A chronology of Mars hydrological evolution from impact degradation

Conference or Workshop Item

A CHRONOLOGY OF MARS HYDROLOGICAL EVOLUTION FROM IMPACT DEGRADATION. N. Mangold, S. Adeli, S. Conway, V. Ansan, B. Langlais, Laboratoire Planétologie Géodynamique Nantes, CNRS/Universite Nantes, 2 rue de la Houssinière, 44322 Nantes, France, nicolas.mangold@univ-nantes.fr

Introduction: Impact crater degradation provides a powerful tool to analyze past Martian hydrological evolution. Previous studies concluded that large impact craters were strongly degraded during early Martian history, whereas younger craters are only weakly degraded [1]. Degraded craters are therefore one of the main lines of evidence for a warmer climate on early Mars. Global altimetry and recent high resolution imagery enable us to revisit this work. In particular it allowed us to identify preserved impact ejecta, which is strong evidence for limited degradation, and fluvial landforms on rims. These details were particularly pertinent in the case of the craters with alluvial fans [2]. We chose to focus our study on the craters with alluvial fans; their degradation stage, the type of fluvial erosion, and on their chronology relative to other climatic markers such as the global valley networks.

Qualitative classification: Our study focused on two large areas of the Noachian highlands where alluvial fans in craters were found by Moore and Howard [2]: Northern Hellas Planitia (NHP) at -17°S to -30°S latitude and 51°E to 85°E longitude and Southern Margaritifer Terra (SMT) at 13°S to 28°S latitude and 320°W to 350°W longitude. We distinguished only three classes, using two main parameters: the presence of preserved ejecta and of fluvial activity:

Type I: Craters with fluvial erosion on walls and rim but lacking an ejecta blanket.

Type II: Craters with fluvial erosion on walls and rim and a preserved ejecta blanket.

Type III: Fresh craters lacking any fluvial erosion on rim with a preserved ejecta blanket.

A total of 283 craters were able to be classified according to our scheme. In both regions, a large majority (~70%) are classed as type I. Type II craters are in equivalent proportion to those of type III. Alluvial fans are observed mainly in type II craters, that display preserved ejecta. This is a surprising result, because the presence of alluvial fans suggests an enhanced fluvial activity [2] that we would have expected more for older craters than fresher craters with preserved ejecta. Most type II and type III craters also display central peaks, suggesting confirming their lower degradation compared to type I craters.

Quantitative results: Figure 1 shows the depth-diameter plots for the two study regions. Both areas show similar patterns with a general trend of depth increasing with diameter. In both areas, the three crater types form groups, but the groups do overlap. Type III, which are the youngest craters have the deepest depths for a given diameter, and type I, the shallowest depths. Type II craters lie in-between these two other types. The fact that type II craters lay between types I and III, shows that this crater type is intermediate in the degradation series and therefore implies that this crater type is intermediate in age. The relatively weakly degraded nature of the type II craters is revealed both through the closer proximity of the type II craters to the type III craters and the proximity of these craters to the fresh global crater curve of Garvin [3].

Chronology: To obtain an overall chronology of the evolving stages of fluvial erosion on Mars we used both large-scale cumulative crater counts and detailed individual crater counts combined with superposition relationships. A regional crater-count for each crater type was performed for the NHP region only using all the craters studied. The chronology of all the craters in this region can be performed using classical isochrons [4] (Figure 2). The first isochron is derived from all the craters in the NHP region, i.e. using all types. For the second isochron, we removed the type I craters from the analysis, because they are the oldest, to derive an age corresponding to the time at which the first type II craters were emplaced. Lastly, the third isochron is derived from a list of type III craters only.

First, all the craters together gives an isochron at 4.00±0.03 Gy, which corresponds to the age of the basement. This age agrees with estimation of Hellas' formation at 3.99±0.04 Gy [5]. The transition between type I and type II craters occurs at 3.70±0.06 Gy, an age corresponding to the middle of the Early Hesperian period in this model age system [6]. This age pinpoints the period during which the strong fluvial degradation of Early Mars stopped. The transition between type II and type III is dated at ~3.32 +0.12/-0.34 Gy, thus at the beginning of the Early Amazonian in this age system.

