CONSTRAINTS ON THE ORIGIN AND EVOLUTION OF IANI CHAOS, MARS. N. H. Warner[1], S. Gupta[1], J. Kim[2], J. Muller[3], L. Le Corre[3], S. Lin[4], J. Morley[5], Chris McGonigle[1], [1]Department of Earth Science and Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, UK, n.warner@imperial.ac.uk. [2]Ziin Consulting, Seoul, South Korea, [3]Mullard Space Science Laboratory, Department of Space and Climate Physics, University College London, UK. [4]Department of Land Economics, National Chengchi University, Taiwan. [5]Centre for Geospatial Science, University of Nottingham, UK.

Introduction: The chaos terrains on Mars consist of semi-enclosed topographic basins that are comprised of, and are surrounded by, extensionally fractured cratered highland terrain [1, 2]. The association of several chaos regions with catastrophic outflow channels implies an origin by evacuation of subsurface water and collapse-induced extension of the crust [2, 3]. Despite the relative certainty that groundwater evacuation and subsidence was involved in formation of most chaos terrains, the precise mechanism of groundwater release and the long-term geologic evolution of individual chaos regions are poorly constrained.

As a prime example of a morphologically complex chaos feature, Iani Chaos (Fig. 1) is located at the head of Ares Vallis. The entire chaos region encompasses a ~400-km-wide zone that contains a series of semi-enclosed circular, elliptical, and curvilinear topographic basins that are comprised of fractured plateaus and conical mounds. The fracture morphology and topography indicate that the chaos likely formed by collapse following the catastrophic release of water and erosion of Ares Vallis [1, 2].

In this analysis we present a topographic, geomorphologic, and chronologic study of the Iani Chaos system using new imagery and topography data sets from Mars Express and the Mars Reconnaissance Orbiter to constrain its origin and geologic evolution (including the deposition of ILDs) as they relate to catastrophic flood events in Ares Vallis. Furthermore, we describe geomorphologic indicators that multiple effusion events occurred from the region [4].

Inter-Chaos Basins: Figure 1 outlines the eight large (15 km to 120-km-wide) topographic basins (B1-B8) that we analyzed in terms of topography, chronology, and geomorphology. Our topographic analysis suggests that the maximum elevation of the non-fractured highland terrain that bounds the margins of Iani Chaos is comparable to the maximum elevation of many of the remnant fractured blocks that surround, and are contained within, the eight inter-chaos basins (Fig. 1). Our observations indicate that the highland terrain was once laterally continuous over these basins and negate the possibility that a single large basin or several smaller isolated basins, corresponding exactly with the modern locations of the eight basins, were present before chaos formation. The inter-chaos depressions therefore, represent regions of significant volume loss within the martian crust. Using a HRSC DTM (Fig. 1) we calculated a total volume of 10^4 km^3 for all the inter-chaos basins. This volume is the same order of magnitude as the total volume of the bedrock eroded canyon of Ares Vallis and is insufficient to explain the erosion of Ares Vallis by a single flood event (without recharge) derived only from volume loss at the locations of the basins.

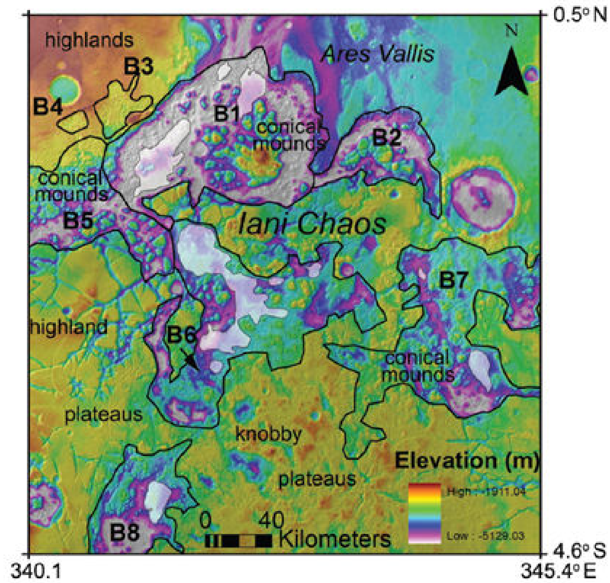

Fig. 1: HRSC DTM (40 m) of the Iani Chaos region. Inter-chaos basins, highland plateaus, knobby plateaus, conical mounds, and interior layered deposits (ILDs) are labled on the image.

