IDENTIFICATION OF AQUEOUS MINERALS AND SUBSURFACE/INTERSTITIAL ICE SIGNATURES FROM A CRATER IN THAUMASIA, MARS

R. Sarkar[1] , P. Singh[1] , A. Porwal[1] , [1]Geology and Mineral Resources Group, CSRE, Indian Institute of Technology, Bombay , 124313001@iitb.ac.in

Introduction: We report aqueous minerals (sulphates and phyllosilicates) from an unnamed crater (centered at 31° 26' 43.71''S; 72° 00' 28.77''W) located in Thaumasia region, Mars using CRISM multispectral imagery. Hydrated sulphates are found on the inner wall and phyllosilicates in the mounds on the floor. We also find evidence of (active?) subsurface/interstitial ice within and around the crater.

Geology: The Thaumasia region of Mars is mostly a plateau area consisting of high lava plains formed during the Noachian and Hesperian and having a complex volcano-tectonic past [1]. The crater is located on the Thaumasia Highlands which is an ancient mountain range [2,3]. It has a diameter of 45 km and is about a kilometre deep. The main geomorphic units are:

Rim: The rim is quite distinct geomorphologically in the northern and southern ends. On the northern wall we find lobes of rim forming material (black arrows in Fig. 1a), separated by dry gully-like features (blue arrows in Fig. 1a), creeping down the walls towards the crater floor in a quasi-viscous manner.Some of these lobes superpose the crater floor indicating a much younger age. The southern wall is devoid of such features. The lobes appear to be rock glaciers, in particular protalus lobes [4].

Ejecta blanket: The ejecta blanket is readily observable outside the southern rim where it is more expansive. It is dissected into southwards advancing lobes, resembling protalus lobes [4] (black arrows in Fig. 1b) by gullies running southwards though them.

Gullies: Gullies (or putative water flow channels) originate from the northern wall (blue arrows in Fig. 1a) and also from within the south facing ejecta blanket (outside the southern rim) (Fig. 1b). These are filled with erosional debris exhibiting surface lineations and their points of origins are marked by surface collapse (Fig. 1a). Due to the absence of any feature indicative of an external source for these gullies, mobilization/destabilization of subsurface ice and/or water becomes a possibility for the formation of these features.

Mounds: The mounds are in all probability the remnants of the central rise in a complex crater [5,6]. The amount of stratigraphic uplift can be calculated using the relation SU=0.086D1.03 [7] where SU= Stratigraphic uplift; D= crater diameter. Using D=45km, we see that the stratigraphic uplift is 4.3km.The mounds are highly fractured/faulted and have suffered intense erosion (indicated by black arrows in Fig.1c).They do not show any tendency to flow/creep, nor do they carry any of the characteristics imparted by ground ice.

Craters on the floor: Among the numerous craters on the floor, there are four near the northern wall (the largest among these is shown in Fig. 1d) which display a clear dichotomy: their northern portion is rugged and knobby while the southern portion is smooth and intact. The smooth and intact material appears to mantle the rugged and knobby terrain and the latter is revealed where the former is absent. The mantle appears to have a uniform thickness and sufficient strength to support its own weight to prevent spreading like dry sand, indicating induration/cementation. Interstitial ice is an appropriate agent in this case to act as cement for the mantle [8].Moreover there are well defined curvilinear lines of collapse along and within the mantling material particularly near the edges where it merges into the rugged northern portion.The uniform mantle could be dust and soil permeated and cemented by ground ice; the rugged and rocky appearance could be produced by the lag left behind when the ice sublimates/melts away [8]. Next, the occurrence of the rugged northern floor and a smooth southern floor could be explained by differential heating by solar insolation [9].

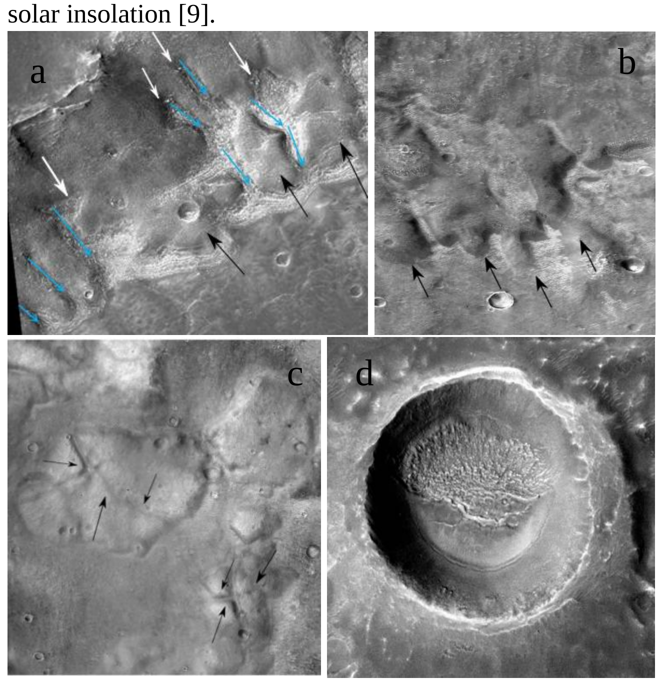

Figure 1: (a) Wall of the crater: *blue arrows*: gullies; *black arrows*: advancing lobes; *white arrows*: surface collapse. (b) Black arrows indicate lobes originating from the ejecta blanket. (c) Fractured/faulted mounds. (d): Crater with dichotomy. In all the images North is to the top.

