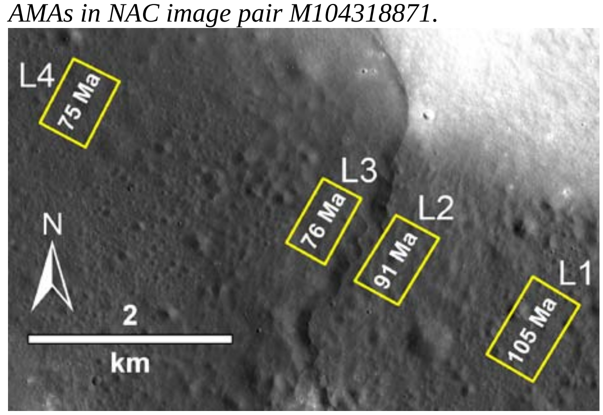
DERIVATION OF ABSOLUTE MODEL AGES FOR LUNAR LOBATE SCARPS. C. H. van der Bogert[1], H. Hiesinger[1], M. E. Banks[2], T. R. Watters[2], and M. S. Robinson[3]; [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (vanderbogert@uni-muenster.de); [2]Smithsonian Institution, Washington DC, USA; [3]Arizona State University, Tempe, AZ, USA.

Introduction: The relatively fresh appearance of lunar lobate scarps, including their sharp morphology, undegraded appearance, and the absence of large (>400 m) superposed craters, indicates that they are very young [1-3]. Binder and Gunga [2] derived age estimates for 20 scarps using crater degradation measurements on craters transected by or superposed on the scarps. Their method yielded minimum and maximum ages that they interpreted to bracket the formation age of the scarps. Most scarps gave relatively well-defined formation ages indicative of a very short formation period, while a few scarps seemed to have experienced multiple episodes of deformation [2]. The age estimates of the scarps range from 60±30 Ma to 680±250 Ma, indicating that lunar scarps are Copernican in age [2].

The Lunar Reconnaissance Orbiter Camera provides new and higher resolution coverage of previously known scarps, including some measured by [2], as well as coverage of newly discovered scarps [3,4]. In addition, the method of crater size-frequency distribution (CSFD) measurements was developed [5,6] since the work of [2]. CSFD measurements are traditionally used to derive ages for geologically distinct units, such as mare basalt flows and impact deposits. Here, we investigate the possibility of their use for discrete tectonic events, such as scarp formation. We present measurements for two scarps, Mandel'shtam segment 3 (S3) (5.67N, 161.62E) (*Fig. 1*), also investigated by [2], and Lee-Lincoln (20.27N, 30.56E) (*Fig. 2*).

Data and Methods: NAC (Narrow Angle Camera) image data were processed using Integrated Software for Imagers and Spectrometers (ISIS) [7] and imported into ArcGIS. The counting areas and craters were generated using CraterTools [8]. The CSFDs were plotted and fit with CraterStats [9], using the techniques described in [5]. The derived absolute model ages (AMAs) are based on the chronology function (CF) and production function (PF) of [6], valid for lunar craters >0.01 and <100 km in diameter.

Figure 2. *Locations of count areas at Lee-Lincoln scarp (20.27N, 30.56E) with youngest corresponding AMAs in NAC image pair M104318871.*



Results: Measurements directly adjacent to the Mandel'shtam (S3) scarp gave single AMAs; the hanging wall (M4) is ~91 Ma, whereas the footwall (M2) is ~146 Ma (*Fig. 1*, *Table 1*). The M3 area, on the hanging wall distal to the scarp, yielded two distinct AMAs: ~128 Ma and ~307 Ma. The M1 area, distal to the footwall, is ~372 Ma.

Measurements directly adjacent to the Lee-Lincoln scarp also yielded CSFDs with single resolvable AMAs of ~76 Ma (L3) on the hanging wall and ~91 Ma (L2) on the footwall (*Figs. 2 and 3*, *Table 1*). Two discrete AMAs fit CSFDs farther from the scarp – at L4, ~75 and ~207 Ma, and at L1, ~105 and ~797 Ma.

