to re-examine these questions. In this study, we use LOLA-derived digital terrain models to measure impact crater size-frequency distributions for 30 lunar basins that we classify as certain or probable on the basis of LOLA topography (one further basin that would fit in this category, Sikorsky-Rittenhouse, is so modified by its proximity to Schrödinger that it is not measurable). To be classified as certain or probable, we require that candidate basins have a region of low topography at least partially bounded by a circular or elliptical rim of high topography. We require that this rim be recognizable around at least 40% of the basin, although in most instances much more of the rim is intact. A number of additional, more degraded basins exist on the Moon [*Wilhelms*, 1987; *Frey*, 2011; C. A. Wood, Impact basin database, 2004, available at http://www.lpod.org/cwm/DataStuff/Lunar%20Basins.htm, hereinafter referred to as Wood, Impact basin database, 2004]. However, not all the basins that have been suggested are verifiable on the basis of LOLA topography using our criteria. This is discussed in more detail in section 3.5.

[4] In addition to determining superposed impact crater size-frequency distributions for each of these basins, we also (1) discuss the implications these results have for lunar stratigraphy and basin sequence, particularly with regard to several important individual basins and the Pre-Nectarian/Nectarian boundary, (2) use these data to examine hypothesized transitions in the impact crater populations affecting the Moon, and (3) discuss the hypothesis that saturation equilibrium was achieved on heavily cratered portions of the lunar surface.

1.1. Past Measurements of Basin Crater Statistics

[5] There have been a series of past efforts to systematically determine the relative age and superposed crater statistics for lunar basins [*Stuart-Alexander and Howard*, 1970; *Hartmann and Wood*, 1971; *Baldwin*, 1974; *Neukum*, 1983; *Wilhelms*, 1987].

[6] *Stuart-Alexander and Howard* [1970] attempted to ascertain the age of impact basins by considering their degradation state and by examining the largest craters superposed on each basin. Although essentially qualitative, their results give a first-order picture of basin age. The most comprehensive early survey to apply crater statistics to determine the age of large basins was accomplished by *Hartmann and Wood* [1971]. They report crater densities for many of lunar basins relative to the nearside lunar maria, and accounted for the effects of post-basin modification in their reported data. *Baldwin* [1974] also provided a series of crater counts on both basins and smaller craters; he divided his count results into age classes based on power law fits to the data. *Neukum* [1983] also made counts on a series of lunar basins, which have been translated into a more recent absolute chronology scheme by *Werner* [2008].

[7] Along with these important early efforts, the most widely cited stratigraphic sequence for lunar basins and analysis of broader lunar chronology was developed by *Wilhelms* [1987] in his classic The Geologic History of the Moon. Wilhelms relied on both stratigraphic inferences and crater counting to determine basin age and sequence. We compare our new results with the Wilhelms age sequence in detail.

[8] From all of these approaches and studies, there was widespread agreement that a representative sequence of basins exists, from youngest to oldest, of Orientale, Imbrium, Crisium, Nectaris, and Smythii. Most measurements also explicitly or implicitly recognize that the distinction between Imbrium and Crisium (or Imbrium and Nectaris) is far firmer than distinctions between Nectaris and many of the other basins of approximately the same age; many basins exist with superposed crater densities that are similar to Nectaris. However, disagreements existed between earlier workers about (1) the age of certain individual basins (e.g., Serenitatis, Humorum, Mendel-Rydberg, and Humboldtianum), and their position in the larger stratigraphic sequence, (2) the quantitative crater densities superposed on basins, and (3) the implications of these results for broader lunar geological history. In this study, we seek to resolve some of these differences.

1.2. Measurement Technique

[9] We derive impact crater size-frequency distributions for each basin by first mapping the preserved basin-related materials and facies, aiming to include the area that would have been unambiguously reset by the basin-forming event. In general, this is the area inside the basin not covered by later materials, and the region immediately proximal to the rim. Areas resurfaced after the basin event by volcanism or by ejecta from other basins are excluded. Along the edges of our count area, we use a buffered area correction and include craters which are superposed on the basin, but which are centered outside the count region (Figure 1). This buffered approach is similar to that of *Fassett and Head* [2008], though with a stricter buffer (no ejecta area is included and the rim of superposed craters must fall within the count area).

[10] This technique has two advantages. First, it expands our effective count area, since it takes advantage of the fact that large craters subtend more area than small ones, and second, it makes the mapping of the count area more straightforward and potentially more objective. This allows exclusion of resurfaced regions from the mapped count area without losing information about craters superposed on the edge of basin material, and there is no uncertainty about how to map the count area when craters are buried. To verify this procedure, we also compared results derived in this manner to a traditional (unbuffered) count area definition. The differences in results from these methods are below the uncertainties that arise from counting statistics, and systematic differences are negligible. Given the advantages we describe, we prefer the buffered methodology applied here to more traditional crater counting approaches for this particular problem.

[11] For our crater data, we begin with the catalog of lunar craters ≥20 km in diameter from LOLA data [*Head et al.*, 2010; *Kadish et al.*, 2011]. We then re-examine each basin using LOLA digital terrain models (DTM; updated June 2011) to systematically search for additional craters beyond the global database. In total, a modest number of additional craters were found (12%); these are predominantly small (<40 km) and degraded. We use the 64 pixel per degree (ppd) (equivalent to 473 m/px at the equator) DTM and shaded relief generated from this model. Higher resolution