Age: Here absolute age is adopted from the chronology model given by [10]. The crater-count statistics was built over CTX imagery d09_030690_1474_xn_32s071w. Cumulative size frequency curve is drawn and is fitted with production function derived by [11] (Fig. 2). The diameter of the crater is 45 km, and 234 sq km area was chosen from the central mounds of the crater and 180 craters were counted within the selected area. The absolute age of crater is obtained as ~3.46 Ga, which belongs to Late Hesperian.

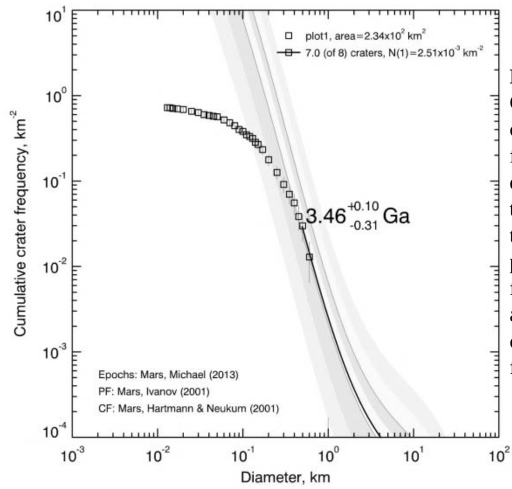

Figure 2: Cumulative crater size-frequency distribution of the mounds on the floor; PF is production function [11] and CF is chronology function [10].

Mineralogy: We have used CRISM multispectral image t0572_mrrif_30s288_0256_3 after applying the photometric and volcano-scan corrections [12]. We have detected Mg-smectites (absorptions at ~1.4, ~1.9 and ~2.31 μm [13]) (Fig. 3a) and hydrated sulphates (absorptions at ~1.4/1.6, ~1.9/2.1 and ~2.4 μm [14]) (Fig 3b). The sulphates are possibly kieserite and some polyhydrated species.

Observations: Firstly, features indicative of subsurface/interstitial ice activities are found in the walls, ejecta blankets and smaller craters on the floor. These are particularly developed on south facing surfaces which are possibly related to differential solar insolation [9]. The mounds do not display any affiliation to subsurface ice. Secondly, the crater belongs to Late Hesperian as deduced from crater count statistics. Lastly, we have also detected hydrated sulphates in the walls and phyllosilicates in the mounds using CRISM multispectral data.

Discussions: Phyllosilicate formation requires non-acidic environments while hydrated sulphates require an acidic environment, which have existed on Mars at different eras, namely the Noachian and the Hesperian [15]. We find both to be present within the crater at different locations.

The phyllosilicates could be of Noachian age, occurring in the subsurface, which had been uplifted and exposed through the crater formation [15]. A second possibility is that these have formed during Hesperian through hydrothermal activity and aqueous alteration triggered by the impact cratering [16,17]. This would assign a much younger age to the phyllosilicates, much later to the Noachian [16,17]. Following from this, it could be possible that both the phyllosilicates and hydrated sulphates are results of cratering.

Moreover, subsurface/interstitial ice was/is still present in this area and perhaps continues to shape the landforms. This observation is in convergence with the reports of [18].

Higher spectral and spatial resolution imagery would help us look into the geology more closely and interpret the formational histories of the sulphates and phyllosilicates.

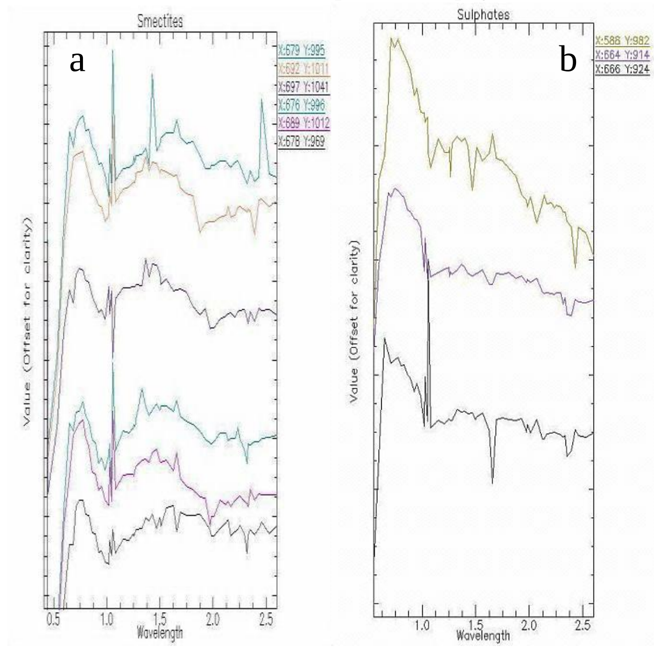

Figure 3: (a) Phyllosilicates, mostly Mg-smectites. (b) Hydrated sulphates, top spectrum is of a polyhydrated and bottom two are of a monohydrated variety. In both images the pixel numbers are provided to the right and are in the same vertical order of the given spectra.

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