VARIATION OF THE RECENT MARTIAN IMPACT CRATERING RATE FROM EJECTA BLANKET AGES.

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Introduction: Apollo samples datings suggest an abrupt decline of the cratering rate around ~3.9 to ~3.5 Gyr, followed by a constant rate after 3.5 Gyr for kilometer-sized craters. The geological histories of all inner solar system bodies are based on this general pattern with variations among various authors for the mathematical expression of the lunar production function and cratering rate. However, the post 3.5 Gyr impact rate is only weakly constraints for ages younger than 3.5 Gyr (no Apollo samples between 3.25 and 0.8 Gyr, and 4 samples younger than 0.8 Gyr). A constant rate shall be considered as a simplification is the absence of better knowledge. This simplification has been also challenged by evidence for one or two major cratering spikes over the last 500 Myr due to asteroid breakup in the asteroid main belt[1,2,3]. Here we aim to test whether a constant or time variable impact rate scenario applies to both large (> 5 km in diameter) and small impact craters on Mars, in particular over the last 3 Gyr.

Methods: Layered ejecta blankets of Martian impact craters larger than 5 km in diameter exhibits continuous deposits and offer a better surface for crater counts in comparison with rayed/ballistic ejecta. One single area, located at the south of Acidalia Planitia (33°-46°N/46°-10°W) has a sufficient number of layered ejecta, and no resurfacing since their emplacement[5] (Fig.1). Each CSFD (Cumulative Size Frequency Distribution) of layered ejecta has been determined and counts were achieved on craters larger than 100 m. The derivation of each age has been performed by using CraterStats II[6] with Hartmann's equation for the production function and the impact rate[4,7] (named here and hence after "model clock"). Craters counts were also achieved over the entire intercrater plain to deduce its model age. The absolute model ages of large impact craters according to the model clock may be determined from small crater counts on each crater blanket[11]. If the complete cratering record may be documented for a given region of Mars, then the formation rate of large impact craters may be derived (named "control clock"). The control clock may be then compared with the model clock. An optimal impact rate scenario is found when the model clock equals to the control clock. Such a scenario describes the rate of formation of both large (>5km) and small impact craters. A first test is to determine the level of agreement between the control clock and the model clock corresponding to the constant impact rate scenario over the last 3.5 Gyr[4].

Results: Impact craters ages vary from $\mu 0.05 \pm^{0.02}_{0.01}$ Gyr to $\mu 2.20 \pm^{0.29}_{0.30}$ Gyr. The age of the study area was estimated to be $\mu 2.23 \pm^{0.10}_{0.10}$ Gyr from craters larger than 500 m. The rate of formation of large (≥ 5km) impact craters (control clock) is derived from the summation of all craters' Poisson distributions over the period extending from the age of the surface until present. It is found that the mismatch between the model and control clocks is large (Fig.2.a) and reflects the fact that a constant impact rate of formation since 3 Gyr, common to both small and large impact craters, is not a valid assumption.

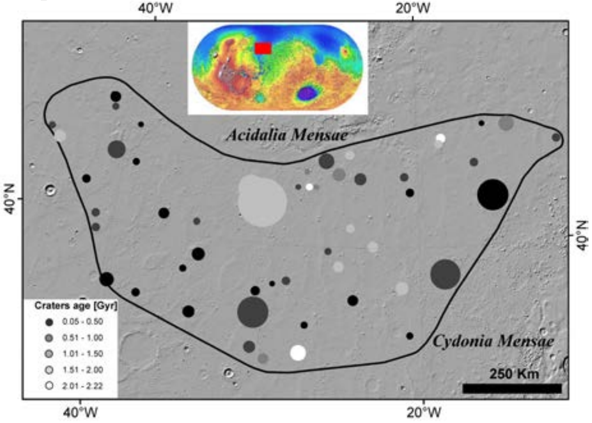

Fig.1: Study area delineation, location and model age of craters larger than 5 km which have been dated.

We have therefore explored a series of alternative model clock scenarios.The search for a model clock that minimized the distance (RMS) between control and model clocks is achieved by the direct exploration of the parameters of the different mathematical expressions of the model clock. Some authors have hypothesized that the impact rate varied in the inner Solar System over the last 3 Gyr according to: (a) a linear variation[1,8] (Fig.2.b), (b) a fluctuation during the most recent periods of the inner Solar System[9] (Fig.2.c), (c) spikes due to asteroid break-up events[1,2,3] (Fig.2.d). All of these hypotheses have been tested by modifying the mathematical expression of the Hartmann's impact cratering rate. The CSFD is assumed to be constant with time[10]. Results are shown in Fig.2. Hypothesis (c) has been simulated by introducing a Gaussian function defined by its amplitude, position and width.

