GLOBAL DISTRIBUTION OF LOBATE SCARPS ON THE MOON: IMPLICATIONS FOR THE CURRENT STRESS STATE. T. R. Watters[1], M. S. Robinson[2], M. E. Banks[1], K. Daud[1], N. R. Williams[2], M. M. Selvans[1], and G. C. Collins[3]. [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, USA (watterst@si.edu); [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85251, USA; [3]Physics and Astronomy Department, Wheaton College, Norton, MA 02766, USA.

Introduction: Lobate scarps are common contractional tectonic landforms on the terrestrial planets [1]. In contrast to lobate scarps on Mercury and Mars [2, 3], lunar scarps are relatively small-scale landforms, with maximum lengths typically only a few tens of kilometers and less than 100 m in relief [4-7]. Because of their small scale, lunar scarps were only first detected in the highest resolution Lunar Orbiter and Apollo Panoramic Camera photographs [7, 8]. Based on morphology, crosscutting relations, reversals in vergence, segment linkage, and modeling, lobate scarps are interpreted to be thrust fault scarps [4, 5, 7-9]. The lack of superposed, relatively large-diameter (>400 m) impact craters, and the generally crisp morphology and crosscutting relations with small-diameter impact craters show that lobate scarps are among the youngest endogenic landforms on the Moon (<< 1 Ga) [5]. The presence of small-scale graben located in scarp back-limb areas, likely a consequence of flexural bending, with depths as shallow as 1 m, indicates these graben and associated scarps may be <50 Ma old [10].

The true global distribution of the population of young thrust fault scarps is being revealed in high resolution 0.5 to 2 m/pixel Narrow Angle Camera (NAC) images obtained by the Lunar Reconnaissance Orbiter Camera (LROC) [11]. The spatial distribution and orientation of the lobate scarps is an expression of the very recent stress state of the Moon and provide insight into the origin of global stresses.

Spatial Distribution: The locations of lobate scarps, identified in an ongoing survey of LROC NAC images that to date cover ~65% of the lunar surface, are digitized directly from map projected mosaics [12]. Thus far, over 2,700 confirmed lobate scarps have been mapped (Fig. 1); the scarps are globally distributed, confirming predictions based on earlier, sparse surveys [5]. Lobate scarps occur at all latitudes on both the nearside and farside. They are found in mare basalts, but are much more common in the lunar highlands and are the dominant tectonic landform on the farside. Many scarps associated with lunar mare occur along the margins of the nearside basins. Although individual scarps reach maximum lengths of only a few tens of kilometers, clusters of scarps in linear and curvilinear patterns may extend for several hundred kilometers (Fig. 1).

In order to evaluate the distribution of orientations of the lunar scarps, digitized segments are sampled in areas with dimensions of 40°×20° (longitude and latitude). The median orientations are plotted and scaled by total length of the structures within the sampled areas (Fig. 2) revealing that the orientations of many lunar scarps are generally N-S. However, significant deviations from N-S orientations, particularly at mid- to high-latitudes are found (Fig. 2). At high latitudes (> ±50°), the dominant orientations are more E-W.

Implications for Global Stresses: Thermal history models for both a totally molten early Moon or an early Moon with a magma ocean predict late-stage global contraction [13-17]. Global contraction in the absence of other influences will result in horizontally isotropic compressional stresses. The expected result is a more or less uniformly distributed population of randomly oriented thrust faults. Although the population of young thrust faults is evidence of late-stage contraction [5], the non-random distribution of orientations of the fault scarps (Fig. 2) is not consistent with global contraction as the sole source of stress. Tidally-induced stresses also contribute to the stress state of the Moon [5]. The Moon is a tidally locked satellite with diurnal tidal stresses raised by the Earth. Diurnal stresses are compressional in the region around the sub-Earth and anti-sub-Earth points at apoapsis. The magnitude of the diurnal stresses are low (maximum of tens of kPa) compared to those from global contraction, estimated to be <10 MPa [5]. The Moon is undergoing orbital recession that also results in compressional stresses in the sub- and antisub-Earth regions [17]. The magnitude of these stresses are up to tens of kPa over the last several hundred million years. However, tidal and orbital recession stresses superimposed on stresses from global contraction will result in a non-isotropic compressional stress field and thrust faulting with preferred orientations (Fig. 3). Preliminary modeling of diurnal stresses superposed on global contraction predict generally N-S oriented thrust faults at low- to mid-latitudes and more E-W oriented faults at high-latitudes, broadly circumferential to the sub- and antisub-Earth regions (roughly centered at 0° and 180° longitude but vary due to libration). The predicted fault orientations are in good agreement with the observed orientations of the lobate scarps (Fig. 3). Thus, global contraction in combination with tidal stresses may account for the distribution of orientations of the population of young lunar thrust fault scarps.

