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How long and intense was Early Mars ?

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Abstract

Despite recent observations about the processes that occurred on early Mars, we have yet to reconstruct the early climatic evolution of the red planet. Did Mars experience an early wet and warm climate as suggested by the presence of valley networks on Noachian terrains? If so, how long and intense (in term of erosion rates) was this wet period? Was this warm and wet period episodic or sustained? Here, we present a numerical model that generates a synthetic crater size distribution based on an applied model of impact rate evolution as well as a modeled erosion rate. The results provide a basis for understanding the duration and the intensity of the climate of Early Mars.

1. Introduction

Currently erosion rate estimates have been suggested from the age deduced from analyses of crater density as well as the morphologies of valley networks and modified impact crater [1,2,3]. The estimates of Noachian erosion rates range from 0.8 m/My to 7.7 m/My [4].

Crater size distributions of a planetary surfaces, and especially old surfaces of Mars, record both the cratering rate and the erosion history. Variations from a theoretical crater size distribution that would result from meteoritic bombardment is interpreted as erosional or depositional processes and is called the Opick effect [5,6].

Here, we develop a numerical model to generate synthetic crater size distributions while applying a model of impact rate evolution as well as a model erosion rate evolution. First, we present the model and few cases of synthetic crater size distribution. These allows us to suggest explanations for Noachian terrains crater size distributions, and they raise discussions on the duration and the intensity of the climate on early Mars.

2. The Model

We used the cratering rate model defined by [7] from the cratering analysis of the lunar surface and Apollo sample radiometric ages and applied to Mars [6]. The temporal resolution of the model is 1 My. For each periods of Mars history, the model calculates the number of impact craters per surface unit for each crater size bins defined by [6]. Based on the crater diameter to depth ratio, we estimate the average crater depth of a crater size bin. We then apply the erosion model. We used the threshold of 1 m of depth to remove the crater from the record.

The free parameter of the model is the type of erosional process. From a simple case of a biphasic model with two constant erosion rates, the model may have several erosion phases with evolution of the erosion rate from linear to exponential. Cyclic high erosion rate phases are also tested. The rate of erosion and the duration of the phases are also free parameters.

4. Results

Figure 1 presents two simple biphasic models. The first examples presented in figure 1 (top plots) are the result of a biphasic model with a first period with a linear decrease of the erosion rate from 10 m/My to 0.01 m/My between 4.2 Gy and 3.5 Gy and a second phase with a constant erosion rate from 3.5 Gy to 0.01 m/My today. The corresponding synthetic crater size distribution reveals that the Opick effect starts for crater smaller than around 50 km.

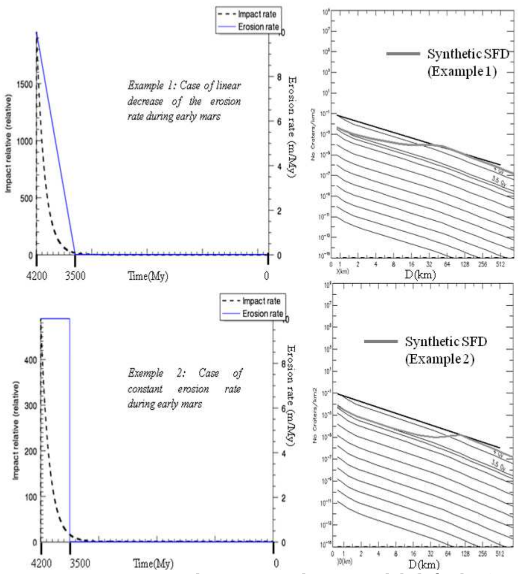

Figure 1: cratering and erosion evolution model (left plots) applied to generate the synthetic crater size distributions (right plots) plotted here in incremental representation that is more sensitive to the Opick effect [6]

The second example is the simple case of a first erosion phase from 4.2 Gy to 3.5 Gy at 10 m/My and a second phase from 3.5Gy to today at 0.01 m/My. The corresponding synthetic crater size distribution reveals more intense erosion with the Opick effect starting for crater smallest than around 100 km.

The next step is to compare these synthetic SFD to real crater size frequency distributions of Nochian Martian terrains. We will study several examples of Martian Noachian terrain crater size frequency distributions (SFD). We will then suggest a scenario of erosion evolution that best fits crater density derived for the Martian terrains. We will examine several Noachian-age regions of Mars distributed around the planet and assess their erosion history (duration and intensity).

6. Summary and Conclusions

This model allows us to constrain the maximum erosion rate that Noachian Martian cratered terrains have experienced. This model permits us to speculate about the duration and the intensity of Early Mars

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