MAPPING LOBATE SCARPS ON THE MOON. D. M. Nelson[1], T. R. Watters[2], M. E. Banks[2], M. S. Robinson[1], N. R. Williams[1], K. Daud[2], W. A. von Dassow[2,3]. [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281 (nelson99@ser.asu.edu), [2]Center for Earth and Planetary Studies, Smithsonian Institution, Washington, DC, 20560, [3]Dept. Geology and Environmental Geosciences, Lafayette College, Easton, PA 18042.

Introduction: High resolution Lunar Reconnaissance Orbiter Camera (LROC) images reveal a globally distributed population of lobate scarps—small, curvilinear, contractional structures [1,2,3]. We are digitizing these scarps, recording their locations and lengths and generating a Geographic Information Systems (GIS) database allowing a detailed investigation of their spatial distribution. Prior to the Lunar Reconnaissance Orbiter (LRO) mission, mapping of the lobate scarp population was limited to a subset of Apollo Panoramic Camera images with optimum solar incidence angles, which covered less than 10% of the lunar surface [4,5,6] and was confined to within approximately 21° of latitude from the equator [7]. Because of the polar orbit of LRO, LROC can image any illuminated portion of the Moon enabling the global mapping of these and other small-scale landforms at optimal incidence angles.

LRO entered lunar orbit in June 2009 and began a multi-year collection of image data. LROC consists of three cameras, including two panchromatic Narrow Angle Cameras (NAC) and a single UVVIS Wide Angle Camera (WAC), that are capable of acquiring 0.5 m/pixel and 100 m/pixel images, respectively, from a nominal altitude of 50 km [8]. As of January 2013, LROC has collected over 686,000 high-resolution NAC images (those with no data quality problems and with solar incidences <88.5° and slew angles <65° from normal). Approximately 63% of these images are favorable for identifying lobate scarps—where the solar incidence is between 50° and 85°.

Lobate Scarps: Lobate scarps are interpreted to be shallow thrust faults [7,9] with relatively low angle scarp faces (~5° to <30°) [2,3]. Elevation measurements of lobate scarps using Lunar Orbiter Laser Altimeter (LOLA) data and 5 NAC stereo-derived digitial terrain models DTMs indicated a mean relief of ~35 m, with a range from ~5 m to 150 m (n=26), and lengths of ~0.6 to 21.6 km (n=79) [3]. These landforms occur as single isolated structures, discontinuous chains, or subparallel en echelon clusters [Figs. 1, 2]. Lobate scarps are found in lunar mare, often associated with wrinkle ridges, but are more commonly found in the highlands [2,4,7,9] and are the most prevalent tectonic features on the lunar farside [2]. Cross-cutting of small impact craters (<50 m diameter) and relative crisp appearance of the landforms indicate that lobate scarps are relatively young (<few hundred Ma [2,7,10]).

Mapping Lunar Features: Apollo Panoramic images revealed 67 lobate scarps; the lengths of each were measured but the relief for only 9 scarps could be estimated by shadow measurements [1,7,9] in the Apollo era datasets. With the new LRO imaging and topography, our goal is to identify and map all lobate scarps to determine their global spatial distribution, morphometric parameters, and orientation patterns. In ongoing surveys, individual lobate scarps and scarp clusters in well over 150 different locations, and candidate scarps (landforms tentatively identified as scarps) in over 350 additional locations have been discovered. These scarp locations are being used as the basis of our mapping campaign.

We perform our mapping in ArcGIS following the guidelines established by the USGS [11], using image data of a consistent resolution and delineating features at a scale appropriate to that resolution. A WAC monochrome (643 nm) mosaic serves as the global basemap. This mosaic was derived from over 15,000 images acquired under similar lighting conditions [12], sampled to 100 m/pix, and registered to the GLD100 lunar shape model [13]. An equirectangular projection of the mosaic is used for mapping between 60°N to 60°S and polar stereographic projections are used for latitudes above 60°N, S. At the resolution of the WAC mosaic it is possible to see some of the more prominent lobate scarps, but the majority of lobate scarps are not resolved at that scale. For more positive identification, tens of thousands of NAC images have been visually scanned. The NACs used for mapping were selected based on three criteria. First, a portion of the image must fall within 50 km of an identified site. Second, each image must have been acquired with a solar incidence between 40° and 85° for up to latitudes 75° N or S; for poleward of 75°, incidences up to 88.5° needed to be included. Third, to minimize projection distortion, no images taken during slews >30° have been used. Once selected, NACs are calibrated, projected, and downsampled to 10m/pix,to accommodate image file size (~250MB each) while maintaining sufficient resolution to allow lobate scarp identification. During digitizing, images are visually scanned at scales of 1:75 k to 1:100 k to identify features and all mapping is done at 1:50 k in order to represent the features at a reasonable level of detail. Thus far, over 1350 individual lobate scarps and over 1100 candidate scarps have been mapped.

