CONTROL OF EXPOSED AND BURIED IMPACT CRATERS AND RELATED FRACTURE SYSTEMS ON HYDROGELOGY, GROUND SUBSIDENCE/COLLAPSE, AND CHAOTIC TERRAIN FORMATION, MARS. **J.A.P. Rodriguez[1], S. Sasaki[1], J.M. Dohm[2], K.L. Tanaka[3], H.Miyamoto[2], V.Baker[2], J.A. Skinner, Jr.[3],G.Komatsu[4] , A.G. Fairén[5] and J.C. Ferris[6]:**[1]*Department of Earth and Planetary Sci., Univ. of Tokyo, 7-3-1 Hongo, Bunkyo-ku Tokyo 113-0033, Japan (Alexis@space.eps.s.u-tokyo.ac.jp),* [2]*Department of Hydrology and Water Resources, Univ. of Arizona, AZ 85721,* [3]*Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ 86001,* [4]*International Research School of Planetary Sciences, Università d'Annunzio, 65127 Pescara, Italy,* [5]*Centro de Biología Molecular, Universidad Autónoma de Madrid, 28049 Cantoblanco, Madrid, Spain ,* [6]*U.S. Geological Survey, Denver, CO, 80225.*

Introduction. Mars is a planet enriched by groundwater [1,2]. Control of subsurface hydrology by tectonic and igneous processes is widely documented, both for Earth and Mars [e.g., 3]. Impact craters result in extensive fracturing, including radial and concentric peripheral fault systems, which in the case of Earth have been recognized as predominantly strike-slip and listric extensional, respectively [4]. In this work we propose that basement structures of Mars largely result from impact-induced tectonism, except in regions that are dominated by magmatic-driven activity such as Tharsis [e.g., 5] and/or possible plate tectonism during the extremely ancient period of Mars e.g., [6]. In many cases, impact-induced faults appear to have been reactivated and/or displaced by subsequent magmatic-driven groundwater-flow and collapse processes [7].

Fractured impact crater floors: These features are concentrated in the ancient cratered highlands along the margins of plain regions and within the lightly cratered plains near the canyon system of Valles Marineris [8]. Moats within some of these craters of varying diameters and relative ages surround plateaus and contain broken material (Fig. 1). The moats appear to be restricted to the margins of highly degraded crater rims. Only certain craters in a given region, however, display these characteristics. Schultz and Gliken [8] proposed that modificational processes were localized by the impact structures and restricted to the crater interiors. They interpret this to be the result of heat generated by a tabular magmatic intrusion injected beneath the brecciated zone of an impact crater, which raises the temperature of the overlying material. Thawed materials would then subsequently escape through the peripheral fracture system surrounding the crater, or alternatively, a metastable state of liquification could occur, if the material is confined or the rate of thawing exceeds the rate of escape. The collapsed material within a moat marking a highly degraded impact crater rim forms ridges around a central plateau region (Fig. 1B). This suggests that the degradational processes may have been controlled by extensional concentric faults, possibly initiated during the inward collapse of the transient crater walls [4] and/or by concentric fractures produced by the uplift of the crater floor, possibly resulting from the injection of a tabular magma body beneath the crater floor [8]. The water-enriched source region, which may have contributed to the formation of the features shown in Fig. 1A,B, has been destroyed, suggesting that the formation of the moat may have involved hydrologic processes. In addition, a depression that transects an impact crater (Fig. 1B) forms part of a longer valley, which terminates at the western margin of the Hydaspis Chaos (Fig. 1, V-B). This scenario may be explained by tabular intrusions being injected under crater floors and/or by hydrologic processes controlled by structures within impact craters [8].

Progressive highland subsidence and collapse: Rodriguez et al. [9] described the progressive highland subsidence and collapse of the Late Noachian subdued crater unit [10] in Xanthe Terra (Fig. 1). They propose that regional subsidence and collapse resulted from the release of pressurized groundwater in confined caverns. The release of water described in [9] served as an important, previously unproposed source of the water that carved the outflow channels. Terraced terrain marked by both chaotic terrain and channel bedforms (Fig. 2) may also indicate the release of large quantities of water and related collapse. These observations suggest that the plateau material was degraded and removed more efficiently from within craters than from the surrounding country rock (Fig. 3).

