CRATER RETENTION AGES OF LUNAR SOUTH CIRCUM-POLAR CRATERS HAWORTH, SHOEMAKER, AND FAUSTINI: IMPLICATIONS FOR VOLATILE SEQUESTRATION. A. R. Tye[1], J. W. Head[1], E. Mazarico[2], C. I. Fassett[3], A. T. Basilevsky[4], [1]Dept. of Geological Sciences, Brown University, Providence, RI 02912, USA, [2]Dept. Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge, MA 02139, USA, [3]Mount Holyoke College, 50 College St., South Hadley, MA 01075, USA, [4]Vernadsky Institute, 119991 Moscow, Russia.

Introduction: Craters Haworth, Shoemaker, and Faustini (diameters 52.1 km, 52.7 km, and 41.6 km respectively) in the lunar South circum-polar region have permanently shadowed interiors and have been interpreted to contain volatiles [1-6]. Altimetry data from the Lunar Orbiter Laser Altimeter (LOLA) [7] onboard the Lunar Reconnaissance Orbiter (LRO) provide a way to examine the crater interiors and surroundings in unprecedented detail, despite the permanent shadow. From superposed impact crater size-frequency distributions (CSFD), we derive crater retention ages for the floors, walls, and ejecta deposits of Haworth, Shoemaker, and Faustini. We use these ages and CSFDs to contextualize observed volatile deposits in the crater interiors, particularly in light of the recent Lunar Explorer Neutron Detector (LEND) data suggesting the presence of hydrogen in all three craters [8, 9], but not to represent absolute ages.

Cratering observations: We catalogued the distribution of superposed impact craters >250m in diameter on the floor, wall, and ejecta deposits of Haworth, Shoemaker, and Faustini (Fig. 1), excluding obvious secondary craters. Visually, there appear to be fewer preserved superposed craters on the crater walls than on floor and ejecta deposits, where there is no major topography. In Haworth, we note that the NW and S regions of the crater wall are more highly cratered than other parts of the wall; these regions are also less steeply sloping.

Crater retention ages. We dated the floor, wall, and ejecta deposits of Haworth, Shoemaker, and Faustini (Table 1) using crater size-frequency analysis of superposed craters [10] (Fig. 2). Our derived ages correspond to a good fit between the model production function (MPF) and our CSFDs primarily for small craters, typically in the 250 – 450 m diameter range. Thus, these crater retention ages reflect resurfacing processes which have preferentially affected small craters. We identified these deposits using LOLA altimetry data, and we defined ejecta deposits as being within one crater diameter from the crater rim and being relatively flat.

Slope, Deposition, and Crater Retention: Crater-ages for the floor deposits of Haworth, Shoemaker, and Faustini are comparable to one another. The CSFD diagrams for the floor deposits, particularly of Haworth, are slightly less steeply sloping than the MPF, possibly reflecting long term degradation from micro-meteorite bombardment; they do not show evidence for partial resurfacing in the same fashion as the crater walls and ejecta deposits do [10, 11]. Our results are consistent with the interpretation that the interiors of these three craters have been fully resurfaced by Imbrian plains material [12]. Anomalous large craters observed in the floor of Shoemaker (Fig. 2, II-A) may be secondaries or the remnant of an original crater floor.

Our crater-ages for the walls of Shoemaker and Faustini show crater retention varying with surface slope, in that the crater-ages of their sloped walls are less than the crater-ages of their floor and ejecta deposits. None of the three craters we examine has as dramatic age variations between wall and other deposits as Shackleton, however. In fact, the crater-age of the wall of Haworth is comparable to that of its ejecta deposit. To test whether the age of the Haworth wall is affected by secondaries, we re-analyzed the crater wall of Haworth excluding 28 craters with diameter >1.5km (Fig. 2, I-D), which yielded an age of 3.33 Ga, not less than the original in a statistically robust way. We calculated mean slopes of the wall deposits for Haworth, Shoemaker, and Faustini, respectively: 14.21º, 14.67º, and 14.96º, based on slope maps (Fig. 1). Haworth does have a slightly lower mean slope than Faustini and Shoemaker, which is consistent with an earlier formation and more degradation. Spudis et al. [12] interpret the Haworth wall as being pre-Nectarian in age and the walls of Shoemaker and Faustini as Nectarian. Our data is consistent with Haworth being older, but our crater-ages do not match these epochs.

The CSFD diagrams (Fig. 2) of all three crater walls suggest they each experienced similar partial resurfacing [10]. They appear to be composed of three sections, a small diameter section where the CSFD slope is fit reasonably well by the MPF, an intermediate diameter section where the CSFD is less sloped than the MPF, and a large diameter section where the CSFD can again be fit to the MPF. Surface slope is known to affect superposed crater retention as superposed craters are obliterated by downslope movement induced by subsequent impacts [13]; this downslope movement would preferentially erase the evidence of smaller craters first. The CSFDs of the ejecta blankets we date for Haworth, Shoemaker, and Faustini also show evidence of having been resurfaced, though surface roughness may also play a role.

Ages of formation: Because the floor deposits have been interpreted as resurfaced [12] and wall and ejecta deposits of these three craters show evidence for resurfacing, it is likely that Haworth, Shoemaker, and Faustini are older than these crater retention ages suggest. Their highly-degraded morphologies suggest that they are older than Shackleton. One possibility is that these craters were formed before the end of the Late Heavy Bombardment and were subject to basin ejecta and seismic shaking that disrupted their crater-records [14]. In this case, all of the crater retention ages we measure are a result of these resurfacing processes, rather than reflective of the timing of crater formation. Closer analyses of specific regions inside the craters and their CSFDs may help to clarify their ages of formation.

