MAPPING LUNAR MARIA EXTENTS AND LOBATE SCARPS USING LROC IMAGE PRODUCTS.

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Introduction: Controlled images and mosaics from the Lunar Reconnaissance Orbiter Camera (LROC) enable more precise demarcation of lunar mare boundaries than with previous datasets. The LROC team digitized mare boundaries, calculated individual areas and perimeters, and generated a Geographic Information Systems (GIS) database of these geologic features. Our new products are two digital shapefiles derived from LROC Wide Angle Camera (WAC) [1] and Clementine image data [2]. High-resolution LROC Narrow Angle Camera (NAC) [1] images were used to identify lobate scarp features. The mare shapefile covers the Moon from 64.7°N to 66.5°S and the lobate scarp map covers the entire lunar surface.

Mare Boundary Mapping: Our team used ArcGIS for digital mapping following USGS guidelines [3]. Extensive mare units were found across the globe, primarily in and around near side impact basins, and also in far side locations such as the Aitken Basin. Mapping was done to identify the geographic extend of the mare and to calculate the surface area of each feature. The LROC mappers used three global basemaps in their investigation: 1) a 100 m/pixel LROC WAC monochrome (643 nm) mosaic [5], with an average solar incidence of 60° (from surface normal), 2) a 400 m/pixel image mosaic generated from a ratio of LROC WAC 321nm and 415nm bands that shows variations in titanium abundance [5, 6], and 3) a 1 km/pixel Clementine UVVIS color ratio (Red: 750/415, Green: 750/950, Blue: 415/750) mineral map [7]. They also used historic global geologic maps, 1:5M scale [8-13], for supplemental reference.

Basemaps were set to equirectangular projection for the equatorial regions. Datasets were stacked in layers to enable our mappers to "blink" between them for more precise contact demarcation.

Mare boundaries were mapped by zooming in to the resolution of the basemaps where features could be distinguished within a few pixels. Where boundaries could not be easily identified by any of the datasets, boundaries were digitized as straight lines to approximate contacts. Geologic boundaries in maria were identified by spectral differences (basaltic flows and impact ejecta), at breaks in slopes along basin margins, where mare materials embayed interior basin materials and crater rims, and around topographic features that stick up through mare material ("kipukas").

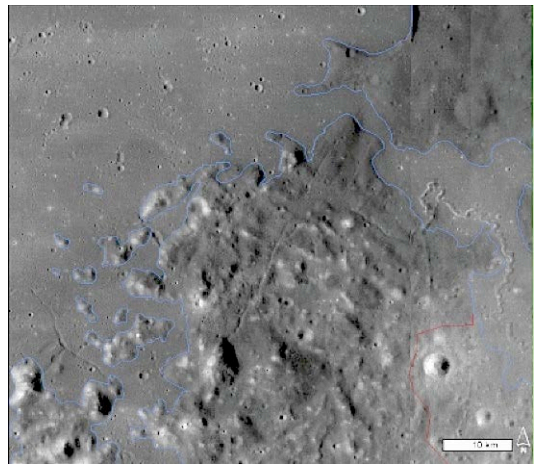

Fig. 1. Mare contact (blue) outlines the highland area and kipukas. Fig. 3 shows the approximate location of this figure.

Mapping of Lobate Scarps: Lunar lobate scarps are relatively small-scale tectonic landforms [14] that are interpreted to be the surface expression of low angle thrust faults [15]. We digitized these structures as polylines. Digitization was completed on a 100m/pixel LROC WAC monochrome (643 nm) mosaic supplemented with, where available, NAC images that have resolutions of up to 0.5 m/pixel. NAC images with incidence angles between 50° and 80° were optimum for identifying and digitizing the lobate scarps. Polylines were digitized at a scale of up to 1:20,000 in an equirectangular projection in equatorial regions (60°N and 60°S), and polar stereo graphic for the regions poleward of 60° latitude.

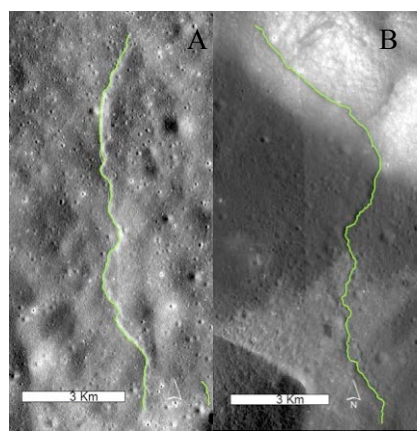

Fig. 2. A) Digitized scarp in highlands centered at 6.8°N, 161°E. **B)** Digitized scarp crossing the transition from mare to highlands at 20.3°N, 30.6°E. The green lines are the digitized features along the scarp face.

Lobate scarps were digitized at the base of the scarp face. Lobate scarps often are associated with complexes or clusters consisting of a large number of

individual scarps [16]. We digitized the largest scarps in the area to capture the orientation. The smallest digitized segment in length was ~300 m.

