EVOLUTION OF CHAOS TERRAIN IN THE ERIDANIA BASIN, MARS. K. B. Golder and M. S. Gilmore, Dept. of Earth and Environmental Sciences, Wesleyan Univ., 265 Church St., Middletown, CT 06459, (kgolder@wesleyan.edu).

Introduction: Martian chaos terrain is typified by angular mesas and knobs separated by fractures and has been interpreted to result from subsurface collapse [1]. A general spatial association with large outflow channels led [2] to propose that the channels are derived from the catastrophic release of water from aquifers beneath chaos terrain. But not all chaos terrain is associated with outflow channels. Here we examine 5 degraded impact basins that contain chaos terrain: Ariadnes Colles, Atlantis Chaos, Gorgonum Chaos, and two unnamed basins that lie in the southern martian highlands between Terra Cimmeria and Terra Sirenum. This region lies within the Eridania basin which has been interpreted to have contained a paleolake that was the source of the Ma'adim Vallis outflow channel [3]. We have prepared a geologic map [4] using contemporary data in order to better understand the history of water and chaos in the region and to constrain models for chaos origination.

Methods: Mapping was performed at the ~1:1.4M scale in ArcGIS on a CTX basemap supplemented with HRSC and THEMIS IR data. MOLA, THEMIS IR day- and nighttime, MOC, and HiRISE are used for unit definition and contact determinations [4].

Stratigraphy: We have mapped several geologic units within the region [4]. The earliest materials are *Mountainous Terrain*, which correspond to Noachian basement materials [5,6]. This is overlain by *Electris Terrain*, interpreted to be a regional ash airfall deposit by [7]. *Bright Electris* deposits are high albedo, high thermal inertia materials within Electris with meter scale polygonal fracturing. *Etched Terrain* has lobate margins and is interpreted to consist of lava flows. These materials cover Electris units. *Chaos* formation predates some etched members, and postdates others. The emplacement of Sirenum Fossae graben, dated to the early Hesperian by [8], occurs after chaos formation in each basin. Later ice/sediment mantling deposits formed during the Amazonian [9].

Material Alteration: Two locations within Atlantis Chaos and an unnamed basin contain Electris plateaus that have been directly modified into chaos knobs. All chaos knobs consist of bright materials where exposed. CRISM analyses within Ariadnes indicate the presence of Fe/Mg-rich phyllosilicates and sulfates [10]. Bright material is mostly confined below 1100 m (with respect to the MOLA datum), which would be within the margins of the paleolake. We hypothesize that Electris materials suffered subaqeuous alteration due to interaction with paleolake waters. Phyllosilicates are a typical product of the aqueous alteration of ash [11].

Basin Hydrology: We observe a high density of valley network incision occurring through mountainous terrain and extending into Electris deposits. Valley morphologies range from steep v-shaped mountain valleys to steep-scarped flat-floored meandering channels in Electris, all of which have extensive branching tributary networks. The widths of Electris valleys increase from their inception points, and attain their widest extent (between 3 and 8 km) at their termini. Most Electris channels terminate at an elevation of ~1100 m; this was noted by [3] and is primary evidence of the presence of a paleolake in this region. In this model, the 1100 m elevation corresponds to the approximate lake highstand level which was breached to form Ma'adim Vallis [3]. Once the water levels dropped below ~900 m, the 5 basins of the study area would have been isolated from the Ma'adim Vallis system [3]. We see no evidence of channels flowing from these basins and thus assume that the remaining water in the basins would have been lost through evaporation and groundwater seepage.

Channels continue within the interiors of Ariadnes, Atlantis, and Gorgonum basins, down to ~500 m elevation, but the channel density and widths decrease significantly (<1 km width) from those at higher elevations, indicating decreased flow volumes. Rarely channels extend below 500 m into the chaos fields, and nearly all terminate at 0 m elevation. These channels are found on etched terrain that embays the chaos terrain. Therefore, a pre-chaos surface appears to have existed in the basins at ~500m. This may have been the lowstand of the paleolake, or the lake bottom.

The present day topography of the basins are bowl-shaped with dips between 0.5-1.5° [3], vertical relief in excess of 1 km and depths down to -600 m elevation. Typical highland degraded basins >60 km in diameter have nearly flat-floors, with sharp breaks in slope along the rim base; these flat floors are hypothesized to be due to sedimentation [12,13]. The general termination of valley networks at 500 m elevation and the restriction of chaos below 500 m leads us to propose that the basins were flat-floored and filled to the ~500 m elevation contour. At that time, the basins contained Electris deposits which were overlain by etched terrain. Our interpretation of etched terrain as volcanic flows is consistent with emplacement at a equipotential surface.

Chaos formation occurred, disrupting the flat-floored crater, etched and Electris deposits. This subsidence event must have occurred rapidly to produce the observed extension and fracturing. Further etched terrain units were emplaced after chaos formation. Assuming that these were flat-lying at emplacement, their observed regional tilt and present day depths require 100s m of subsidence after chaos formation. Since additional chaos fields were not formed, we suggest this secondary process was slower. Rare valley networks atop the etched terrain attest to continued incision on these subaerial surfaces.

