

LUNAR GEOLOGIC MAPPING PROGRAM: 2008 UPDATE. L. Gaddis¹, K. Tanaka¹, J. Skinner¹, and B.R. Hawke², ¹U.S. Geological Survey, Astrogeology Program, 2255 N. Gemini Drive, Flagstaff, AZ (lgaddis@usgs.gov); ²PGD/SOEST, Univ. Hawaii, Honolulu, HI.

Introduction: The NASA Lunar Geologic Mapping Program is underway and a mappers' handbook is in preparation. This program for systematic, global lunar geologic mapping at 1:2.5M scale incorporates digital, multi-scale data from a wide variety of sources. Many of these datasets have been tied to the new Unified Lunar Control Network 2005 [1] and are available online. This presentation summarizes the current status of this mapping program, the datasets now available, and how they might be used for mapping on the Moon.

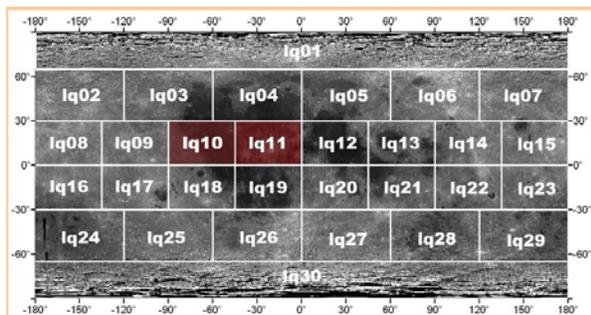


Figure 1. Mapping quad scheme for lunar geologic maps at 1:2.5 M scale. Image base is Clementine 750-nm albedo. Quads lq10 and lq11 have been assigned to mappers.

Background: The primary image bases for early lunar geologic mapping were photographic prints (~400 to 2 m ground resolution) from the five Lunar Orbiter (LO) missions in 1966 and 1967 [2-4]. Forty-four geologic maps at 1:1 M scale were made using the LO data, followed by 1:5 M near side, north, south, east, west and central far side geologic maps [5-10]. These maps were based upon the foundation established by Shoemaker and Hackman [11], who applied well established stratigraphic methods to map materials observed in and near Copernicus crater (~90 km dia.). This new mapping program builds further on this foundation by incorporating new digital datasets and mapping methods that enable far more detailed identification and mapping of geologic units on the Moon.

Mapping Status: Two quadrangles have thus far been assigned (Figure 1) and several more have been proposed to NASA. Quad lq11 was the first in this series, centers on Copernicus crater, and is now in draft form in preparation for

review [12]. Quad lq10 was assigned recently and is now in the early stages of development [13].

Digital Image Bases: Following the early spacecraft observations of the Moon in the 1960s and 70s, a second era of global observation began in the 1990s. The global color, elemental abundance, and topographic datasets from these missions (including Galileo, Clementine, and Lunar Prospector or LP) have led to the development of a newer generation of digital data products that are tied to an updated global geodetic control network [14, 15]. Two major projects to scan and process photographic data from Lunar Orbiter [16] and Apollo [17] missions have produced digital products that can be analyzed in the context of the new generation of global datasets. Further, the LO and Apollo metric and panoramic digital data can be used to make controlled, high-resolution digital terrain models (DTMs) and image mosaics that will be useful for both local and regional scale mapping. When used with data from the next generation of lunar observing instruments [including the micro-Imager (AMIE) from SMART-1, Europe; Lunar Imager/Spectrometer from Kaguya (SELENE), Japan; the Stereo Camera and Laser Altimeter from Chang'e-1, China; the Terrain Mapping Camera, Hyperspectral Imager, and Moon Mineralogy Mapper from Chandrayaan-1, India; and the camera and laser altimeter from Lunar Reconnaissance Orbiter, United States] the collection of digital image data for the Moon will soon exceed the volume of data for all previous lunar and planetary missions combined. Effective use of these data for lunar geologic mapping will require (a) creation of cartographic mapping products that can readily be integrated, (b) advances in storage, manipulation, and analysis of high-volume, multidimensional data, and (c) expertise in use of advanced methods of data interpretation and digital mapping.

Many of the available digital lunar image bases are described on the Lunar Geologic Mapping site (see <http://astrogeology.usgs.gov/Projects/PlanetaryMapping/Lunar/>) and are available on the PDS

