EXPLORING THE SEISMIC RECORD AROUND LUNAR LOBATE SCARPS. J. D. Clark[1], C. H. van der Bogert[1], H. Hiesinger[1], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 49149 Münster, Germany (j.clark@uni-muenster.de),

Introduction: Lunar lobate scarps are the surface expression of low-angle thrust faults formed by contraction of the crust due to long-term interior cooling [1-7] and tidal deformation [8]. Based on their fresh morphology, the scarps are some of the youngest landforms on the Moon [4, 7, 9-12]. First scarp age estimates using Apollo panoramic camera images and crater degradation measurements on craters pre- and post-dating the scarps revealed that they formed in the last ~700 Ma [10].

Today, the Lunar Reconnaissance Orbiter Camera (LROC; [17]) provides high-resolution, 0.5 to 2 m/pixel Narrow Angle Camera (NAC) images, allowing the exploration of previously known and newly discovered scarps on a global scale [7]. Along with new imagery, techniques to derive surface ages using crater size-frequency distribution (CSFD) measurements were also developed since the study by [10] and have been tested [13] for 5 scarps previously studied by [10]. These recent age determinations, in addition to other work [12-16] using both traditional and buffered crater counting (BCC) CSFD measurements, revealed they were active in the late Copernican, having ages as young as 14 Ma.

Using the technique of [13], we expanded our data set to a total of 34 scarps to investigate whether there are global trends with age and distribution, how the crustal stresses developed over time, and whether scarps formed during punctuated episodes or continuously [16]. Our data also allow us to investigate the seismic record around the scarps. [13] showed that the crater record adjacent to the scarps is reset due to seismic shaking related to scarp formation. CSFDs both proximal and distal to the scarps could thus reveal information about the extent and severity of the seismic activity on the faults [13]. Here, we explore the variations in the CSFDs and derived AMAs for 34 lobate scarps.

Methods: For our study, we used the traditional CSFD method, as tested by [13] for application to lunar lobate scarps, which measures all primary craters within a single geomorphologic unit, excluding secondary and endogenic craters. Representative count areas are placed both proximal and distal (~3-4 km away) to the fault trace [12, 13]. Slopes from large craters (>1km) and regional topography are avoided since CSFDs on inclined surfaces (≥ 10˚) can result in younger apparent AMAs due to mass wasting [20, 21]. We fit the CSFDs in cumulative form with pseudo-log binning [19, 22, 23], using the lunar production function and cratering chronology of [24]. We often measured craters smaller than the 10 m production function threshold to ensure that our dataset was complete to the limit of the image resolution.

Results: Measuring the crater population on scarp surfaces revealed that the thrust faults have been active in the last ~400 Ma and as recent as ~24 Ma. The majority of faulting events occurred in the last ~200 Ma, with an average age of 105 Ma. Of the 34 scarps, ~53% of the proximal footwall surfaces were younger than the adjacent hanging wall. Approximately 75 % of the distal count areas are older than their proximal counterparts.

Discussion: In many cases, the increase of the ages away from the scarp traces is consistent with the attenuation of seismic shaking with distance from the fault. If correct, could an evaluation of the ranges of crater diameters reset by the event (Fig. 1) give us information about the geographic extent and severity of shaking? To answer this question, we assessed the fit ranges of the AMAs we determined that best represent each scarp age. We theorize that the erasure of larger-sized craters requires either a greater level or longer period of shaking or a larger number of events than for removal of smaller-sized craters.

Many of the ages that we fit use a minimum fit diameter of 10 m, because this is the limit allowed by the lunar production function of [24]. Thus, for the time being, 10 m is a boundary condition for our analysis until the production function has been extended to smaller crater diameters. Occasionally, the CSFDs cannot be fitted with the production function down to

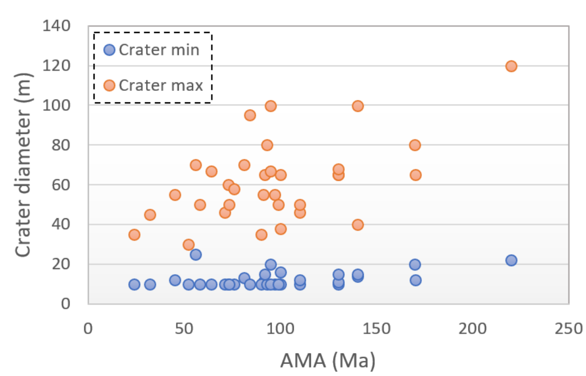

Fig 1: The maximum and minimum fitted crater diameters affected by seismic resetting events related to scarp activity at 34 lunar scarps.

