project to digitize existing 1:5M-scale lunar paper maps, we have renovated the digital versions of all of the 1:5M series geologic maps [1-6]. Because of increasing emphasis on lunar studies from recent orbital data returns, the renovations used new topographic data and image mosaics to adjust the original linework and the map boundary to the current ULCN2005 and the Lunar Reconnaissance Orbiter (LRO) Lunar Orbiter Laser Altimeter (LOLA) control networks [7-8]. The far-side maps [4-6] were digitized to the new bases and are ready for distribution.

These maps are not reinterpretations of the original geologic units or relationships, but a spatial adjustment to make the original work more compatible with current digital datasets. This increased compatibility allows these maps to be compared and utilized with ongoing and future lunar mapping projects. This work does include alterations to the linework and changes to areal extents of some units to better represent the fidelity of data currently available.

Background: The 1:5M near-side map published by [1] was effectively a synthesis of 36 1:1M maps produced from Earth-based telescopic observations and Lunar Orbiter data sets. The purpose of the synthesis was to produce a coherent and consistent near-side time-stratigraphy [1]. The base image for the 1:5M map was generated by the United States Air Force Aeronautical Chart and Information Center (USAF-ACIC) in 1966 in an Orthographic projection. The irregular boundary for the map area follows the boundaries for the 36 1:1M maps and narrows in steps as it approaches the poles.

The near-side map delineated 43 geologic units that are broken down into the following major groupings: dark materials (5 units), circum-basin materials (7 units), crater materials (20 units), and terra plain, plateau, and dome materials (11 units). The units span the pre-Imbrian to the Copernican Systems. The only linear representations on the map are geologic contacts and basin rings. There is no distinction between contact types (e.g., certain, approximate, or concealed) used in the original map.

The lunar north pole map was generated in 1978 and delineated 34 units split into the following groups: crater materials (13), basin materials (9), other terra materials (9), and mare and other dark materials (3). These units span the pre-Nectarian through the Copernican Systems. The linear representations included approximate contacts, crests of buried crater rims, and certain and approximate crests of basin ring structures. The north pole map utilized a Polar Stereographic shaded-relief base map generated by the USAF-ACIC.

The lunar south pole map was generated in 1979 and delineated 37 units split into the following groups: materials of primary impact and their secondary craters (13), basin materials (11), probable basin related materials (8), and mare and other dark materials (5). These units span the pre-Nectarian through the Copernican Systems. The linear representations included certain and queried contacts, crests of buried crater rims, certain and approximate crests of basin ring structures, fissure and narrow fault grabens, sinuous ridges, and sinuous scarps. The south pole map utilized a Polar Stereographic shaded-relief base map generated by the Defense Mapping Agency in 1970. This map included a location near the pole where there was no photographic coverage, thus no units were mapped.

The lunar east side map was generated in 1977 and delineated 30 units split into the following groups: cratered materials (12), basin materials (7), other terra materials (8), and mare and other dark materials (3). These units span the pre-Nectarian through the Copernican Systems. The linear representations included certain and queried contacts, crests of buried crater rims, and crests of basin ring structures. This map also included a bright sinuous markings stipple pattern. The eastern far-side map utilized a Mercator projected shaded-relief base map generated by the Defense Mapping Agency in 1970.

The lunar central far-side map was generated in 1978 and delineated 27 units split into the following groups: crater materials (11), basin materials (7), and other materials (9). These units span the pre-Nectarian through the Copernican Systems. The linear representations included certain contacts, generalized crests of basin ring structures, slopes, and covered crater rim crests. The central far-side map utilized a Mercator projected, shaded-relief base map generated by the Defense Mapping Agency in 1970.

The west side map was generated in 1977 and delineated 22 units that were not split into groups. The units span the pre-Nectarian through the Copernican Systems. The linear representations included certain contacts, mare ridges, rilles, faults, lineaments, large troughs, mare domes, Orientale ring structures, older basin rings, buried crater outlines, and buried Orientale secondary crater outlines. This map also included dark mantling material and blue mare material stipple patterns. The west side map utilized a Mercator projected, shaded-relief base map generated by the Defense Mapping Agency in 1970.

