THE SEARCH FOR LUNAR LOBATE SCARPS USING IMAGES FROM THE LUNAR RECONNAISSANCE ORBITER CAMERA. M. E. Banks[1], T. R. Watters[1], M. S. Robinson[2], J. F. Bell III[2,3], M. E. Pritchard[4], N. R. Williams[4], K. Daud[1,5], 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, [3]Department of Astronomy, Cornell University, Ithaca, NY 14853, USA, [4]Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853 USA [5]Department of Geography and Geosciences, Bloomsburg University, Bloomsburg, PA 17815, USA.

Introduction: Lobate scarps are believed to be among the youngest tectonic landforms on the lunar surface [1-3], and are interpreted to be the surface expression of low-angle thrust faults [2-5]. Other tectonic landforms such as contractional wrinkle ridges and extensional rilles or graben, are directly associated with mare basins [5-6]. Lobate scarps are observed in both mare basalts and highlands, but most often occur in the highlands and are the dominant tectonic landform on the lunar farside [5]. Prior to Lunar Reconnaissance Orbiter (LRO), less than ~10% of the lunar surface had been imaged at a resolution and with illumination conditions appropriate for detecting relatively small-scale landforms. Lunar lobate scarps, typically only tens of meters in relief, were only easily detected in Apollo Panoramic Camera and the highest resolution Lunar Orbiter images which were primarily restricted to the equatorial regions of the Moon [2, 4-5]. As a result, the global spatial distribution of the lobate scarps could not be determined.

High resolution images from the Lunar Reconnaissance Orbiter Camera (LROC), enable a close-up view of the lunar surface at all latitudes [7]. The purpose of this study is to use high resolution imagery to target known lobate scarps to gain a better understanding of their characteristics and morphology, and to conduct a global search for previously undetected lobate scarps to determine both their spatial distribution and the distribution of their orientations. The results of this study will place bounds on the contractional strain and global radial contraction expressed by these landforms and provide insight into the mechanical properties of the lunar regolith and lithosphere, and into the Moon's tectonic and thermal evolution.

Data and methods: The search for previously undetected lobate scarps was conducted using images from LROC. 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 [7]. Detection of low relief features is optimized with NAC images with incidence angles between 50-85°. To date, WAC mosaics covering the entire lunar surface and over 70,000 NAC images have been analyzed for evidence of lobate scarps.

Results: To date, previously undetected lobate scarps and scarp clusters have been identified in NAC and WAC images and mosaics in 73 different locations (Fig. 1). These newly detected lobate scarps are observed on both near and far sides of the Moon, and at latitudes ranging from the equator to ±86°. Over 20 of these scarps are located at latitudes greater than ±60°. Many of the newly detected scarps occur in highland material and many are seen to crosscut walls and floors of impact craters. The distribution of lobate scarps at low to high lunar latitudes and on both the nearside and farside, suggests that thrust faults are globally distributed [1].

Like the previously known scarps, many of the newly detected scarps appear as individual landforms or as a series of en echelon stepping scarp segments, while others occur as scarp complexes or clusters consisting of a number of individual scarps [2, 5]. One such newly identified, high latitude scarp cluster is located on the floor of Schwarzschild (~71.9° N, 120.8° E), a ~200 km diameter crater (Fig. 2). This cluster contains at least 9 scarps and spans over 700 km^2; the full extent of Schwarzschild is not known as it has not yet been completely covered by NAC images. Scarps within the cluster have orientations that vary from E/W to NE/SW and N/S. The vergent sides of nearby fault segments sometimes reverse directions and are often oriented up-slope (Fig. 2). At least one scarp segment exhibits multiple terraces suggestive of imbricate thrust faulting [1,5] (Fig 3). Continued NAC imaging will provide a better understanding of the full extent of these clusters and may reveal that some currently identified individual scarps, may be members of scarp clusters.

Using data from the Lunar Orbiter Laser Altimeter (LOLA) and LROC NAC digital terrain models, preliminary results indicate that the newly detected high latitude lobate scarps and the previously known lower latitude scarps, have a range of relief of ~4 to 130 m and an average relief of ~25 m (n = 23) [8]. This value is much smaller than that found for lobate scarps observed on Mercury [9-12] and Mars [13], some of which have measured reliefs of over 1 km.

