LUNAR GRABEN AS A TOOL FOR PROBING THE THICKNESS OF MARE BASALT. E. S. Martin[1] and T. R. Watters[1], [1]Smithsonian Institution, National Air and Space Museum, Center for Earth and Planetary Studies, Washington DC, 20013 (martines@si.edu).

Introduction: The nearside mare are closely associated with concentric and radial graben [Fig. 1] frequently attributed to macson tectonics [1,2,3]. Previous work suggests that in the cases of mare not associated with mascons [4], the loading of the basalt on a thinner or weaker lithosphere may be sufficient to produce graben comparable to mascon mare [4] (Fig. 2). To assess whether there are sufficient loads to induce lithospheric flexure we must first understand the spatial distribution and variability of mare basalt thickness. Thus, an accurate assessment of the thickness is critical to constraining stresses from loading by mare basalts on the lunar lithosphere.

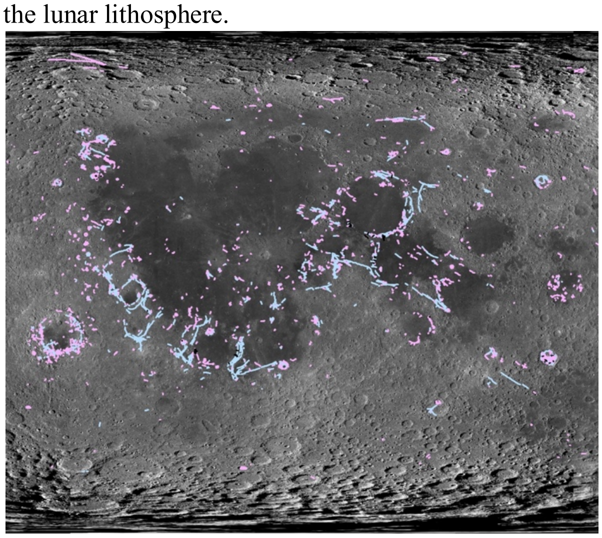

Figure 1: A selection of the global distribution of flat-floored and v-shaped graben [5].

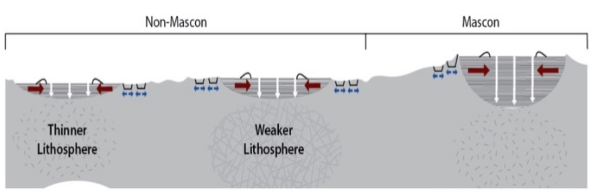

Figure 2: Schematic of the effect of denser basalts on a thinner or weaker lithosphere in the absence of a mascon. After [17].

The thicknesses of mare basalt on the nearside has been the focus of myriad studies [6-15], many employing various techniques including the use of ghost craters to estimate the minimum basalt fill [11-14] (Table 1). We aim to better understand the controls of mare localized graben formation by using graben as a means of inferring the minimum depth of the brittle basalt sequence in which they formed. In the case of a simple graben (Fig. 3) made up of two antithetic normal faults, the graben width is related to the depth of convergence of the faults and is often controlled by the depth to a mechanical discontinuity [16]. For graben in mare basalts, this convergence depth may be to an interbed in lava flow sequence or more likely the contact between the basalt sequence and the highlands substrate. Thus, assuming a simple graben made of two 60° dipping faults, the depth where the normal faults intersect should represent a local minimum estimate of ~~t~~the thickness of the mare basalts Using the width of a graben measured from images, a simple trigonometric relationship can be used to infer the normal fault convergence depth.

Table 1: Comparison of mare thicknesses from two studies. Modified from [15]. (*) an estimate of the mare thickness at the center of the basin from [14].

Basin	**Williams & Zuber, (1998)**	**DeHon (1974, 1979); DeHon & Waskom (1976)**
Grimaldi	3.46	0.5
Serenitatis	4.30	3.5
Humorum	3.61	2.5*
Smythii	1.28	0.5
Nectaris	0.84	2.3
Orientale	0.63	--
Crisium	2.94	3-4
Imbrium	5.24	1.5

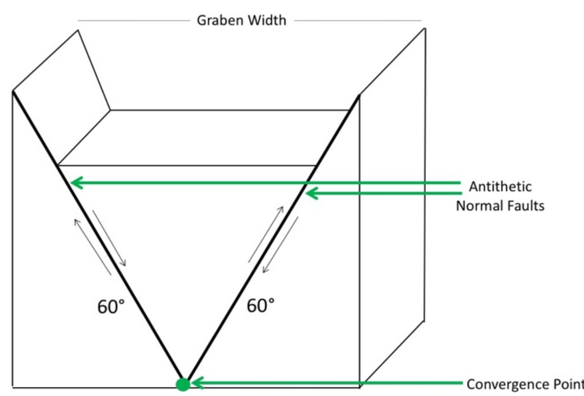

Figure 3: Schematic of a simple graben with theoretical 60° dipped antithetic normal faults.

Methods: We use the global graben map [5] to identify flat-floored graben sufficiently preserved to accurately measure their widths from rim to rim. Graben were mapped to identify individual, well defined segments. The width of each segment (perpendicular to their strike) was measured in an ArcGIS environment.

Each graben segment width was then converted into a depth assuming each fault has a 60° dip (Fig 4).

Results: We find graben widths in mare range from ~400 m to ~5 km with a mean of ~2 km [Fig. 4, 5]. This corresponds to a mean convergence depth of ~1.7 km (Table 2).

