[44] Many other Pre-Nectarian basins, perhaps excepting Apollo and Freundlich-Sharonov, are characterized by densities that likely imply that they also reached saturation. This means that their age and sequence may be imperfectly tied to the density of craters that are superposed on their surface (Table 1). Most Pre-Nectarian basins are clustered at N(20)∼165 to 265 and N(64)∼30 to 48; equivalent to R_{20}∼0.1–0.15 and R_{64}∼0.25–0.4 with a highlands-like crater size-frequency distribution. If all of these basins are saturated, differences in degradation state and topography hint at how long the basin has been in this condition, although this relationship should be size-dependent. For basins the size of SPA, later cratering is almost certainly ineffective as a process to completely erase basin topographic signatures. However, for small 300–500 km diameter basins, this is potentially a far more efficient process.

[45] The apparent saturation of early surfaces on the Moon that our measurements support weakens the evidence for forms of the Late Heavy Bombardment hypothesis that postulate a lower impact flux before Nectaris, because the cratering record of the Pre-Nectarian must be incomplete [see also *Hartmann*, 1975; *Chapman et al.*, 2007]. Since this early impact record is missing, the large number of Nectarian and younger basins (at least 13; Table 1) need not require an anomalously high basin-forming flux compared to the preceding pre-Nectarian period, although the impact flux in early periods was far higher than that during later times.

3.5. Degraded and Uncertain Basins

[46] In addition to the basins documented and discussed here, there are numerous less well-defined basins [e.g., *Wilhelms*, 1987; *Frey*, 2011; Wood, Impact basin database, 2004] that have been suggested to exist on the Moon. A number of these suggested basins do not appear to have a clear signature in LOLA altimetry data. In other instances, some evidence exists for basins that are now simply too ambiguous to be confidently identified using our criteria. The list we provide here (Table 1) is conservative in the sense that we are confident that all of the basins that we measure have a very high probability of being impact basins. The vast majority of the remaining highly degraded, ambiguous and uncertain basins are Pre-Nectarian in age, as discussed further below, and thus do not affect the observations and conclusions discussed above.

[47] *Frey* [2011] evaluated the basins compiled by *Wilhelms* [1987] using the Unified Lunar Control Network topography of *Archinal et al.* [2006]. Additional efforts to analyze the degraded basins with LOLA topography are ongoing, so we do not dwell on this issue here and address only a few points. First, there is significant agreement between the *Frey* [2011] judgments of the *Wilhelms* [1987] basin list and our independent evaluations, although we additionally exclude as doubtful Keeler-Heaviside, Fecundatitis, Mutus-Vlacq, Lomonosov-Fleming, and Tsiolkovsky-Stark (as well as Balmer-Kapteyn and Bailly, which we assess as having smaller main ring diameters than our size cutoff).

[48] We also examined the additional suggested topographic basins of both Wood (Impact basin database, 2004) and *Frey* [2011]. A few of these meet our criteria as probable-to-certain basins; in the *Frey* [2011] naming scheme these are TOPO-30 (Cruger-Sirsalis) [*Spudis et al.*, 1994; *Cook et al.*, 2002], TOPO-24 (Dirichlet-Jackson) [*Cook et al.*, 2000], and TOPO-41 (Fitzgerald-Jackson) [*Cook et al.*, 2000]. Conversely, in a few instances, we think 'positive evidence' exists against some suggest candidates being actual impact basins, such as TOPO-38, which is entirely inside Imbrium and demarcated by wrinkle ridge ring. We interpret this as an inner ring of the Imbrium basin rather than a separate basin. Again, most of the suggested basins that we do not include here are ambiguous; some evidence would argue for their existence and some against.

[49] What do we know about the age and crater statistics of these ambiguous basins? In general, the vast majority must be Pre-Nectarian in age. We have made measurements which support this view in regions that have traditionally been suggested to have one or more basins by various authors, such as Australe, Lomonosov-Fleming, and Werner-Airy. All have superposed crater densities of N(20) > 180 and N(64) > 35, indicative of Pre-Nectarian ages (see Table 1). As discussed above, these densities are at levels consistent with saturation equilibrium, which also would explain the very highly degraded state of the purported basins.

[50] Younger impact basins also should obviously not have high crater densities or saturated surfaces, nor have subtle basin topographic signatures (excepting any that were erased by direct superposition of later, larger basins). For these reasons, the Nectarian and younger basins in Table 1 are likely to be a nearly complete representation of the basins that actually formed on the Moon during this period.

3.6. Calibrating Ages and Sampling Suggestions

[51] Better understanding of the absolute ages of various basins on the Moon is important for understanding lunar geology as well as for understanding the impact record across the inner solar system. This problem is highly convolved with the provenance of the lunar samples, and making progress in this area may require additional in situ fieldwork and/or robotic sample return.

[52] When considering how to calibrate the translation of measured crater size-frequency distributions into absolute ages, one issue is that the most commonly applied models for lunar crater statistics [e.g., *Neukum et al.*, 2001] do not yet account for the fact that the impactor population on the Moon appears to have evolved with time [*Strom et al.*, 2005]. Recent work by *Marchi et al.* [2009] has made some progress in considering this problem, but the detailed nature of the transition between the two populations has been uncertain, which complicates any attempt at incorporating this into absolute age models. Our work supports the conclusion that basins from the mid-Nectarian onwards were dominated by Population 2 impactors. The radiogenic dates derived for the relatively late basins and the mare, and their associated crater frequencies, represent only the younger population and no confident calibration of a surface with the earlier population presently exists.

[53] At present, suggested ages exist for Imbrium, Orientale, Crisium, Nectaris and Serenitatis [see *Stöffler et al.*, 2006], although the youthful ages that have been interpreted to represent Serenitatis are certainly inconsistent with our preferred interpretation of its stratigraphy (see section 3.3.2 [see also *Spudis et al.*, 2011]). It remains plausible that many of the absolute ages for basins that have been assigned on the basis of samples actually relate to Imbrium because of its potential for having played a dominant role in