Fractures: For this analysis, we mapped the location and orientation of fractures within Iani Chaos to constrain the regional, paleo-stress field and to identify patterns relative to the inter-chaos basins. As for all chaos terrains, fractures within Iani Chaos are extensional, resulting from local and regional subsidence. Individual fractures have steep interior slopes (up to 50°) and are characterized by a linear, curvilinear, or pit-chain planform morphology. On a regional scale, the fractures form complex polygonal networks that have an anisotropic pattern (Fig. 2). In northern Iani Chaos, the dominant fracture pattern has a ENE-WSW strike that is parallel to the orientation of the linear inter-chaos basin B5. In southern Iani Chaos, the fractures follow a dominant NNE-SSW pattern, parallel to B8. This indicates that the collapse induced fracturing within Iani Chaos followed regional patterns that are also represented by the orientations of the associated inter-chaos basins. The fracture analysis also demonstrates that there are multiple overlapping fracture systems, suggesting that there were multiple collapse/subsidence events.

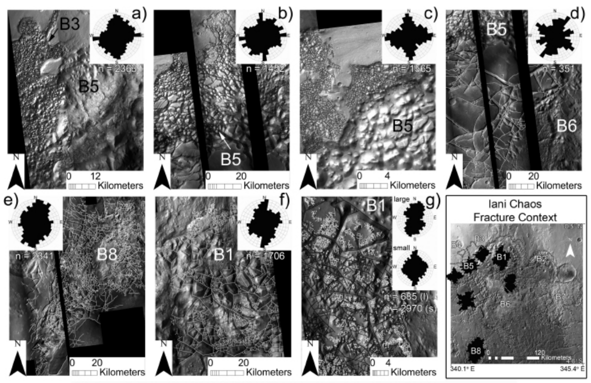

Fig. 2: CTX mosaics illustrating regional fracture patterns in Iani Chaos.

Inter-Chaos Flood Surfaces: Inter-chaos flood surfaces were identified along the northwest margin of Iani Chaos. They are identified by the occurrence of sub-parallel grooves that emanate directly from shallow inter-chaos basins, including B3 and B4. We interpret these grooves to be the result of erosion by macroturbulence (e.g. roller vortices) in a flood [5]. Topography and impact crater chronology data indicates that these inter-chaos surfaces are related to the earliest flood events within Ares Vallis [4]. The flood surfaces are truncated in places by deeper (1 to 2 km) basins that are associated with the younger catastrophic flood canyons of Ares Vallis. These observations suggest multiple phases of collapse and flooding.

Interior Layered Deposits: Interior layered deposits (ILDs) in Iani Chaos are identified by discrete stacks of meter-scale, sub-horizontally layered, light to medium-toned materials that superimpose chaos blocks and fractures. Importantly, the ILDs are not always associated with the topographically lowest points in Iani Chaos, but occur both within the inter-chaos basins and along their elevated margins. The stacks range in thickness from 60 m to possibly as high as 800 m. Individual layers show variation in relative albedo, ranging from light-toned to medium-toned. It is from these units that hydrated mineral signatures associated with sulfate and hematite have been detected from visible-light, near-infrared, and thermal infrared spectral data [6, 7, 8].

From CTX image observations it is clear that all the major ILD outcrops rest on top of chaos mounds and superimpose both large and small fracture systems. This indicates that the ILDs were deposited after Iani Chaos was fully developed, after basins B1-B8 were formed. From cross-cutting relationships between the flood grooves of the proximal channels in Ares Vallis and the interior walls of B1-B2, we suggest that these basins, and therefore the ILDs, formed after all flooding events in Ares Vallis. Most importantly, the upper surfaces of most of the major ILDs are topographically higher than the lowest flood channels of Ares Vallis. From this observation, and the observation that the ILD's must have formed after the flood channels of Ares Vallis, we suggest that it is topographically impossible for the ILD's to have formed by sedimentary deposition or evaporative accumulation within a standing body of water (lake) within the inter-chaos basins. This is because there was no topographic boundary at the northern margin of Iani Chaos that was high enough to allow for deposition of the upper most layered unit of the majority of the ILD mounds. Rather, an alternative explanation for the deposition of the ILDs and aqueous alteration is required (e.g., spring, air-fall, volcanic, etc.).

Conclusion: This study demonstrates that the morphology of Iani Chaos evolved through intermediate stages in response to multiple releases of groundwater throughout the Hesperian and Early Amazonian. Basin volume calculations and topography data indicate that the water involved in these release events must have been recharged from distal sources, suggesting a regionally extensive, connected aquifer. We describe a pattern in the basin and fracture morphology that indicates localized, fracture controlled subsidence of the crust. Furthermore, we constrain both the timing and topography of chaos formation and ILD deposition relative to flooding in Ares Vallis, suggesting that the ILDs could not have formed within lacustrine environments after the primary flood channels of Ares Vallis were eroded.

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