TORO CRATER: THE CASE FOR HESPERIAN PHYLLOSILICATES ON MARS

A. G. Fairén[1,2], G. A. Marzo[2], V. Chevrier[3], P. Gavin[3], A. F. Davila[1,2], C. Gross[4], T. Kneissl[4], T. L. Roush[2], J. L. Bishop[1,2], J. M. Dohm[5], L. L. Tornabene[6] & C. P. McKay[2]
[1] SETI Institute, 515 N Whisman Road, Mountain View, CA 94043, USA. [2] Space Science and Astrobiology Division, NASA Ames Research Center, Moffett Field, CA 94035, USA. [3] W. M. Keck Laboratory for Space and Planetary Simulation, Arkansas Space Center, University of Arkansas, Fayetteville, AR 72701, USA. [4] Institute for Geological Sciences, Planetary Sciences and Remote Sensing, Freie Universität Berlin, Malteserstr. 74-100, 12249 Berlin, Germany. [5] Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721, USA. Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA. Email:alberto.g.fairen@nasa.gov

Introduction: Phyllosilicates inside impact craters on Mars have been suggested to be excavated pre-existing phyllosilicate-rich sediments formed during the earliest times of the geological history of the planet [1]. Here we propose and test the hypothesis that at least some of these phyllosilicate deposits have been formed after the impact excavation.

Thermal stability of phyllosilicates: We have experimentally tested the thermal stability of phyllosilicates known to be present in central uplifts of Martian craters against the shock-induced temperature created by an impact event. Our results show that phyllosilicates become unstable at high temperatures, resulting in phase transformation and loss of volatile components (mainly adsorbed water and OH groups) contained in the crystal lattice. These changes are apparent in our laboratory spectra of phyllosilicates that have been reported to be present on Mars[2]: nontronite, montmorillonite, chlorite, kaolinite, prehnite, and serpentine (Fig. 1). A complete loss of spectral signature is noted in all cases at temperatures over ~1000 K.

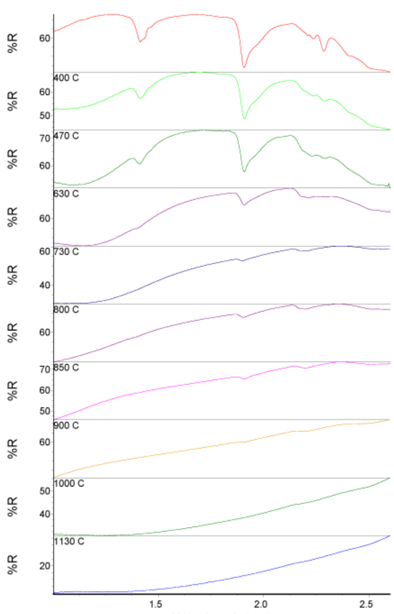

Fig. 1: Example of laboratory spectral measurements illustrating the thermal stability of nontronite.

Impact excavation: We have modeled the shock pressure and the following residual temperature induced by an impact event on Mars adopting previous approximations from [3,4]. In Fig. 2 we report the diameter of the region enclosing a residual temperature of 1000 K in a 42 km diameter impact crater on Mars, for different densities and velocities of the impacting object.

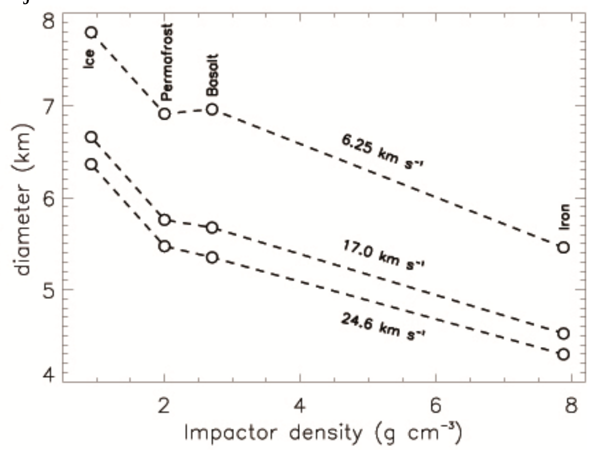

Fig. 2: Region enclosing a residual T ~1000 K.

The case of Toro crater: We have applied our results detailed above to a crater we named Toro (International Astronomical Union approval on November 24, 2008). Toro is an impact crater 42 km in diameter and 2 km depth, located on the northern edge of the Syrtis Major Volcanic Plains (71.8E, 17.0N).

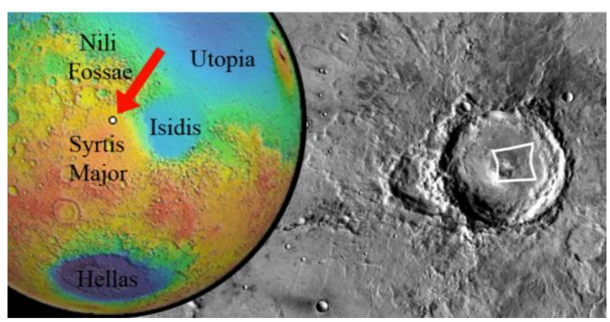

Fig. 3: MOLA colorized shaded relief map of Mars centered on Toro (red arrow), and THEMIS grayscale mosaic of Toro. The hourglass shape represents the location of the CRISM observation FRT0000B1B5 (Fig. 4).

Spectroscopic observations of Toro have been used to identify extensive hydrated and hydroxilated silicate deposits [5] (Fig. 4).