The derived AMAs range from youngest to oldest in the following order: proximal hanging wall ≤ distal hanging wall < proximal footwall < distal footwall.

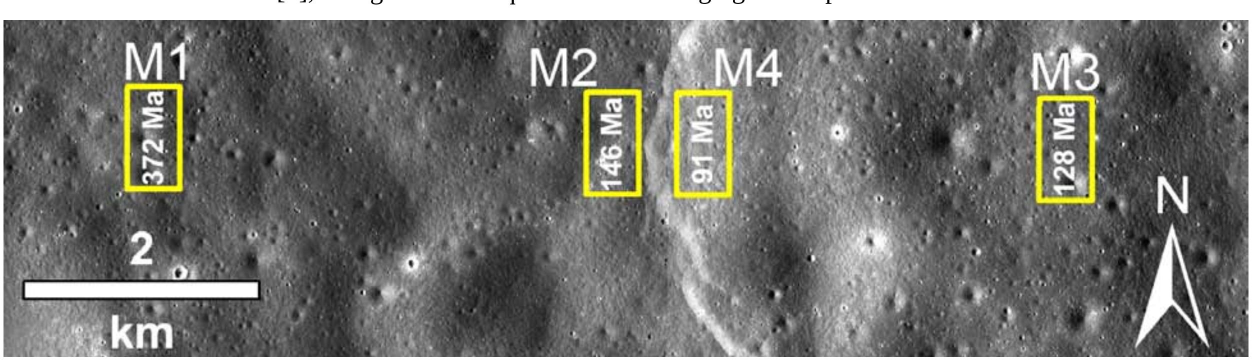


Figure 1. *Locations of count areas at Mandel'shtam (S3) scarp (5.67N, 161.62E) with youngest corresponding AMAs in NAC image pair M103460280.*

Discussion: The young ages derived for count areas proximal to the scarps suggest that small craters (<~100 m diameter), are indeed destroyed during scarp formation, thus resetting the surface age. Because preexisting craters may not be completely destroyed during scarp formation, the ages we determined are maximum ages. With increasing distance from the scarp, the ages generally increase and also include older surface ages, likely representing nearby impact and/or mare deposits. These areas were less affected by the seismic effects of scarp formation, such that their ages were not completely reset.

We interpret the Mandel'shtam (S3) and Lee-Lincoln scarps to have been active as recently as ~91 Ma and ~75 Ma, respectively. Our results confirm those of [2] who found lobate scarps to be some of the youngest non-impact features on the Moon. Indeed, our work suggests that Mandel'shtam (S3) is even younger than the ~180±50 Ma age determined by [2]. Their ages are also upper bounds on the actual formation ages based on error considerations [2].

Immediately south of our Lee-Lincoln scarp count areas is a landslide thought to have been initiated by a secondary impact from Tycho [10,11]. The age of the landslide was determined to be ~75 Ma [12] to ~86 Ma [13]. Given that the age of the landslide is similar to the scarp age, could the landslide have instead been triggered by the scarp formation? The occurrence of well-defined narrow scarp-related extensional troughs or graben in the back scarp area [3,14], that seem to post-date the landslide, argues that the landslide may have occurred before or during scarp formation, prior to the scarp reaching its maximum structural relief. Because the landslide age is bracketed by the scarp ages, it is possible that the landslide is associated with the scarp formation. Even if the landslide occurred prior to scarp formation, its age may have been reset by the formation of the scarp. Thus, the use of the landslide age to date the Tycho impact event is equivocal.