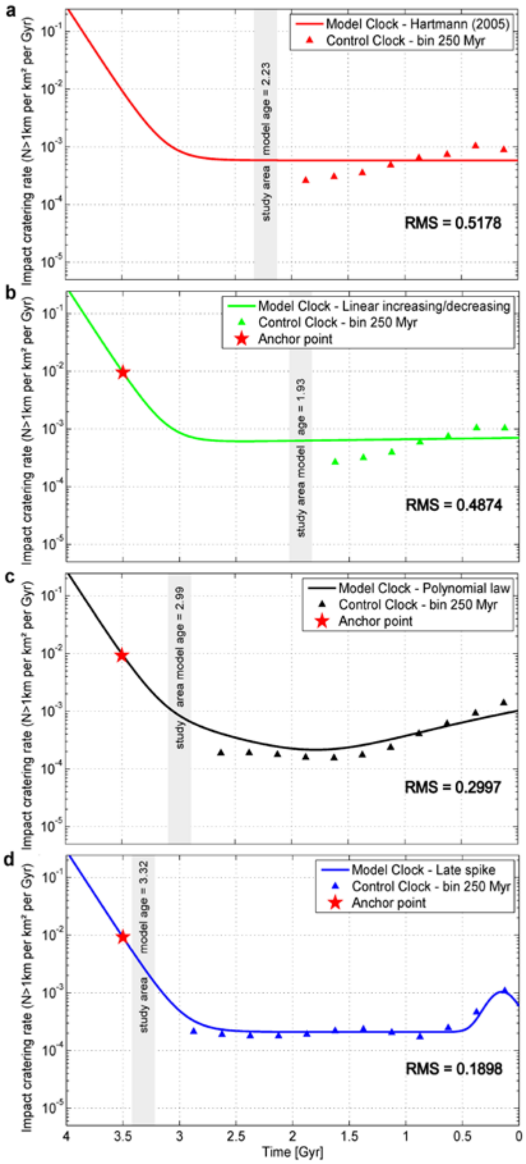

Fig.2: Martian impact rate from crater count model ages produced under the assumption of different cratering rate scenarios. **a**, Model clock associated with a constant impact rate. **b**, Model clock associated with a progressive increase of the impact rate by a factor of 1.2 at present time. **c**, Results of the application of a model clock described by a third degree polynomial law. **d**, Model clock with a cratering spike. Impact rate before the red star is equal to that of Hartmann.

A better match between the control clock and the model clock is obtained for the scenario (c): a constant impact cratering rate being ~3 times lower than Hartmann's rate and a spike at 150 Myr with a standard deviation of 120 Myr (Fig 2d). This control clock associated with this model clock produces a good match and returns a RMS equal to 0.1898.

Discussion: These results are in excellent agreement with the factor of ~2 increase in the km-sized impactor flux inferred from terrestrial and lunar craters[11,12,13] and the large amount of young lunar glass spherules (<400 Myr) found on lunar samples[1]. According to these studies, cratering spikes have resulted from two main asteroids breakups occurring respectively at 470[1,13] and 160 Myr[2]. We note that our results are consistent with one spike of 500 Myr, centered at 150 Myr which could correspond to the combination of the two cratering spikes at 160 Myr and 470 Myr (our observation does not allow resolving individual peaks).

Conclusion: The consequences of our new equation for the impact rate are especially relevant to recent geological activity and evidence of a recent climate change on Mars: terrains younger than 600 Myr with Hartmann's model are rejuvenated with our rate. The increasing of the proportion of the young Martian surface inferred by this cratering rate also reduces the difficulty to explain the frequency of young samples (Shergottites) among the Martian meteorites[14]. All inner Solar System terrestrial bodies cratering history had to be affected by these disruptions in the asteroid belt but to a different degree. In this case, the mean Venus surface age would be younger than the current estimate of 500 Myr[15]. Conversely, geological events on the Moon that appears to be recent from crater counts[16] would be older than previously assessed. Variation of the flux of bolides colliding with the Earth is also of great importance to examine the terrestrial impact record, its connection with mass extinction and, more generally evolution of life.

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