Datasets: Four orbital datasets were used to renovate the lunar near-side map (listed in order of utility): Lunar Orbiter global mosaic (~63 m/pix), Kaguya Digital Terrain Model (~2 km/pix), Clementine UVVIS (100 m/pix), and the Clementine Mineral Ratio (200 m/pix). The Lunar Orbiter global mosaic provides visible imagery of the lunar surface allowing for distinct delineation of the morphologic and geologic relationships. The Kaguya Digital Terrain Model (DTM) provided rough topography allowing for delineation of features that were less prominent in the Lunar Orbiter mosaic. The Clementine UV-VIS provided a tool for identifying the mare geologic units which make up 40% of the total map area [1]. The Clementine Mineral Ratio map was used sparingly but was helpful in some locations where it was necessary to delineate ejecta blankets.

For the polar maps, we used 3 datasets: the LRO LOLA DTM (100 m/pix), Lunar Reconnaissance Orbiter Camera wide-angle camera (WAC) mosaic (100 m/pix), and Lunar Orbiter global mosaic (~63 m/pix).

Methodology: The current renovation of the digital maps adhered to strict guidelines for vector generation and used recent datasets to spatially adjust the location of the geology and linework. This adjustment did not change the original geologic framework but sought to update the locations of the contacts and geology. These adjustments resulted in the omission of some discrete units by connecting areas that were previously mapped as isolated portions and, vice versa, isolated previously grouped units. The sole new addition to the map was the use of both certain and approximate contacts to indicate areas where (1) the geologic relationships were unclear to the digital author and (2) where the datasets did not provide adequate information for the interpretations of the original map.

The data sets discussed above were used in combination with ESRI's ArcMap Geographic Information System (GIS) software, to draw vectors on the Lunar Orbiter global mosaic. The vectors were drawn with a consistent vertex spacing of ~3 km at 1:1.5M scale, and were smoothed using a maximum allowable offset tolerance of ~16 km. The adjustments and adherence to these guidelines resulted in a product that increased the feature location accuracy at the 1:5M scale and makes the product more cartographically appealing.

No nomenclature is included on the map because of the availability of digital nomenclature provided by the U.S. Geological Survey's IAU Gazetteer of Planetary Nomenclature website (planetarynames.wr.usgs.gov). This site allows users of the map to choose which features are displayed digitally and in paper copies they generate.

Results: The renovated geologic maps provide the community with a means to digitally view and analyze the data from the original map. The ability of GIS to analyze data reinvigorates the 30- to 40-year-old products and makes them viable products for a new generation of planetary scientists due to an increasing reliance on digital resources. Additionally, with a new influx of lunar data, it is important to preserve and extend the capabilities of this useful heritage map.

Subtle changes to all the maps improved the location of units, contacts, and structures. For the south pole, the zone of "no-data" has been filled in with interpretations stemming from recent LOLA topographic coverage. This provides an update to the map that may prove helpful given the increased interest in the permanently shadowed craters at the lunar poles.

Future Work: Now that all of the maps are completed, the feasibility of merging the maps will be assessed. We foresee that 3 of the 6 maps will be easily merged with the near-side map being the most difficult due to: (1) it being a compilation of the 1:1M scale maps and telescopic mapping, (2) it's stair step-shaped border, and (3) its significant overlap with four of the adjacent maps. The 2 polar maps are the other areas where overlap may become a significant problem. To begin this process, we will merge the 3 far side maps because their borders abut each other but do not overlap.

Another area of concern is the inconsistency of mapped linear feature types. These mapped features do not appear to follow systematic parameters for uniformity (i.e., map all crater rim crests for crater 10 km in diameter and younger than Imbrian). This will require further study to determine best practices.

References: [1] Wilhelms, D.E. and J.F. MacCauley (1971) *Map I-703*. [2] Wilhelms, D.E., et al. (1979) *Map I-1162*. [3] Lucchitta, B.K. (1978) *Map I-1062*. [4] Wilhelms, D.E. and F. El-Baz (1977) *Map I-948.* [5] Stuart-Alexander, D.E. (1978) *Map I-1047.* [6] Scott, D.H. et al. (1977) *Map I-1034.* [7] Archinal, B. et al. (2006), *Open-File Report 2006-1367*. [8] Smith, D. E. et al, (2008) NASA Goddard Space Flight Center.