MORPHOLOGICAL ANALYSIS OF LUNAR LOBATE SCARPS USING LROC NAC AND LOLA DATA: PRELIMINARY RESULTS. M. E. Banks[1], T. R. Watters[1], M. R. Robinson[2], L. L. Tornabene[1], and the LROC team [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, USA (banksme@si.edu), [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85251, USA.

Introduction: Lobate scarps on the moon are relatively small-scale tectonic landforms that are observed in mare basalts and more commonly, in the highlands [1]. They are interpreted to be the surface expression of low-angle thrust faults and are the dominant tectonic landform on the lunar farside [1-4]. Prior to Lunar Reconnaissance Orbiter (LRO), lobate scarps were only confidently detected in equatorial regions in Apollo Panoramic Camera and the highest resolution Lunar Orbiter images [1-3]. Lunar Reconnaissance Orbiter Camera (LROC) images and Lunar Orbiter Laser Altimeter (LOLA) ranging enable detection and detailed morphological analysis of the lobate scarps at all latitudes.

Previous measurements of maximum relief for lobate scarps were primarily determined from shadow measurements for a limited number of low-latitude scarps (<±20°), and ranged from ~6 to 80 m, with a mean maximum relief of ~32 m (n = 9) [1]. Outstanding questions include what is the range of maximum relief of lunar lobate scarps and what is the contractional strain expressed by the faults. In this study, we use LROC stereo-derived digital terrain models (DTMs) and LOLA data to measure the relief of several previously known and newly detected low and high latitude lobate scarps.

Data and Methods: LROC consists of a Wide Angle Camera (WAC) which provides global imaging at a scale of 100 m/pixel in seven color bands, and two Narrow Angle Cameras (NACs) which provide 0.5-2 meter-scale panchromatic images over a combined 5-km swath [5]. To date, previously undetected scarps have been identified in LROC images and mosaics in 73 different locations, over 20 of which occur at latitudes greater than ±60°, and appear to be globally distributed [6]. Four DTMs derived from LROC NAC stereo pairs were analyzed to obtain measurements of maximum relief for 5 lobate scarps (Fig 1).

The LOLA instrument transmits 5 beams, each illuminating a 5 m spot from a 50 km altitude orbit. Five parallel profiles, ~12 m apart, are created with individual observations separated by ~56 m along each profile [7]. LOLA ranging has a vertical precision of up to ±0.1 m. Because of LRO's polar orbit, only primarily E-W trending scarps with sufficient NAC coverage and available LOLA profiles were examined. Data points were acquired using Orbiter Data Explorer [http://ode.rsl.wustl.edu/], plotted, and detrended. Multiple LOLA profiles were analyzed to measure the relief in several locations along 18 scarps where the profiles traverse the scarps at orthogonal or near to orthogonal angles (Fig 2). Here we report the greatest measured relief, although not necessarily the maximum relief as the LOLA data is discontinuous, for each of these scarps.

Results: Relief was measured using LOLA data and LROC NAC DTMs for a total of 23 lobate scarps ranging in latitude from ~74°S to 88°N and occurring on both the near and far sides of the Moon. Six of the scarps were previously known and 17 are newly detected in LROC imagery. The measured relief of the scarps analyzed in this study ranges from ~4 to 130 m with a mean relief of ~25 m (Fig 3); the mean relief will likely increase as more LOLA data and DTMs become available and the maximum relief for each scarp can be determined. All but three of the scarps measured so far have a relief of less than 41 m. While the two scarps with the largest measured relief (Lee-Lincoln and Montes Riphaeus) are located near the equator (<±20°), scarps with a relief up to ~20 m are observed at nearly all latitudes (Fig 3B). The current data indicate that the lobate scarps as a whole typically exhibit tens of meters of relief, and are consistently smaller than those observed on Mercury [8-11] and Mars [12], some of which have measured reliefs of over 1 km.

Like planetary lobate scarps, the lunar examples analyzed in this study typically have an asymmetric profile with a relatively steeply sloping scarp face and more gently sloping back scarp [1, 13] (Fig 1 and 2). Many of the profiles show a reversal in slope at the base of the scarp face (Fig 2). For scarps located on slopes, the vergent side of the fault is commonly oriented up slope (Fig 1). The maximum measured slopes of the scarp faces range from ~4°-16°, which is very similar to the range determined for moderate-scale martian lobate scarps (~3°-9°) [13].