Map-a-Planet site (<http://www.mapaplanet.org/explorer/moon.html>) and/or the USGS 'Planetary Interactive GIS on the Web Interactive Analyzable Database' (PIGWAD) site (<http://webgis.wr.usgs.gov/>). Primary image bases for lunar geologic mapping are the global Clementine mosaic of "albedo" at 750-nm [18] and the highly complementary Lunar Orbiter mosaic [16]. Additional mapping layers include the global Clementine multispectral mosaic (available at 100 m/pixel for five ultraviolet-visible or UVVIS wavelengths [19]: 415, 750, 900, 950, and 1000 nm; and six near-infrared or NIR wavelengths [20]: 1100, 1250, 1500, 2000, 2600, and 2780 nm) and Clementine topography and shaded relief data [21]. Derived maps of Clementine 'standard' color-ratio (e.g., R=750/415; G=750/950; B=415/750), optical maturity, FeO, and TiO₂ content [22-25], 'rock types' [26], and LP measured elemental abundance maps [27-32] are also available at these sites. An alternative method for deriving FeO content and removing the effects of maturity differences among lunar soils [33] is also available for application to the Clementine 11-band data and for comparison to other methods. Use of these digital data and derived products support image manipulation and enhancement, and further derivation of products such as spectral band-depth maps, slope and image texture maps, density-sliced albedo and color, as well as other 2- and 3-D analyses and visualizations for geologic mapping. Derived maps of optical maturity of lunar soils have been used to refine stratigraphic assignment of several impact craters in the Copernicus quadrangle (lq11; [34]) and will be very helpful in modifying the lunar stratigraphic column [35, 36] as needed based on new mapping.

In recognition of the extreme importance of coregistered image products for geologic mapping, mosaics of Clementine UVVIS and NIR data and derived products, as well as the global mosaic from Lunar Orbiter, have been warped to the latest lunar control network [1, 14, 15] and are online at the PIGWAD site. Reconstruction of the Clementine 750-nm map mosaic using the 2005 lunar control network is now underway at USGS [37] and is expected to result in a more spatially accurate product than the warped version. Construction of the other Clementine

UVVIS and NIR bands is not currently planned but is being considered at USGS and elsewhere. Further improvements of the lunar control network are underway and can be applied directly to these products when available.

Summary: The Lunar Geologic Mapping Program is continuing to progress and to make use of the new lunar data that have recently and will soon become available. We are working with the Lunar Geodesy and Cartography working Group [38] to ensure that these data will be useful for geologic mapping applications. Proposals for participation in this mapping program can be submitted to the NASA Planetary Geology and Geophysics Program science research opportunity that is included in the annual NASA Research Opportunities in Space and Earth Sciences (ROSES) announcement on the NSPIRES web site (see <http://nspires.nasaprs.com/external/>).

References: [1] Archinal et al., 2006, USGS OFR 2006-1367. [2] Hansen, 1970, NASA SP-242. [3] Kosofsky and El-baz, 1970, NASA SP-200. [4] Bowker and Hughes, 1971, NASA SP-206. [5] Wilhelms and McCauley, 1971, USGS I-703. [6] Lucchitta, 1978, USGS I-1062. [7] Wilhelms et al., 1979, USGS I-1162. [8] Wilhelms and El-baz, 1977, USGS I-946. [9] Scott et al., 1977, USGS I-1034. [10] Stuart-Alexander, 1978, USGS I-1047. [11] Shoemaker and Hackman, 1962, Symp. 14 IAU, 289-300. [12] Gaddis et al., 2006, LPS XXXVII, #2135. [13] Gregg, Tracy, Pers. Comm. [14] Archinal et al., 2008, LPS XXXIX, #2245. [15] Hare et al., 2008, LPS XXXIX, #2337. [16] Becker et al., 2008, LPS XXXIX, #2357. [17] Apollo Image Archive, see <http://apollo.sese.asu.edu/index.html>. [18] Eliason et al., 1999, LPS XXX, #1933. [19] Eliason et al., 1999, Clementine UVVIS Mosaic, PDF Volumes USA_NASA_CL_4001-4078. [20] Gaddis et al., 2008 (in review), The Clementine NIR Global Lunar Mosaic, PDS Volumes USA_NASA_PDS_CL_5001 through 5078. [21] Rosiek et al., 2002, LPS XXXIII, #1792. [22] Lucey et al., 1995, Science 268, 1150. [23] Lucey et al., 1998, JGR 103, 3679-3699. [24] Lucey et al., 2000a, JGR 105, 20,297-20,305. [25] Lucey et al., 2000b, JGR 105, 20,377-20,386. [26] Pieters et al., 2001, JGRP, 106, 28001. [27] Lawrence et al., 2002, JGR 107, 2001JE001530, 13-1 to 13-26. [28] Elphic et al., 2000, JGR 105, 20,333-20,346. [29] Gillis et al., 2003, JGR 108, 3-1 to 3-18. [30] Lawrence et al., 2000, JGR 105, 20,307-20,332. [31] Prettyman et al., 2002a, LPS XXX, #2012. [32] Feldman et al., 2002, JGR 107, E3. [33] Le-Mouelic et al., 2000, JGRP, 105, 9445. [34] Hawke et al., LPS XXXIX, #1902. [35] Wilhelms, 1987, USGS Prof. Paper 1348, 302 pp. [36] Hiesinger et al., 2003, JGR, 108, doi:10.1029/2002JE001985. [37] Lee, E.M., Pers. Comm. [38] Archinal et al., 2008, submitted to the First Lunar Science Conference.