With the exception of Gorgonum, which contained an ice covered lake [14], there is no obvious evidence of standing water in the basins (e.g., shorelines) post-chaos. This suggests that if water was present in the basins, it did not persist, perhaps corresponding to a more evaporative environment. This may explain the presence of sulfate minerals admixed among the phyllosilicates [10]. Similar conditions have been invoked for nearby Columbus crater [15].

Summary of observations. We observe a complex hydrology in this region where valley networks fed a paleolake that altered basin materials. The lake levels dropped due to evaporation and seepage (no outlets observed) reaching 500 m elevation which may correspond to the lake floor. Chaos formation occurred rapidly and regionally, requiring a triggering mechanism that occurred at the same time across the basins. The basins experienced continued subsidence over a longer spatial and temporal scale marked by etched terrain emplacement and rare valley networks.

Constraints on Chaotic Terrain Formation: There are several proposed models for chaos formation. Most of these require a triggering mechanism to release stored subsurface volatiles. Aquifer models [e.g., 2, 16] call for water pressure build-up in pore spaces of a confined aquifer, followed by rupturing of a capping cryosphere layer through erosion. The triggering mechanism in this case can be impact, volcanism or build up of hydraulic head due to aquifer recharge. These systems are predicted to have several recharge/discharge events [17]. Other models call for release of water liberated from subsurface hydrated minerals due to volcanism [18].

We observe that etched terrain, which we interpret to be volcanic, is the unit that precedes chaos formation in each of the basins. The *regional* emplacement of this volcanic material may have provided a *regional* trigger mechanism for the catastrophic release that formed the chaos at the same stratigraphic interval across the basins. At this time we cannot favor an aquifer over dewatered minerals. However, we observe that bright etched terrain, composed of phyllosilicates and sulfates are present in the chaos knobs and exposed to the base of the knobs as layers ~100s of m thick. Some of these minerals are dehydrated [10].

Another model calls for the burial by sediment of a preexisting ice sheet that gradually increases pressure and temperature conditions to the point of melting the ice lens [19]. Continued melting would lead to overburden collapse, forcing high-pressure expulsion of the confined waters. A crater is the optimal site for this model, where a drying paleolake would provide the required ice lens. Since the basins in the study area are roughly the same size and depth, and experienced the same climatic conditions, it is possible that they dried up simultaneously and that chaos formation via this mechanism could occur at the same stratigraphic interval.

In each of these models, the water can only have been released into a transient lake or the groundwater system. Evidence of such a lake may be present in Gorgonum [14], but not elsewhere.

After the formation of chaos terrain, several episodes of etched terrain filled the basins. Assuming that these lava flows were originally emplaced at an equipotential surface, the current basin tilt of 0.5-1.5° requires further subsidence. This event would have been more gradual that chaos formation. We suggest, that surface loading from continued etched terrain deposition may have contributed to the subsidence. Compressional stresses associated with this subsidence may contribute to the wrinkle ridges within the etched terrain in the basins.

References: [1] Sharp, R.P. (1973). J. Geophys Res., 78, 4073-4083. [2] Carr, M.H. (*1979). J. Geophys. Res*., 84, B6, 2995-3007. [3] Irwin, R.P. et al (2004). *J. Geophys. Res.*, 109, E12009. [4] Golder, K.B. and Gilmore, M.S. (2012). *LPS XLIII*, this volume (a). [5] Scott, D.H. and Tanaka, K.L. (1986). *USGS Misc. Inv. Ser.* Map I-1802-A. [6] Greeley, R. and Guest, J.E. (1987). *USGS Misc. Inv. Ser.* Map I-1802-B. [7] Grant, J.A. and Schultz, P.H. (1990). *Icarus*, 84, 166-195. [8] Anderson, R.C. et al (2001). *J. Geophys. Res.*, 106, E9. [9] Mustard, J.F. et al (2001). *Nature*, 412, 411-414. [10] Gilmore, M.S. et al (2011). *J. Geophys. Res.*, 116, E07001. [11] Bishop, J.L. et al (2008b). *Science*, 321, 830-833. [12] Howard, A.D. (2000). *Eos Trans. AGU*, 81,48. [13] Craddock, R.A. and Howard, A.D. (2002). *J. Geophys. Res.*, 107, E11. [14] Howard, A.D. and Moore, J.M. (2004). *Geophys. Res. Let.*, 31, L01702. [15] Wray, J.J. et al. (2011). *J. Geophys. Res.*, 116, E01001. [16] Meresse, S. et al (2008). *Icarus*, 194, 487-500. [17] Andrew-Hanna J. C. and Phillips (2007) *JGR, 112* E08001. [18] Montgomery, D.R. and Gillespie, A. (2005). *Geology*, 33, 8, 625-628. [19] Zegers, T.E. et al. (2010). *Earth and Planet. Sci. Let*., 297, 496-504.