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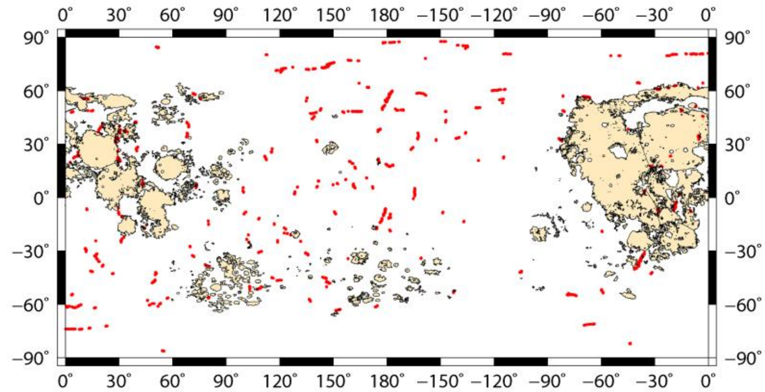

Figure 1. Map of digitized locations of lobate scarps (red) on the Moon. Mare basalt units are shown in tan [12].

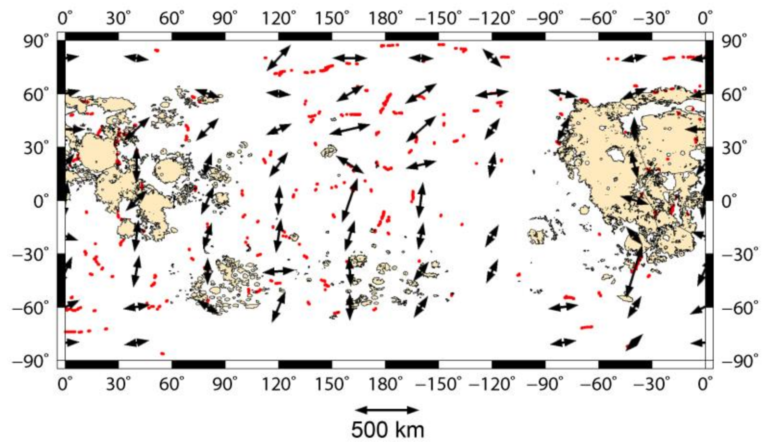

Figure 2. Plot of the median orientations of the lobate scarps (black double arrows) sampled in areas with dimensions of 40°×20° (longitude and latitude) and scaled by the total length of structures in the sampled areas. Mare basalt units are shown in tan [12].

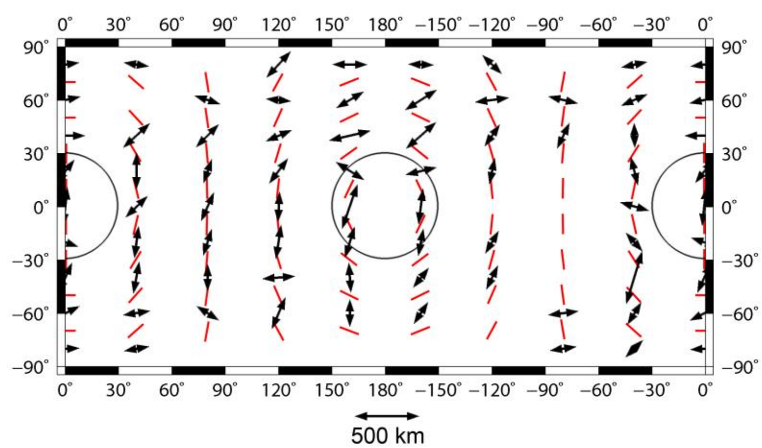

Figure 3. Orientations of predicted faults (red lines) due to diurnal tidal stresses at apoapsis and global contraction plotted with the median orientations of the lobate scarps sampled in 40°×20° areas (black double arrows). Sub-Earth and antisub-Earth regions show by black circles.