Location	**Area (km^2 x 10^{-1})**	**N(1) (x 10^{-5})**	**Model Age (Ma)**
L4 (h)	3.62	6.27	74.8±9.8
		17.3	*207±120*
L3 (h)	3.12	6.34	75.7±10
L2 (f)	3.66	7.64	91.2±11
L1 (f)	4.67	8.77	105±15
		66.8	*797+270-280*
M4 (h)	3.93	7.63	91±11
M3 (h)	3.93	10.7	128±12
		25.7	*307±140*
M2 (f)	3.93	12.3	146±13
		58.2	*694±270*
M1 (f)	3.93	*31.2*	*372±80*

Table 1. *Areas, N(1), and AMAs for count areas at Lee-Lincoln and Mandel'shtam (S3) scarps. Italics show older resolvable AMAs. Hanging walls (h) systematically give younger ages than footwalls (f).*

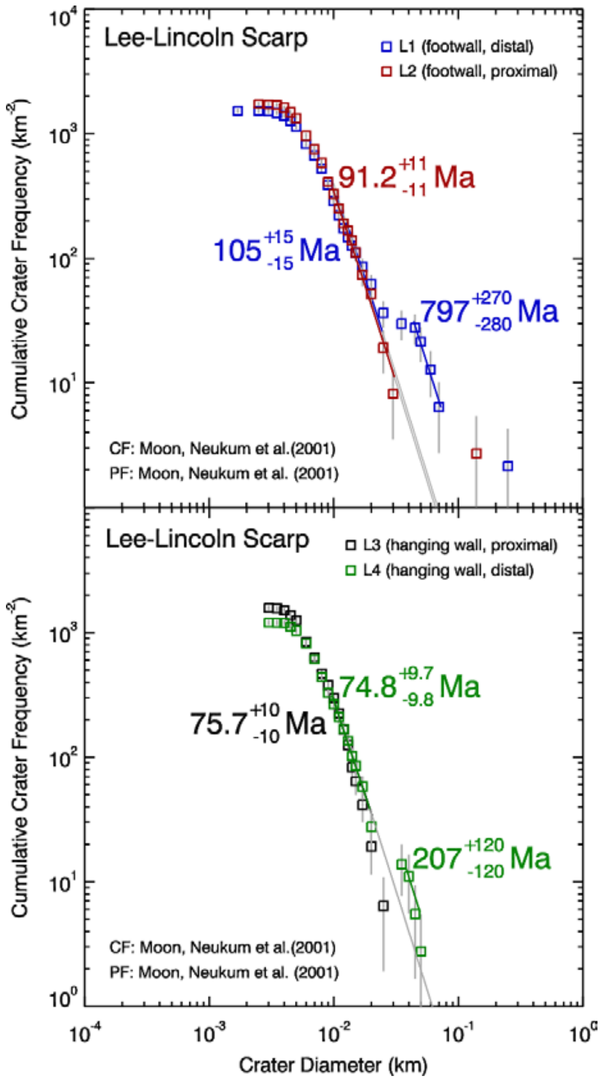


Figure 3. *CSFDs measured at the Lee-Lincoln scarp. Similar data quality was obtained for Mandel'shtam.*

References: [1] Schultz (1976) *Moon Morphology*, Austin, TX. [2] Binder and Gunga (1985) *Icarus, 63*, 421. [3] Watters et al. (2010) *Science 329*, 936. [4] Banks et al. (in press) *JGR*, doi:10.1029/2011JE003907. [5] Neukum (1983) *Meteoritenbombardement und Datierung planetarer Oberflächen*, Habil. Thesis, Univ. Munich. [6] Neukum et al. (2001) *Space Sci. Rev. 96*, 55. [7]isis.astrogeology.usgs.gov/TechnicalInfo/index.html. [8] Kneissl et al. (2011) *PSS 59*, 1243. [9] Michael and Neukum (2010) *EPSL, 294*, 223. [10] Wolfe et al. (1975) *PLPSC 6*, 2463. [11] Lucchitta (1977) *Icarus 30*, 80. [12] König (1977) *Untersuchungen von primären und sekundärem Eimschlagsstrukturen auf dem Mond*, PhD Thesis, Univ. Heidelberg. [13] Hiesinger et al. (in press) *JGR*, doi:10.1029/2011JE003935. [14] Watters et al. (in press) *Nat. Geosci.*.