Implications for volatile sequestration: The slopes of the CSFDs of the floors of Haworth, Shoemaker, and Faustini show evidence of crater loss, but we do not observe a rollover associated with the obliteration of small craters during resurfacing. The craters studied here of diameter >250m are >50 m deep [6]; to first order we do not observe evidence for volatile deposits >50 m thick.

Our findings are consistent with results from LEND [8, 9, 15]. These LEND results suggest up to a 500 ppm hydrogen enhancement in the lunar regolith within the crater interiors, rather than a bulk deposition capable of resurfacing an area. The relation between a hydrogen-enhanced regolith and cratering processes is unknown.

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Table 1—Deposit Crater Retention Ages (Ga)

Deposit	Haworth	Shoemaker	Faustini	Shackleton [6]
Floor (A)	3.63	3.58	3.61	3.29
Wall (B)	3.37	2.55	2.49	1.44
Ejecta (C)	3.42*	3.39	3.34	3.69

Table 1. Crater-derived ages for floor, wall, and ejecta deposits of craters Haworth, Shoemaker, and Faustini. Craters >250m in diameter were used, excluding secondaries. Haworth ejecta is marked with an asterisk (*) because we use only a portion of its ejecta deposit.

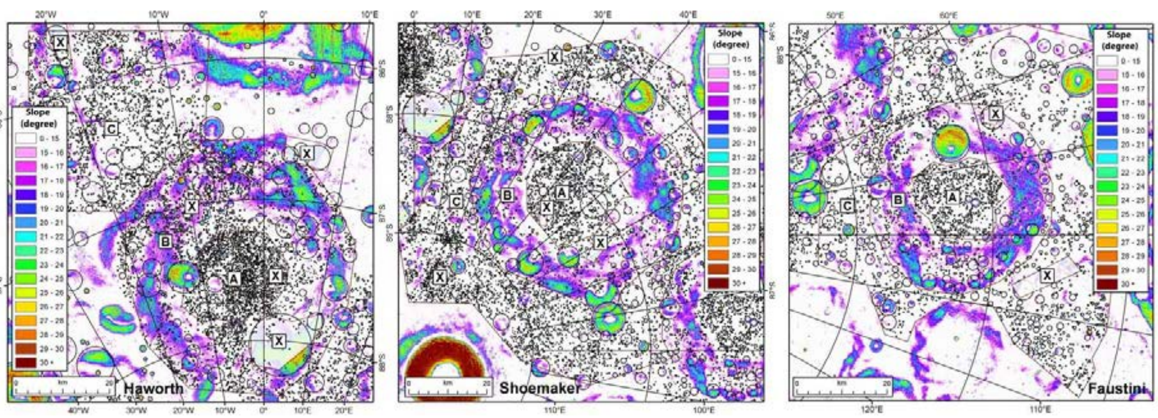

Figure 1. Slope maps of Haworth, Shoemaker, Faustini with slope variation between 15º and 30º emphasized. Slopes are calculated with a baseline of ~20m. Craters are outlined in black. Deposits are outlined in brown and labeled as follows: (A) crater floor, (B) crater wall, (C) crater ejecta deposit, (X) secondary craters omitted from analysis. Note in Haworth the concentration of craters in the Southern and Northwestern portions of the crater wall, areas with particularly low wall slopes. This relationship between wall slope and crater concentration is, to a lesser degree, visible in the wall deposits of Shoemaker and Faustini as well.

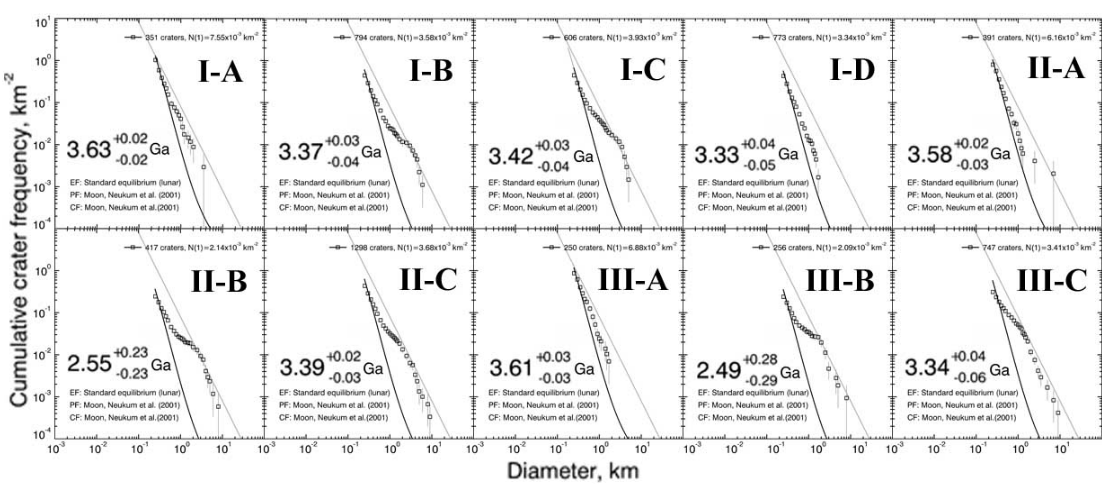

Figure 2. Crater size-frequency distribution (CSFD) plots for each dated deposit. The deposits are labeled as follows: Haworth floor (I-A), wall (I-B), and ejecta (I-C); Shoemaker floor (II-A), wall (II-B), and ejecta (II-C); Faustini floor (III-A), wall (III-B), and ejecta (III-C). Deposit (I-D) is the CSFD for Haworth's wall deposit excluding all craters >1.5 km in diameter.