TORO CRATER: FIRST EVIDENCE FOR HESPERIAN PHYLLOSILICATES ON MARS

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Introduction: Phyllosilicates inside impact craters on Mars have been suggested to be excavated Noachian pre-existing sediments [1]. Here we analyze the case of Toro crater to propose the hypothesis that some of its phyllosilicate deposits have been formed after the impact excavation, ie., during the Hesperian.

Toro crater: We named Toro (International Astronomical Union approval on November 24, 2008) an impact crater 42 km in diameter and 2 km depth, located on the northern margin of the Syrtis Major Volcanic Plains (71.8E, 17.0N) (Fig. 1). The central uplift of Toro is approximately 8 km in diameter and rises more than 300 m above the crater floor at its highest point.

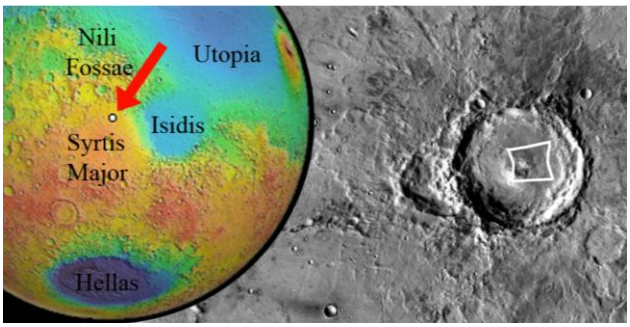

Fig. 1: MOLA map of Mars centered on Toro (red arrow), and THEMIS mosaic of Toro. The hourglass shape represents the location of the CRISM observation FRT0000B1B5 (Fig. 3).

Crater counting indicates that Toro has an estimated age of 3.6 ± 0.1 Ga. (Fig. 2), and therefore the impact event occurred during the Hesperian.

Abundant phyllosilicates have been observed through analysis of CRISM images in the greater Nili Fossae region [2], including Toro crater. Here we focus on identification of distinct hydrated silicate deposits inside Toro using CRISM NIR hyperspectral images. Particularly, the central ring presents a strong occurrence of material consistent with extensive hydrated and hydroxilated silicate deposits [2,3] (Fig. 3).

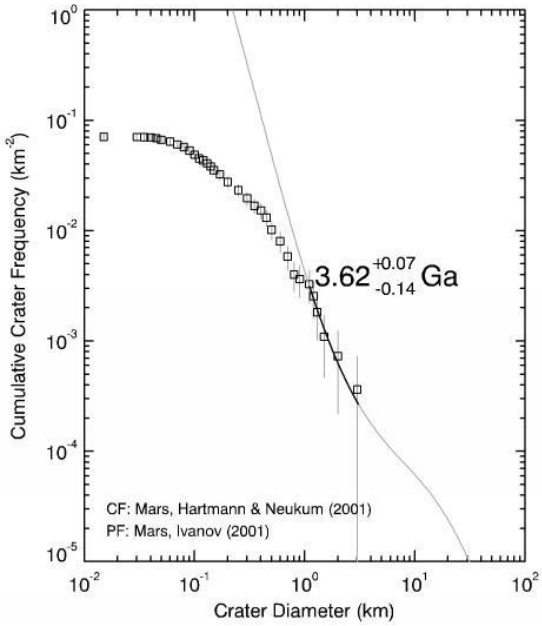

Fig. 2: Crater size-frequency distribution of the ejecta blanket for determining the base-age of Toro crater. CF is chronology funcion [4], and PF is a production function [5].

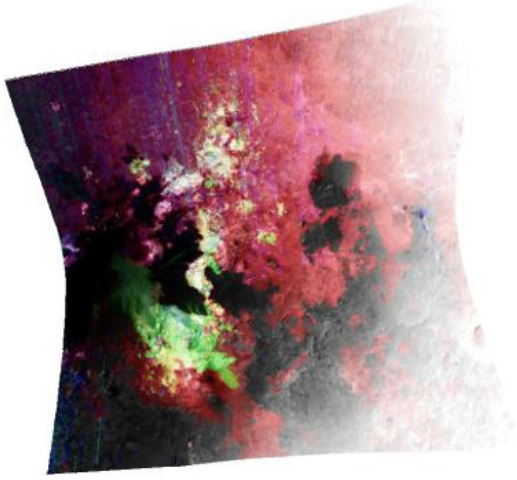

Fig. 3: CRISM observation FRT0000B1B5. Red = smectites, green = prehnite, blue = chlorites. Mixed colors represent mineral mixtures.

