SIGNIFICANCE OF CONFINED CAVERNOUS SYSTEMS FOR OUTFLOW CHANNEL WATER SOURCES, REACTIVATION MECHANISMS AND CHAOS FORMATION. **J.A.P. Rodriguez[1], S. Sasaki[1], H.Miyamoto[2] and J.M. Dohm[2]:** *[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, sho@eps.s.u-tokyo.ac.jp) [2]Department of Hydrology and Water Resources, Univ. of Arizona, AZ 85721 (miyamoto@geosys.t.u-tokyo.ac.jp, jmd@hwr.arizona.edu).*

Introduction: The formation of outflow channels has been attributed to catastrophic discharges of ground water [1,2]. To the present, the following hypotheses have been proposed to explain modes of confinement and release of ground water, trapped within the Martian cryosphere: Catastrophic release of groundwater stored within confined aquifers [3], both catastrophic and non-catastrophic release of groundwater segregated from the permafrost into confined cavernous systems [4], and catastrophic release of groundwater extracted from the permafrost by thermal convection [5]. Ground water release resulted in the formation of chaotic terrains, broad areas of jostled blocks and knobs as much as 2 km deeper than the surrounding highlands, mostly located at the head source regions of the outflow channels [6]. Their formation has been attributed to collapse of plateau material [3,6,7], possibly involving multiple events [5]. Crater counting of the outflow channel floors indicates a late Hesperian age [8].

In this abstract we discuss the geomorphology of a highland region (Hereafter referred to as The Subsided Plateau Region (Figure 1, SPR), located east of Valles Marineris and bounded to the South by the Aureum Chaos, to the West by the Hydraotes Chaos, and to the north by the Hydaspis Chaos. We propose a new hypothesis, which can potentially explain the following unresolved issues: (1) sources for the large volumes of water required to carve the outflow channels, (2) mechanisms of outflow reactivation, which do not involve recharging of the head source region. In this hypothesis we also propose an alternative mode of formation for chaotic terrains.

Highland subsidence: The SPR forms part of the region mapped by *Rotto and Tanaka* [5] as the subdued crater unit and described by them as a Late Noachian region with smooth to undulatory intercrater plains, craters partly buried, mostly rimless and flat-floored, which possibly resulted from resurfacing related to fissure fed lava, eolian materials and perhaps some fluvial deposits.The surface of the SPR is transected by wide deep SE-NW and E-W trending valley systems (E.G.: Figure 1, V-A). The contact with adjacent regions of the subdued cratered unit is gradational in places and sharp in others (Figure 1, SC, GC). Considerable vertical drops in surface elevation happen over short distances at contacts, with a maximum elevation difference of 2 km over 100 km observed from the sharp contact to the bottom of valley A (Figure 1, SC, V-A). In a MOC NA image of a region in the western part of valley-A (Figure 1, V-A), we can observe shallow scarps, which lineate the surface (Figure 2B, S), scarp bounded valleys (Figure 2B, V) and Graben-Horst systems (Figure 2B, GH). We propose that these features are the manifestation of different degrees of relative displacement along extensional normal fault planes, which possibly resulted due to ground subsidence [9].

Post-outflow chaotic terrains: South of the Hydaspis Chaos, the northern region of the SPR the surface is heavily fractured and there are abundant scarps and graben systems. In this region the plateau margin breaks up gradually into chaotic material (Figure 3). Rotto and Tanaka [8] mapped this chaotic region as lower chaotic material, and the adjacent outflow channel, as higher channel floor. They proposed a genetic relationship, which implied collapse of the ground to form the chaos, as water and debris were released catastrophically to form the associated outflow channels. We have observed that the chaotic material overlaps the surface of the outflow channel (Figure 3), what implies that, at least the observed chaotic terrain, post-dates the surface of the adjacent outflow channel. Moreover, the fact that this chaotic region is topologically higher than the floor outflow channel is not consistent with the classic genetic association between chaotic regions and the outflow channels.

Evidence for outflow reactivation: The channel floor remnants A, B and C (Figure 1, RM-A, B, C) were mapped by Rotto and Tanaka [8] as older higher channel floor material. They suggested that these regions represented early and intermediate stages in the excavation of the outflow channels. Elevation profiles taken from MOLA data reveal that these regions have the same maximum and minimum elevation values. These regions also have very similar geomorphic characteristics. We also propose that these regions resulted from contemporaneous channeling activity. A northern branch from the Hydraotes Chaos, Hydraotes branch-1, (Figure 1,HB-1) intercepts the channel floor remnant C (Figure 3). Topographic and interception relationships indicate that subsequently the Hydraotes branch-2 and 3 formed (Figure 1, HB-2, 3). The Hydraotes branch-3 is in turn intercepted by the Tiu valley lower channel floor (Figure 1, TLC), as indicated by a marginal scarp contact. These observations indicate that reactivation of the flow from the Hydaspis source region has taken place.