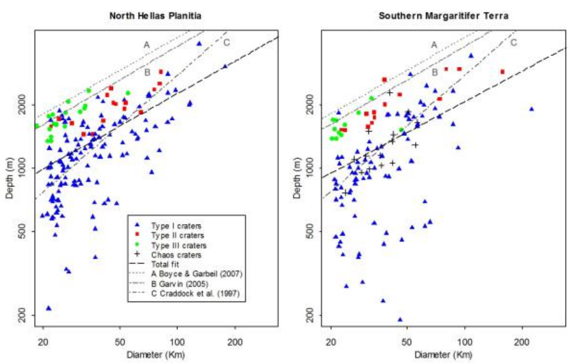

Fig. 1: A plot of depth against diameter plot for both study areas with each crater type having a different symbol.

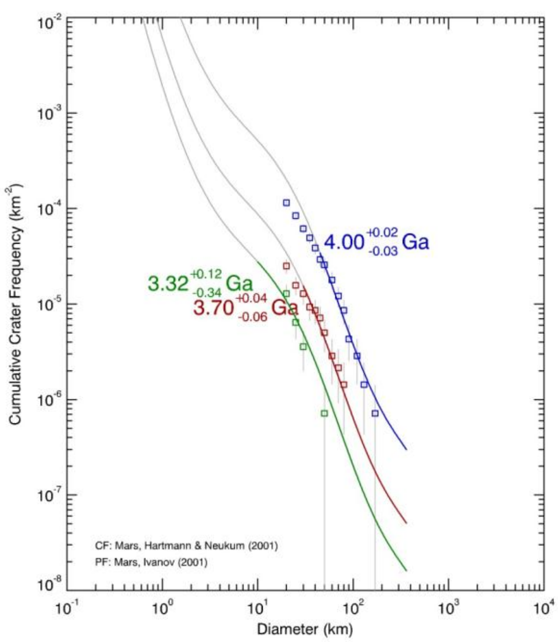

Fig. 2: Chronology of crater degradation at north Hellas Planitia using [4] tools. Age in black obtained from plotting all craters. Age in red obtained by removing type I craters. Age in blue obtained by removing both types I and II. The period defined by blue and red curve accounts for type I crater formation. The period defined by red and green curve accounts for type II crater formation. Fresh craters formed after age in green. Isochron in blue obtained for craters >40 km (shift of smaller craters below isochron due to small craters degradation). Isochron in red obtained for >25 km. Isochron in green obtained with all craters sizes.

Discussion and conclusion: Our chronology shows that type II craters formed from the Early Hesperian to earliest Amazonian epochs that are known to have been significantly colder than the Noachian period. Nevertheless, evidence of fluvial activity during this period has been reported in a number of locations [e.g; 7]. Alternatively, as mentioned by Moore and Howard [2], impact events can create significant warming, which can cause the melting of subsurface ice or surface snow [8,9]. Thus, alluvial fans in type II craters may represent, not a climatic optimum in the Late Noachian early Mars, but transient processes in the late stages of early Mars in the Hesperian. A recent study focused on 250-800-km impact craters and on Hesperian volcanoes showed that the dynamo stopped likely between 3.75 and 3.79 Gy, well after the Hellas impact [10]. This event may have caused a sudden climatic shift, which provoked the sharp shift in crater degradation conditions that we have detected at the end of the Early Hesperian, while subsequent conditions became colder. It appears also from our study that important craters such as Holden and Gale crater follows the type of depth/diameter relationship and style of type II craters formed during this subsequent period.

References: [1] Craddock and Maxwell (1997) *JGR*, 102(E6), 13321-13340, [2] Moore and Howard (2005) *JGR*, *110* (E4), E04005, [3] Garvin (2005) Role of Volatiles and Atmospheres on Martian Impact Craters, no.3052, [4] Michael and Neukum (2010) *Earth Planet. Sci. Lett.*, *294*(3-4), 223-229 [5] Werner (2008) *Icarus*, *195*(1), 45-60, [6] Werner and Tanaka Icarus, doi: 10.1016/j.icarus.2011.07.024. [7] Mangold et al., *Science*, *305*(5680), 78 -81, [8] Segura et al Science, 298, 1977-1980, [9] Segura et al J. Geophys. Res. 113:E11007, [10] Langlais et al EPSC/DPS meeting, Nantes, 2011-773.