Thermal stability of phyllosilicates: We have experimentally tested the thermal stability of the phyllosilicates observed in the central uplift of Toro crater.

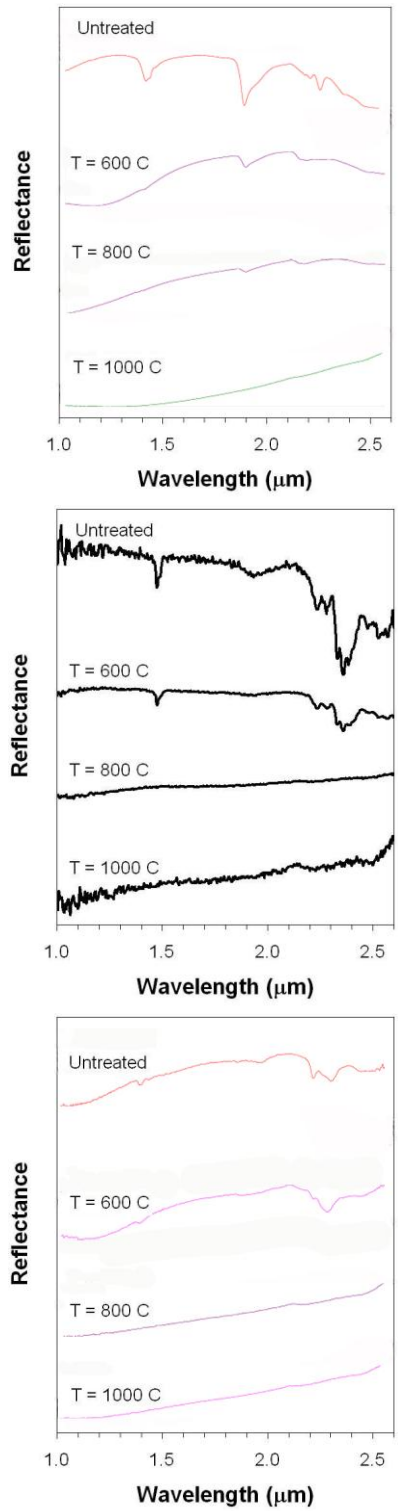

Fig. 4: Laboratory reflectance spectra of heated samples of nontronite, prehnite and chlorite (top to bottom).

Our results show that these three phyllosilicates become unstable at temperatures ~600°C, resulting in both a phase transformation and a loss of volatile components (water and hydroxil) contained in the crystal lattice. A severe modification of the characteristic spectral signatures is noted in all three cases at temperatures over ~800°C [6].

Impact excavation: In Fig. 5 we report the shock-induced ΔT underneath the transient Toro crater. We assume for the Hesperian period a surface T around -75°C [7], and a geothermal heat flow gradient of 50°C/km, four times higher [7] than at present [8]. Fig. 5 shows the case for a 2.5 km basaltic asteroid impacting vertically at 12 kms^{-1}. Our results show that the impacted preexisting rocks, which now form the central peak, reached a T over 900°C during the excavation of Toro.

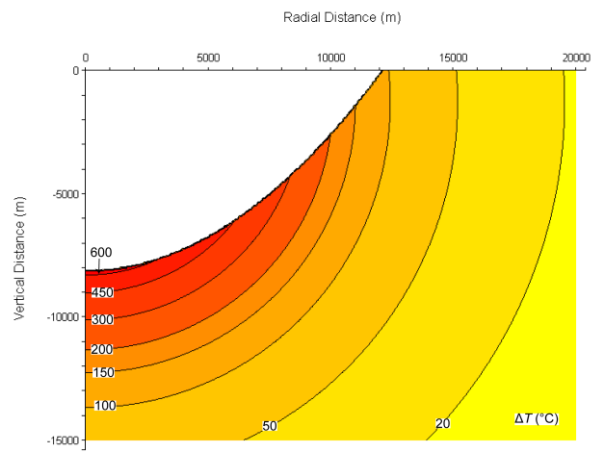

Fig 5: Temperatures in the transient Toro crater.

Conclusions: To understand the nature of the Toro phyllosilicates, the redistribution of highly shock heated materials via excavation and modification need to be assessed. We show here that some preexisting deposits of nontronite, prehnite and chlorites at the Toro site are expected to be dehydrated and dehydroxylated by the impact process, completely losing their spectral signatures. Phyllosilicates tied to the impact would be Hesperian or younger, representing the first documented case of phyllosilicate synthesis occurring after the Noachian. We suggest that these phyllosilicates are the result of Hesperian impact-induced hydrothermalism.

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