Discussion: Rodriguez et al. [4] discussed the existence of Martian confined cavernous systems filled with under pressured water. Rodriguez et al. [10] proposed that these confined systems possibly developed in multiple underground levels, and that large amounts of water were also stored in heavily fractured crustal regions. Our observations indicate that the warped and densely fractured surface of SPR was the result of subsidence. Surface subsidence possibly resulted from compensational sinking due to the removal of underground geologic materials by

subsurface flow and/or by igneously induced segregation of the water phase within the permafrost into discrete regions, and subsequent release. In both cases, cavernous systems are likely to result. The fact that the SPR has well defined contacts and ground subsidence and collapse is patterned into valley systems indicates structural control, which is consistent with the existence of cavernous systems. The SPR progressively fractures up and collapses in the vicinities of the Hydaspis Chaos region. In fact, the observed chaotic material, possibly resulted from collapse of the unstable regions of the SPR margin, and postdated both the stage of plateau subsidence and the formation of the outflow channels. We propose that large volumes of locally extracted water [4] were stored in multiple levels of confined underground caverns. We propose that water released from these confined systems, in addition to water transported in from distal regions within the Tharsis aquifer [11], possibly by subsurface conduits [4] and/or fracture systems [10], formed the primary sources for the large volumes of water required in order to carve the outflow channels, which emerge from the Hydaspis and other Chaotic regions in the Circum Chryse region. The Hydaspis Chaos is mainly made up of a cluster of collapsed craters (Figure 1,CC). Because the lower elevations of the crater floors represent regions of relatively lower lithostatic pressure over the confined cavernous systems, and the ground is heavily fractured under the craters, they are regions where deconfinement is more likely to occur. As water drained away from the cavernous systems, subsequent sinking and fracturing of the plateau surface took place due to the decrease in the basal supportive hydrostatic pressure, what resulted in the formation of the SPR. Reconfinement of the system might result due to freezing of the water emergence region. Reactivation of the hydraulic head might occur if the hydrostatic pressure increases, what could be caused by thickening of the permafrost seal and/or sinking of the cavern roof. Reactivation could also be related to the deconfinement of lower cavernous levels as the confining pressure decreases due to the loss of water and debris from overlying preexisting confined cavernous systems. After water was fully drained away from the cavernous systems, relatively shallow collapse occurred over the unstable cavernous structure, with little or no volatile release, forming the chaotic region at the Hydaspis Chaos.

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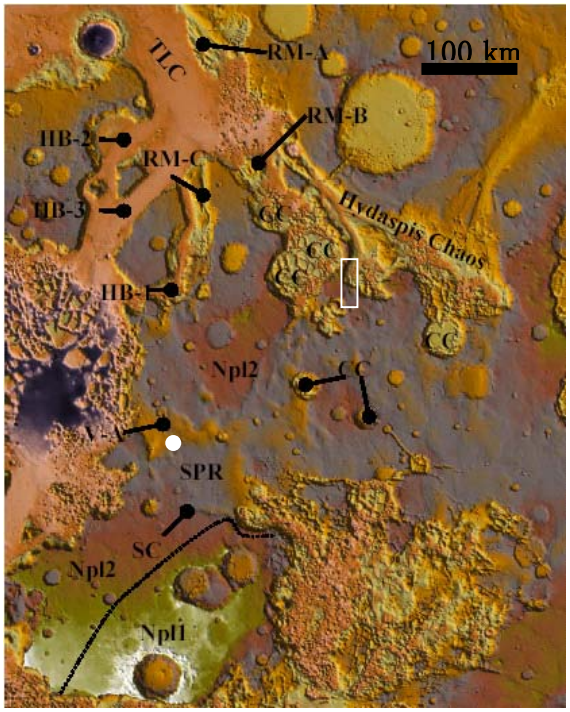
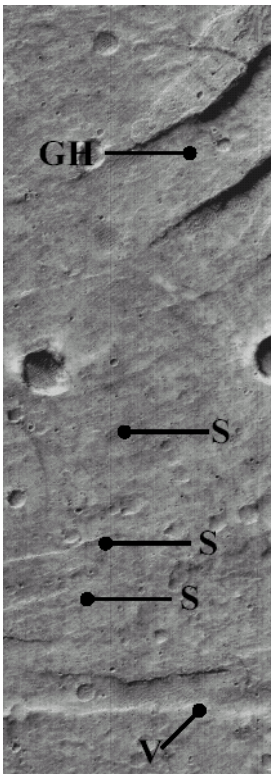
Figure 1. *Context MOLA based DEM. North is up. White circle indicates the location of the MOC subframe in Figure 2. White rectangle indicates the location THEMIS image subframe in Figure 3. North.*





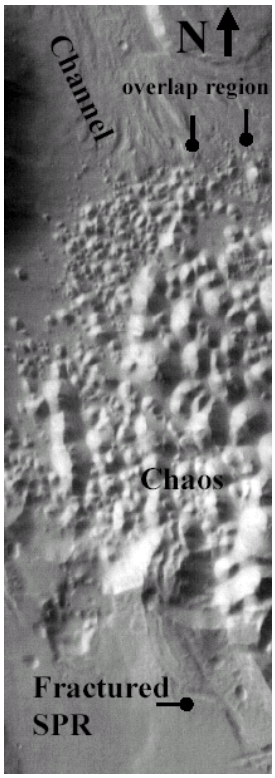


Figure 2. (*Left) MOCNA image m1800610 . Width is 2.77 km. North azimuth is 93. 12°* **Figure 3.** (*Right) THEMIS day IR I03883003. Width is 32 km. North is up.*