The newly detected lobate scarps, like those previously known, appear to be relatively undegraded. They crosscut small-scale features on the surface such as meter-scale craters, and lack superposed 100 meter-scale or larger diameter craters. These characteristics suggest that lobate scarps are relatively fresh or young in age, less than 1 Ga [1-5].

Summary: Seventy three previously undetected lobate scarps and scarp clusters have been identified in LROC NAC and WAC images and mosaics. Lobate scarps are located at low to high lunar latitudes and on both the nearside and farside, suggesting a global distribution. The newly detected lobate scarps, like those previously known, typically have tens of meters of relief, crosscut meter-scale impact craters, and have a relatively undegraded appearance suggesting they are relatively young in age. The small amount of contraction expressed by the lunar lobate scarps, along with their apparent young age and global distribution, supports thermal history models for an initially hot exterior that predict a relatively small amount of radial contraction in the last 3.8 Ga [1, 14-15]. The complete population of lunar lobate scarps will be determined from a continuing global survey of LROC images obtained over the life of the LRO mission.

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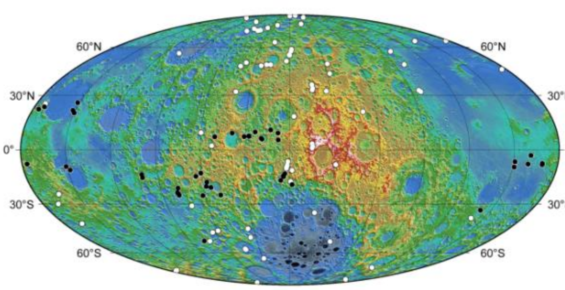

Figure 1: Map showing the locations of previously known (black dots) and newly detected (white dots) lobate scarps. The projection is centered at 180°E longitude.

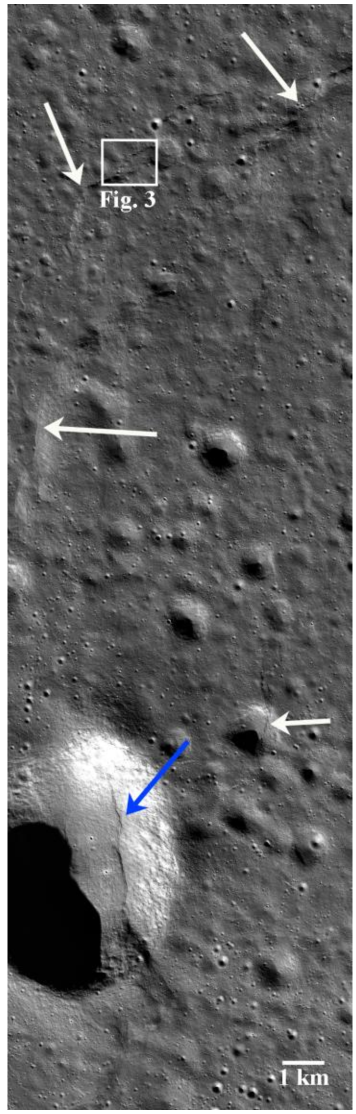

Figure 2: Schwarzschild scarp cluster (~71.9°N, 120.8°E). At least 5 lobate scarps can be seen in LROC NAC image M106079836RE (arrows). The blue arrow indicates a lobate scarp where the vergent side is oriented up slope on the wall of a crater.

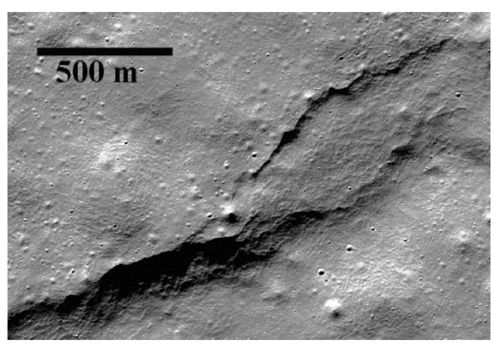

Figure 3: Segment of one of the Schwarzschild scarps with fault-controlled terraces (LROC NAC image M126148854LE).