Map Product: From our mare database we calculated preliminary area statistics, including: total mare 6,151,200 sq km (16.2% lunar surface area), near-side mare 5,713,200 sq km (15.1% lunar surface area), and far-side mare 438,100 sq km (1.2% lunar surface area). Version 1.0 of the mare boundary map and lobate scarps was released to the PDS on 14 Dec 2013 as an archived ESRI shapefile [17]. Future work for the mare boundary map will include the subdivision of mare into component flows and compositional units as well as adding the work area to the poles.

References: [1] Robinson et al. (2010) *Space Sci. Rev., 150,* 81–124. [2] Eliason et al. (1999) *Mission to the Moon*, The Clementine UVVIS Global Mosaic, PDS CL_4001-4078. [3] USGS/Tanaka 2010: http://astrogeology/usgs.gov/PlanetaryMapping/guidelines/PGM_Handbook_2010.pdf. [4] Wilhelms (1987) *Geol. Hist. of the Moon*, US Govt. Press. [5] Robinson et al. (2012) *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XXXIX-B4, 501-504. [6] Robinson (2007) *Geophys Res. Lett., 34, L13203*, pp.4. [7] McEwen et al. (1999) *Science, 266*, pp.1858-1861. [8] Wilhelms and McCauley (1971) *Map I-703*. [9] Wilhelms et al. (1979) *Map I-1162*. [10] Lucchitta (1978) *Map I-1062*. [11] Wilhelms and El-Baz (1977) *Map I-948*. [12] Stuart-Alexander (1978) *Map I-1047*. [13] Scott et al. (1977) *Map I-1034*. [14] Watters T. R. et al. (2010) *Science, 329,* 936-940. [15] Binder A.B. and Gunga, H.C. (1985) *Icarus, 63,*421-441.[16] M.E. Banks, et al. (2012), *Journal of Geophysical Research: Planets, 117, E12.[17]* ESRI: http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf

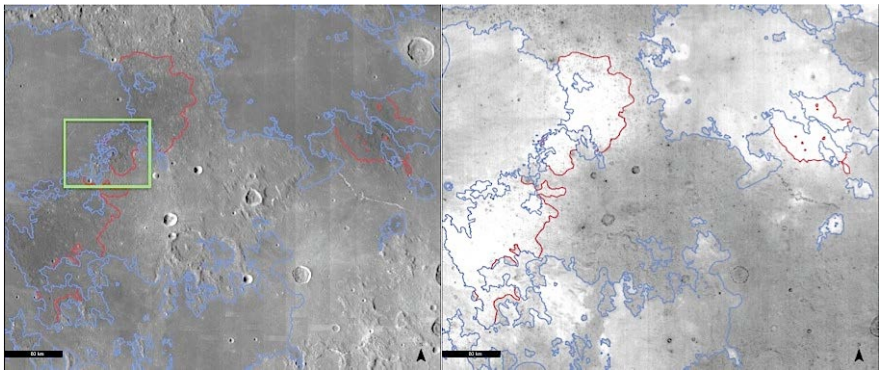

Fig. 3. Mare boundaries outlined in blue and red lines outline areas with pyroclastic material contain a high abundance of Ti A) WAC morphology basemap. B) WAC color titanium abundance map [4]. The green box outlines the approximate location of Fig. 1, while Fig. 4 outlines the approximate location of the two datasets.

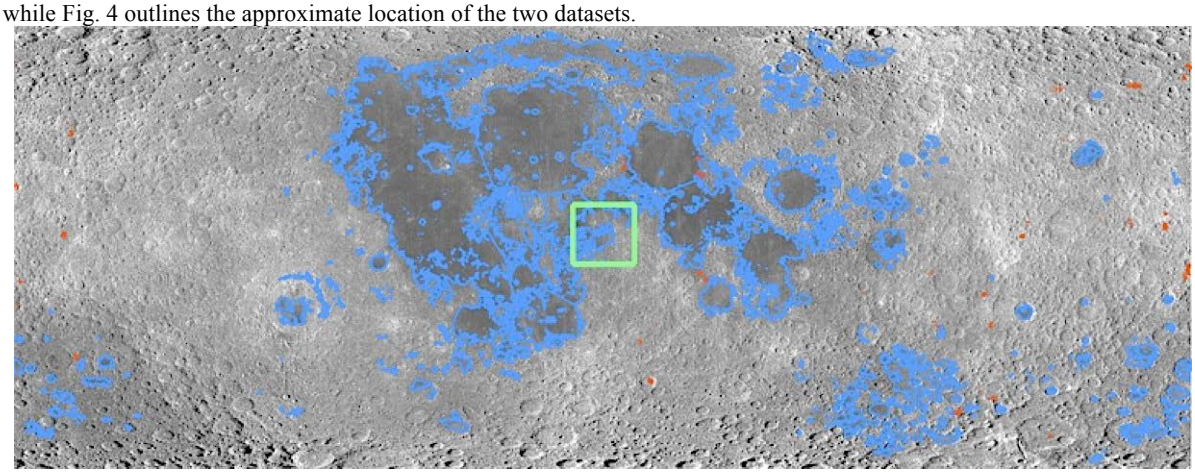

Fig. 4. WAC morphology basemap (~70°N to ~70°S) with. Mare area mapped includes all longitudes between 64.7°N to 66.5°S. The red lines denotes the lobate scraps. The green box outlines the approximate location of Fig. 3.