Future Work: Measurements of the maximum relief of the lobate scarps provide a means to estimate the displacement-length (D-L) relation of the thrust faults and estimate strain and global radial contractional. Estimates of the D-L ratio also provide insight into the friction on the faults and the mechanical properties of the crust. The maximum displacement D on a fault scales with the planimetric length L of the fault [e.g. 14, 15] such that $D = \gamma L$, where the ratio γ is

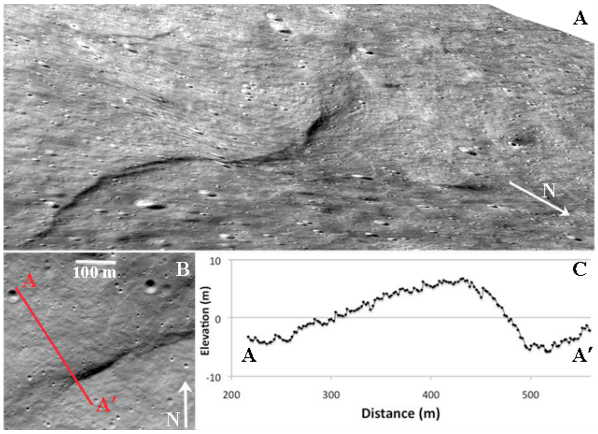

Figure 1: A: Perspective view from a LROC NAC DTM of lobate scarp Simpelius-1 (~73.56°S, 13.04°E) located on the wall of Simpelus crater (vertical exaggeration is 4:1). The vergent side of the scarp is oriented up slope. The DTM has a spatial resolution of 2 m/pixel. Elevations are referenced to a sphere of 1,737,400 m. The length of the scarp in this image is ~1 km. B: Location of the profile in C (red line). LROC NAC frame M139804021LE. C: Detrended profile derived from the DTM. The maximum relief of this scarp is 12.5 m.

constant determined by rock type and tectonic setting [16-18]. Estimates of γ previously reported for the scarps range from ~1.5 x 10^{-2} to ~1.1 x 10^{-2} [1]. With continued LROC NAC and LOLA coverage of the Moon, it will be possible to more accurately determine the maximum relief of many lunar scarps and greatly improve the value of γ for the faults.

Summary: Preliminary results indicate that the relief of high latitude lunar lobate scarps generally falls within the range of relief reported for previously known lower latitude lobate scarps. Lunar lobate scarps as a whole are similar to planetary lobate scarps in their characteristic asymmetric profiles and maximum scarp face slopes [1, 13] but are consistently smaller in scale (tens of meters versus hundreds of meters of relief) [8-12]. The data acquired in this ongoing study will place bounds on the amount of contractional strain and global radial contraction, and provide insight into the mechanical properties of the lunar regolith and lithosphere.

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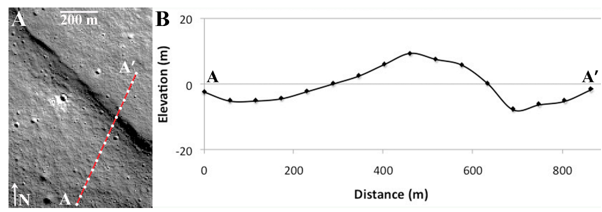

Figure 2: A: Location of a LOLA track (red line) where it traverses the lobate scarp Rozhdestvenskiy-1 (~87.5°N, 212.4°E). LROC NAC image M107957296RE. B: Detrended LOLA profile. The relief of the scarp measured from this profile is ~15 m.

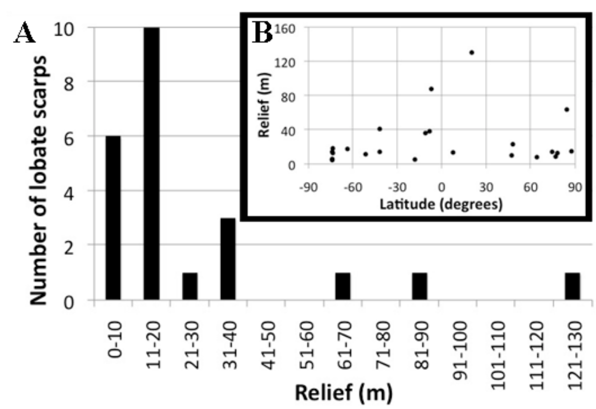

Figure 3: A: Histogram showing the distribution of measured lobate scarp relief. B: Distribution of lobate scarp relief by latitude.