Crater-related fracture networks: Layered materials are pervasive on Mars [11] and may contain numerous buried impact craters of varying degradational states (Fig. 3). We propose that impact-induced fracture systems dominate the fracture population in the ancient highlands, away from volcano-tectonic regions [7].Intermingling concentric and radial fracture systems from multiple impact crater events will result in complex crater fracture networks (CFN). Periods of rapid and/or modest surface burial, or periods of lesser bombardment and higher burial, will result in regions with relatively less abundant buried impact crater populations. As a consequence, the CFN will be less developed. On the other hand, heavy bombardment coupled with slow degradation and/or surface burial are expected to result in denser buried crater populations and highly developed CFN. We propose that the highland plateaus are stratified into zones of variable fracture density. Fractures radial to impact craters will tend to converge near the buried craters' interior deposits. Since heat flow is hydrothermally transferred more rapidly and effectively along fracture planes, a consequence of this scenario is that pulses of heat, generated by magmatism, for example, will result in a highly anisotropic heat flow distribution, with higher heat flow and thus warming in areas of high fracture density. Valley networks dissecting the crater rims in the ancient highlands [1] suggests that crater interior deposits may have contained significant amounts of water-laden sediments. Therefore, buried impact craters are likely to be ice-enriched regions within the Martian permafrost [2]. Warming of the crater interior deposits might have resulted in melting of large volumes of water and intensive hydrothermal circulation and fracture enlargement, forming conduits that allowed subsurface distal migration of volatiles as well as escape to the surface. We propose that circulation within densely fractured regions will be highly effective at removing crater materials, possibly forming cavities, and resulting in the storage of large amounts of water within the subsurface conduit systems and porous media. Lateral interconnection will be enhanced by subsequent impacts. For example, impacted-induced basement structures and uplifted and overturned strata that dip away from the crater will interconnect regions with different permeability and volatile content. We propose that the distinct topographic levels visible in the plateau region of Fig. 2 can be explained by the successive collapse of densely fractured zones. The distribution of moderately vs. highly fractured zones, particularly if stratigraphically controlled, will determine the number of collapsed plateau levels in a given highland region. If collapse occurs to great depths, or the thickness of the collapse region is relatively thick, the plateau surface might respond by simple crustal warping and fracturing. On the other hand, if collapse occurs to shallow depths or the thickness of the collapse region is relatively thin, chaotic material may result. Evidence such as truncated impact craters preferentially preserved at distinct levels of subsidence (Fig. 2) and collapse features more common on crater floors (versus surrounding plateau material; Fig. 1) collectively add credence to our hypothesis that suggests preferential removal of subsurface crater interior deposits. Yet fracturing and collapse of crater floors were not localized to individual impact structures. Non-uniform groundwater and heat flow may explain why only certain craters display the characteristics described above for a given region. The formation of moats encompassing crater infill (e.g., Fig. 1) suggests that impact-induced fractures are more densely packed around the periphery of the crater rather than beneath the central fill.

Although, regional variations in heat-flow, and in the density and distribution of fractures, will result in variable degrees of hydrologic activity, and result in regionally driven and closed hydrologic environments, we propose that CFN formed primarily during the Noachian resulting in global interconnectivity of the subsurface groundwater systems during the early Mars.

Fig. 1. ***A.****THEMIS day-time infrared composite. 50 km in diameter impact crater with a moat around a central plateau (CA). North is at top. Lobate features (L). Impact crater with poorly developed moat (red arrow. A 30 km wide, 300 m deep depression transects the crater (blue pointer).* ***B.*** *Composite of MOLA DEM containing A.*

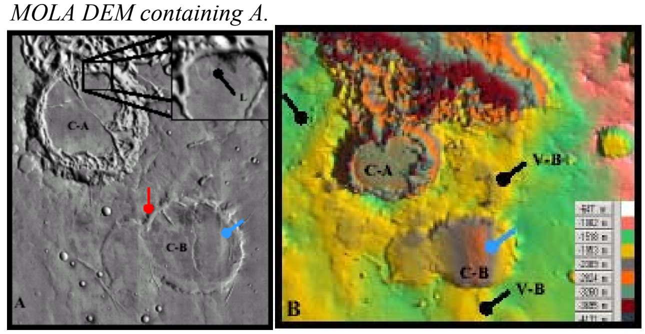
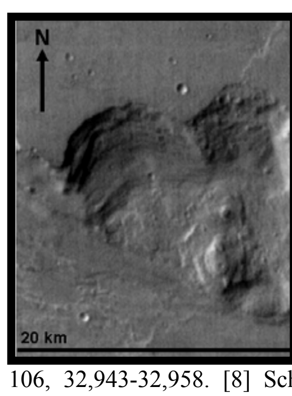


Fig. 2. *MOLA based DEM. Image is 350 km wide. Noachian plateau region located to the north of Eos Chasma. Chaotic materials occur at several topographic levels (CL-A to E). Channel bedforms (blue arrows).Arcuate scarps (red pointers).*

Fig. 3. *THEMIS day-time infrared subframe showing Noachian plateau near Hydaspis Chaos. Arcuate scarp 1000 m high exposes layered sequence.*



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