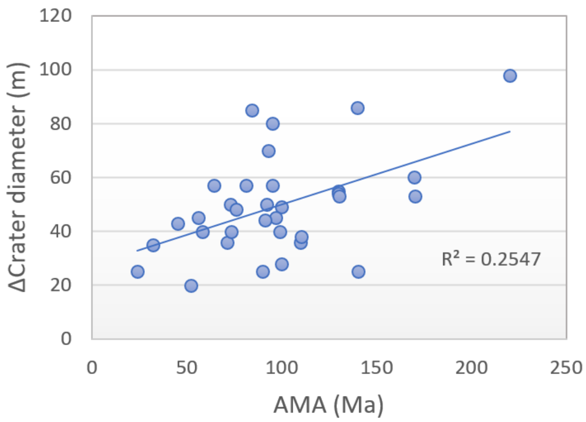

Fig 2: ΔCrater diameter range affected by seismic resetting as determined from Fig. 1 versus the derived AMA (Ma) for each of 34 studied scarps.

the 10 m boundary. Of all the CSFD measurements for scarp surfaces (111 in total), over half of the scarps that have a lower boundary above the 10 m experience equilibrium conditions. The largest crater diameter reset by the scarp activity minus the smallest diameter affected defines the ΔCrater diameter.

ΔCrater diameter vs. AMA (Fig. 2): The diameter ranges reset by the scarp activity varies from 20 to almost 100 ΔCrater diameter (m) (Fig. 2). Here, the ΔCrater diameter has a general upward trend with an increase of AMA. This might suggest that seismic activity (duration and/or magnitude) has been decreasing over the last ~250 Ma that is covered by our dataset, where smaller quakes would erase a smaller size range of craters. We do note that the trend is defined by the few data points at the older ages. As we derive more AMAs for the scarps, it is expected that the R^2 value would become more robust.

ΔCrater diameter vs. location (Fig. 3): As mentioned earlier, distal count areas typically yield older

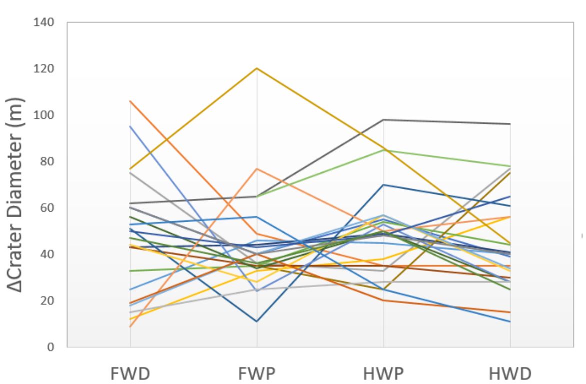

Fig 3: ΔCrater diameter range affected by seismic resetting versus the location of the count area with respect to the scarp, where FW is the footwall, HW is the hanging wall, D is for distal, and P is for proximal.

AMAs presumably because of less seismic shaking. Using only lobate scarps where distal AMAs could be determined, we plotted how the ΔCrater diameter varies among the four count areas for the scarps (Fig 3), i.e., the proximal foot- (FWP) and hanging wall (HWP) count areas and the distal foot- (FWD) and hanging wall (HWD) count areas. First observations reveal that 60% of the scarps tend to have a wider range (e.g. a large number of crater used to dervive an age) of fit for the HWP than the FWP. Dissecting the data even more might help us determine what fault characteristics and/or local geologic settings determine the maximum fault-related shaking?

What can we learn? Beyond determining AMAs for numerous scarps, the goal of this work is to study the CSFD measurements for supplementary information about the seismic activity at the lobate scarps. By exploring the fits of the crater populations, we hope to uncover how seismic shaking is distributed locally, the magnitudes/duration of scarp-related moonquakes, and regional variability of crater resurfacing. More in depth studies of individual scarps [e.g., 25] could reveal more information about the formation and evolution of lunar lobate scarps.

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