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The Lunar and Martian Cratering Records and Chronologies

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The Lunar cratering chronology as a basis for chronologies for Mars and the terrestrial planets (the "lunar reference system") was reinvestigated in a comprehensive effort by Neukum et al. (2001) [1]. The well-investigated size-frequency distribution (SFD) for lunar craters was used to estimate the SFD for projectiles which formed craters on terrestrial planets and on asteroids. The result shows the great stability of these distributions during the past 4 Gyr. The derived projectile size-frequency distribution is found to be very close (cf. also [2]) to the size-frequency distribution of Main-Belt asteroids as compared with the recent Spacewatch asteroid data and astronomical observations (Palomar-Leiden survey, IRAS data) as well as data from close-up imagery by space missions. It means that asteroids (or, more generally, collisionally evolved bodies) are the main component of the impactor family. Lunar crater chronology models of the authors of [1] published elsewhere were reviewed and refined by making use of refinements in the interpretation of radiometric ages and the improved lunar SFD. In this way, a unified cratering chronology model [1] was established which can be used as a safe basis for modeling the impact chronology of other terrestrial planets, especially Mars. Over the past 3 years, the Neukum SFD for small impact craters (D $\leq$ 1km) both on the moon and Mars has been under severe attack by McEwen et al. [3,4] claiming that the majority of small craters are secondaries produced by large primaries. McEwen et al. even claimed that the Hartmann and Neukum Chronology [5] derived from the lunar chronology and making use of small craters is wrong by a factor of up to 2000. It has been quite clear to the author of this abstract and his colleagues making use of the Hartmann & Neukum chronology that McEwen and colleagues are

in gross error and their own interpretation of the dominance of secondaries and the alleged uselessness of small craters for age dating have no real factual basis as discussed by Hartmann (2005) [6]. There are a number of arguments on the basis of real hard data against McEwen's secondary cratering argument for the small-crater steep branch of the crater size-frequency distribution, e.g. that the steep branch at small crater sizes was recognized as the primary population in the source region, the asteroid belt, on the asteroids Gaspra and Ida [7,8] and especially the new detailed measurements for Mars by Werner [9]. The best argument probably comes from the direct measurements of the current impact rates on Mars. Recently, Malin et al. (2006) [10] measured the number of fresh impacts and thus the impact rate on Mars on highest-resolution MOC imagery in the crater-size range of approximately 20m – 100m.

Conclusions: 1) The vast majority of small ($D \leq 1$km) impact craters on the moon and Mars in the steep part of the distribution are of primary origin and can (outside strewnfields of large primaries) be used with confidence for age dating within the statistical uncertainties and tolerable contamination within generally $< 10\%$ by unidentified unwittingly included small secondaries. 2) McEwen's [3,4] arguments of the uselessness of small craters for age dating and alleged incorrectness of the Hartmann & Neukum chronology by a factor of up to 2000 are plainly demonstrably wrong. The new hard data show that the Hartmann & Neukum chronology for Mars is correct, also using small ($D \leq 1$km) craters, within systematic uncertainties of probably less than 30% in terms of cumulative frequencies of the model which translates to absolute systematic age uncertainties of $\leq 30\%$ for ages ≤ 3 Ga and much less for ages > 3 Ga.

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