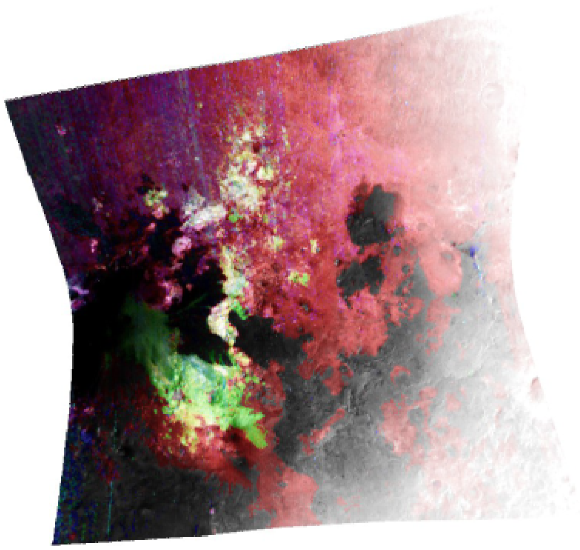

Fig. 4: CRISM observation FRT0000B1B5. Red = smectites, green = prehnite, blue = chlorites. Mixed colors represent mineral mixtures.

In Fig. 5, the area of surface directly hit by the impactor and the surrounding region heated up to 1000 K are drawn for the case of Toro, assuming a quite dense object (e.g., basalt) impacting at 17.0 kms^{-1}.

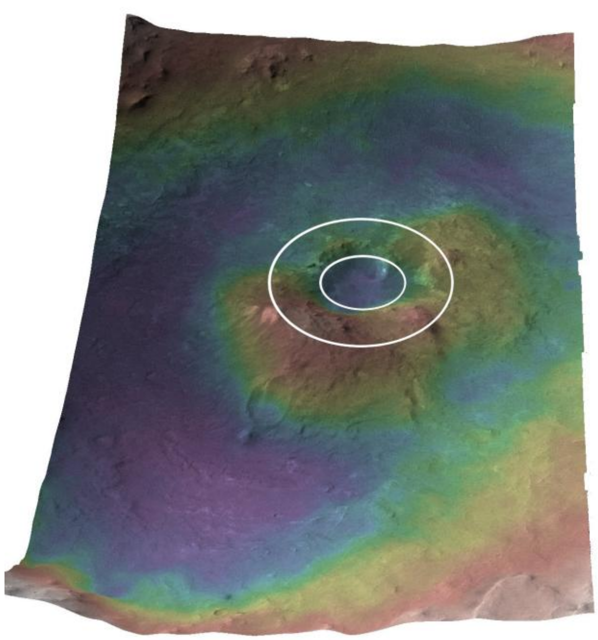

Fig. 5: Digital elevation model of the central peak of Toro crater from HRSC observation 3069_0000. The inner circle marks the diameter of the impactor, and the outer circle defines the area heated at 1000 K, after Fig. 2.

Pre-existing surface and subsurface phyllosilicate-bearing sediments located in and near the impact point are therefore expected to be dehydrated and dehydroxylated by the impact process. The extensive deposits of phyllosilicates associated with the central peak of Toro raises the question if these deposits are exclusively excavated phyllosilicate-bearing materials, or they were formed or deposited after the impact event.

Hesperian phyllosilicates in Toro: Finally, we have determined the age of Toro crater. Crater counting indicates that Toro has an estimated age of 3.6 ± 0.1 Ga. (Fig. 5), and therefore the impact event occurred during the Hesperian.

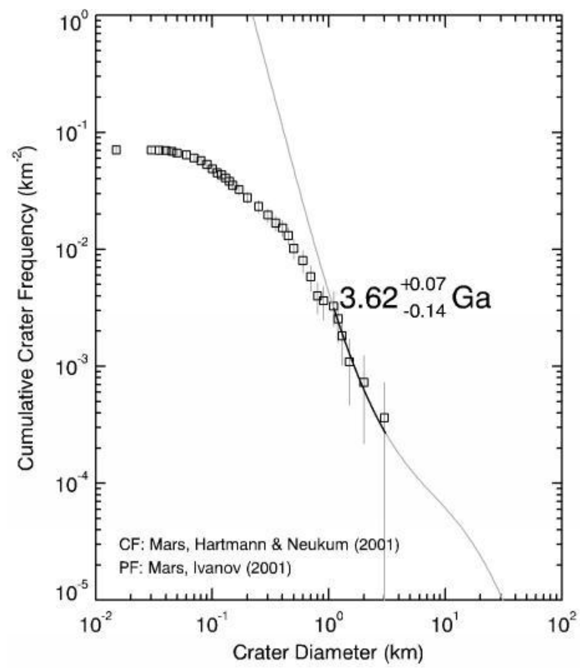

Fig. 5: Crater size-frequency distribution of the ejecta blanket for determining the age of Toro crater. CF is chronology funcion [6], and PF is a production function [7].

Conclusions: At least some of the phyllosilicates in the central ring of Toro are Hesperian or younger, and those prevail as the first documented case of phyllosilicate synthesis occurring well after the Early Noachian. We suggest that the synthesis of these phyllosilicates in the central ring of Toro is the result of Hesperian impact-induced hydrothermalism.

References: [1] Bibring, J. P., et al., Science 312, 400-404 (2006). [2] Gavin, P. & V. Chevrier. Icarus, Submitted. [3] Kieffer, S. W., C. H. Simonds, Rev. Geophys. Space Phys. 18, 143-181 (1980). [4] Carr M. H. Icarus 79, 311 (1989). [5] Marzo, G. A. et al.. Icarus, submitted. [6] Hartmann, W.K. & Neukum, G. Space Sci. Rev. 96, 165–194 (2001). [7] Ivanov, B. A. Space Sci. Rev. 96, 87-104 (2001).