Intended Use Of Products: Maps of the digitized lobate scarps are carefully reviewed and often include reexamination of scarps using full-resolution NACs images. The reviewed tectonic map will be released to the PDS as an archived ESRI shapefile [14], which will include the lengths for each scarp. The global map of lobate scarps will be used to determine if there are patterns in the spatial distribution (i.e., uniform or non-uniform) of the scarps and orientation data will provide insight into the origin and evolution of late-stage compressional stresses. Continued detection of previously unknown lobate scarps will also allow researchers to refine estimates of the age of this population of young tectonic landforms.

References: [1] Watters T.R and Johnson C.L. (2010) *Planetary Tectonics*, Cambridge Univ Press, NY. [2] Watters T.R. et al. (2010) *Science, 329*, 936-940. [3] Banks M.E. et al (2012) *JGR, 117*, E00H11. [4] Schultz P.H. (1976) *Moon Morphology,* Austin TX. [5] Mattingly T.K. et al. (1972) *NASA Spec. Publ., SP-315*, 28-1. [6] Masursky H. (1978) *NASA Spec. Publ., SP-362*, 255. [7] Binder A.B. and Gunga H.-C. (1985) *Icarus, 63*, 421. [8] Robinson M. S. et al. (2010) *Space Sci. Rev., 150,* 81–124. [9] Binder A.B. (1982) Earth Moon Planets, 26, 117-133. [10] Bogert C.H. et al. (2012) *LPSC XLIII*, Abstract #1847. [11] USGS/Tanaka 2010: http://astrogeology/usgs.gov/PlanetaryMapping/guidelines/PGM_Handbook_2010.pdf [12] Robinson et al. (2012) Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XXXIX-B4, 501-504. [13]Scholten F. (2012) *JGR, 117*, E00H17. [14] ESRI: http://www.esri.com/library/whitepapers/pdfs/shapefile.pdf

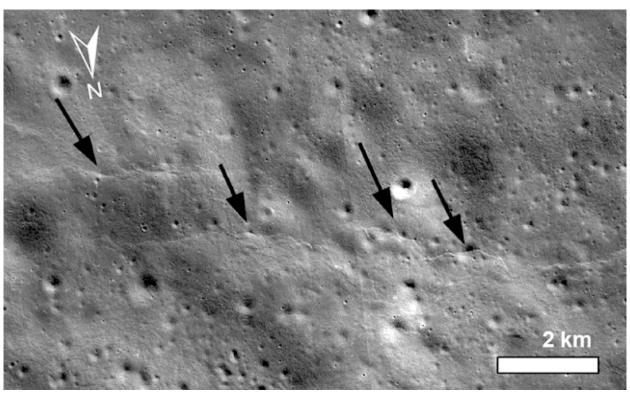

Figure 1. En echelon lobate scarps, centered at 60.5°N, 172.8°W (NAC: M105649747L/R). Sun is to the right of top. Arrows indicate craters buried or deformed by formation of fault scarps.

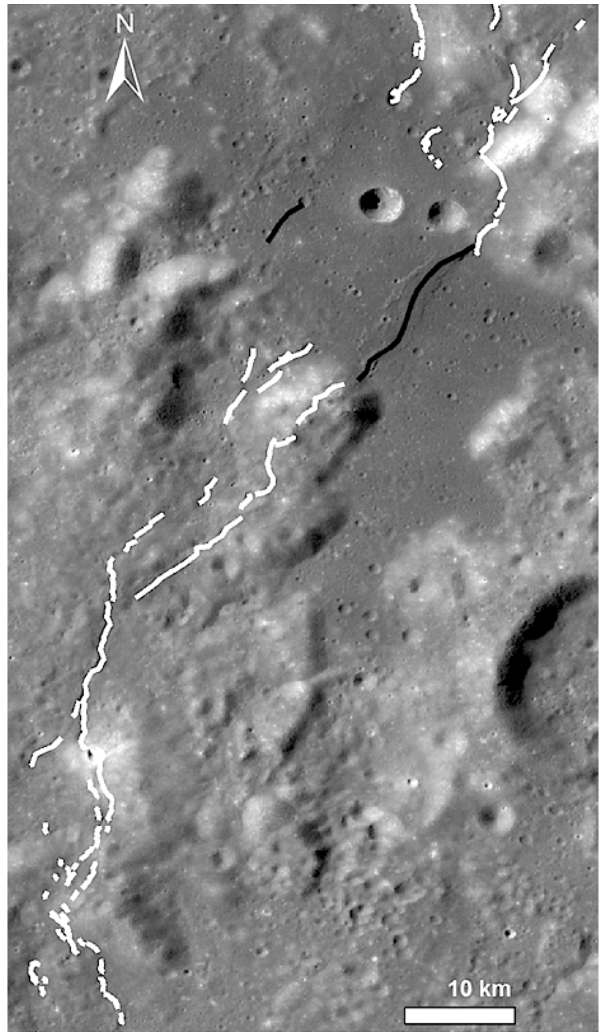

Figure 2. Chains of lobate scarps (white segments) in the highlands transition into a wrinkle ridge in a patch of mare basalts south of Mare Humorum (black segments), and back into highlands as lobate scarps. This assemblage of contractional tectonic landforms indicate different responses of the deformed materials to compressional stresses. Image centered at 37.5°S, 146.1°W (WAC image mosaic).