

Review of Cratering Evidence Regarding Early Solar System Bombardment

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Pre-Apollo lunar crater count analysis indicated that the cratering rate averaged over pre-mare times was much higher than the present rate [1]. Following the dating of nine landing sites on the moon from Apollo and robotic Luna samples, it became possible to plot crater densities as a function of time, at least during a relatively short interval from ~3.9 to ~3.2 Gy ago. Differential crater densities from older to younger sites showed that the cratering rate was declining rapidly during this period [2,3]. Such work was done by the author in the early 1970s, and again independently, and probably with more precision, by Gerhard Neukum in the mid 1970s and 80s [4,5]. The results were very similar in showing the declining rate.

Most workers have assumed that the cratering rate has been more constant since then (probably with crater-size-dependent spikes associated with asteroid breakup events, especially at smaller crater sizes.) However some authors have suggested a gradual increase, and others, a decrease, since 3.0 Gy ago [cf. 6, 7]. Crater counting with anticipated, high resolution imaging may help clarify this issue, although serious progress requires radiometric dating of some young counting surfaces, such as the interior of Copernicus or Tycho.

A problem has been to affirm whether the decline from ~3.9 to ~3.2 Gy ago is (1) simply the tail end of a unique cataclysmic cratering episode centered 3.9 Ga ago, or (2) a time-restricted decline after one of several semi-cataclysmic spikes in cratering, or (3) a decline associated with longer-term sweep-up of interplanetary debris [cf. review in 8].

Comparison of lunar front side impact melts, from Apollo samples, with lunar meteorite impact melts and asteroidal meteorite ages may offer valuable constraints on the nature and time dependence of the intense inner solar system cratering prior to ~3.2 Gy.

References: [1] Hartmann, W. K. 1966, *Icarus* **5**, 406-418. [2] Hartmann, W. K. 1970. *Icarus*, **12**, 131-133. [3] Hartmann, W. K. 1970. *Icarus* **13**, 209-301. [4] Neukum, G., Köngi, B., Storzer, D., and Fechtig, H. 1975 *Proc. 6th Lunar Planet. Sci. Conf.* 598 (abstract). [5] Neukum, G. 1983. Habilitation Dissertation for Faculty Membership, Ludwig-Maximilians-University of Munich. 186 pp. [6] Quantin, Cathy; N. Mangold, W. K. Hartmann, P. Allemand 2007 *Icarus*, **186**, 1-10. [7] Hartmann, W. K., Cathy Quantin, Nicolas Mangold. (2007) *Icarus*, **186**: 11-23. [8] Hartmann, W. K. 2003. *Meteoritics and Planet. Sci.* **38**, 579-593.