Table 2: Results of mare graben width measurements and associated inferred convergence depth.

	WIDTH	DEPTH
Mean	1.97 km	1.70 km
Median	1.91 km	1.65 km
Range	0.41-4.96 km	0.35-4.3 km
# Measured	239	239

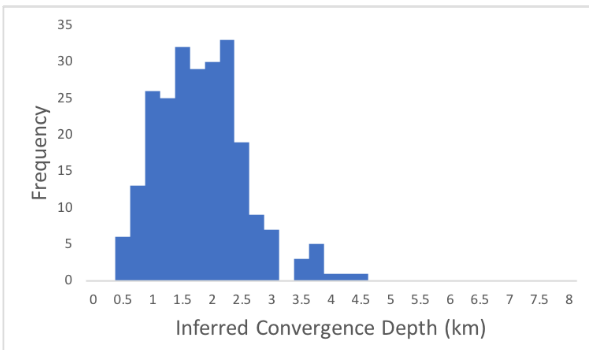

Figure 4: Distribution of convergence depth across lunar mare inferred from graben width.

Discussion: We find the thickness, based on depths of convergence, of mare basalts to be significantly larger than previous estimates [11-14] based on depth-diameter relations of buried impact craters. Mare Humorum (Fig. 4) is useful for comparison across techniques as it is widely reported (Table 3). Estimating mare thickness with graben is location dependent, no graben were found within Humorum basin, however, a mean mare thickness of ~1.99 km (averaged based on measurements in Fig. 5) inferred around Humorum implies that mare thicknesses within Humorum may be thicker. Estimates of mare thickness within Humorum by [10, 15] are at the basin center and are thicker than the average from this study.

Table 3: Comparison of basalt thickness for Mare Humorum. Units are in km. * See Table 2.

	[15]	[10]	[14]	This Study
Mare Humorum	3.61	3	2.5*	1.99

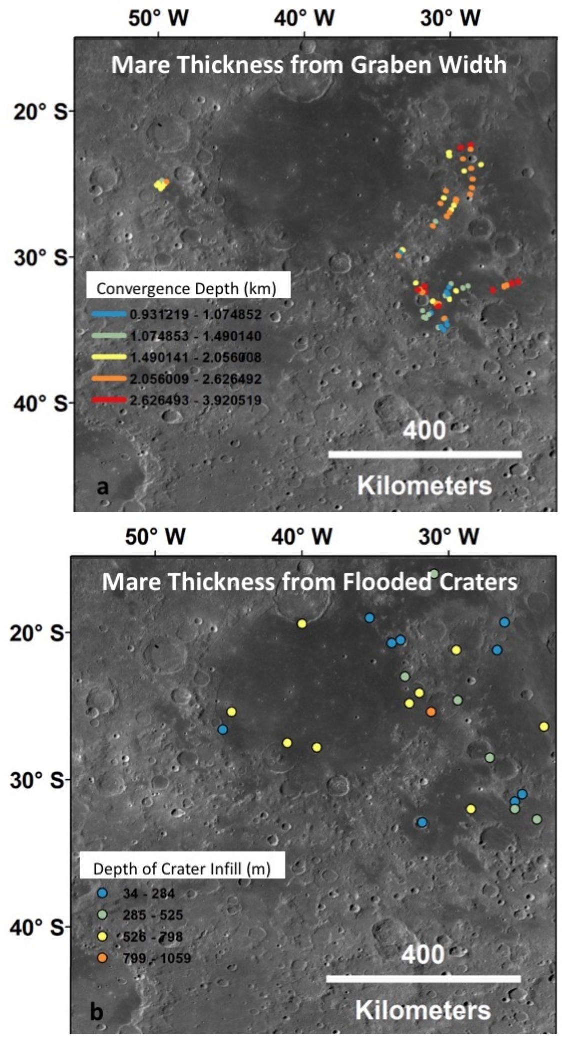

Figure 5: Estimates of basalt thicknesses around Mare Humorum selected from this study (a) using graben widths and (b) using filled craters [13]. There is an order of magnitude difference in estimated thickness between these two methods (a) and (b).

References: [1] Solomon & Head (1979), *JGR,* 84, 1667-1682. [2] Solomon & Head (1980), *Review of Geophysics,* 18, 107-141. [3] Freed et al., (2001) *JGR* 106, 20603-20620. [4] Martin & Watters (2019) 50th LPSC Abs. No. 2011. [5] Nahm et al (2018) 49th LPSC, Abs. No 2074. [6] Budney & Lucey, (1998), JGR, 103-16855-16870. [7] Weider et al., (2010), Icarus, 209, 323-336. [8] Hackwill, (2010), M&PS 45, 210-219. [9] Heather & Dunkin, (2002), P&SS 50, 1299-1309. [10] Melosh et al. (2013), Science 340, 1552. [11] Horz, (1978), 9th LPSC, 3311-3331. [12] Dehon, (1974), 5th LPSC, 5p. 3-59. [13] DeHon, (1977) 8th LPSC, p. 633-641. [14] Dehon, (1979), 10th LPSC p. 2935-2955. [15] Williams & Zuber, (1998), Icarus, 131, 107-122. [16] McGill & Stromquist, 1979, JGR 84, 4547-4563. [17] Schleicher et al, (2019), Icarus, 331, 226-237.