SUBSURFACE HYDROLOGIC ACTIVITY IN NORTHERN ARABIA TERRA: IMPLICATIONS FOR FORMATION OF FRETTED CHANNELS. C. A. Denton[1] and J. W. Head[1], [1]Dept. of Earth, Environ. & Planetary Sci., Brown Univ., Providence RI 02912 USA (adeene_denton@brown.edu)

Introduction: The Arabia Terra (AT) plateau is characterized by a multitude of unusual geologic features, including the fretted terrain and the fretted channels [e.g., 1], which represent the removal of a large volume of material from the region [2]. The fretted channels are steep-walled, flat-floored channels that deeply penetrate the AT plateau and open into the northern lowland basin [1]. Previous researchers have defined two distinctive morphologies for the fretted channels: sinuous channels (analogous to modified valley networks) and quasilinear closed depressions [1, 3]. Previous studies have suggested that these features could have been produced through overland flow of water [3, 4], groundwater sapping [4,5], or one or more mass wasting processes [1,5]. In southern AT, several valley networks (VN) empty into the southern parts of fretted channels, which in turn open into the fretted terrain (FT) along the dichotomy boundary [1,4]; thus, the fretted channels are a key landform marking the transition from typical highlands geomorphic features (including VN) to the unusual FT-related features abundant in northern AT. Here, we perform a detailed geomorphic analysis of Mamers Valles, a prominent fretted channel in the AT plateau, to assess the role of overland and subsurface flow in producing the fretted channels, as well as possible ramifications for the evolution of the AT plateau during the Noachian.

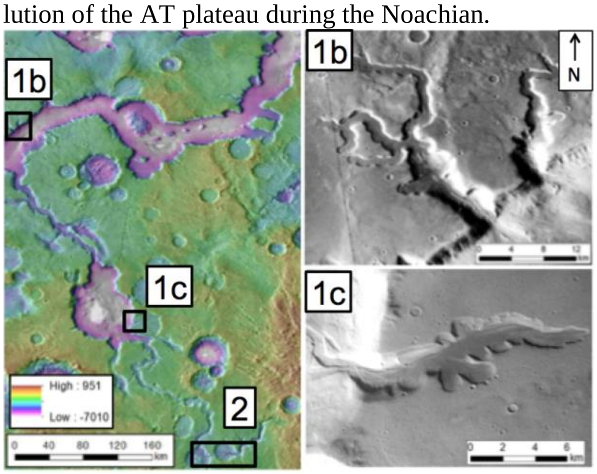

Fig. 1. a. MOLA-derived topographic map of Mamers Valles with sapping channels highlighted. **b.** CTX images of several amphitheater-headed tributaries that incise into the main channel walls. Black boxes indicate the locations of Fig. 1a, 1b, and 2.

Study Area: Mamers Valles, the largest sinuous fretted channel in the AT plateau (Fig. 1a), covers ~2.35 x 10^4 km^2 from its head in the interior of the plateau to the dichotomy boundary, where it opens into the fretted terrain [1]. Amphitheater-headed tributaries incise into the steep-sided walls of the primary channel (Fig. 1b), which is interpreted to be late Noachian in age [3, 6].

Stratigraphic and Geologic Setting: Previous studies have identified the surface of the AT plateau as the culmination of multiple episodes of flood volcanism in the mid- and late Noachian [3, 6]. The stratigraphy of the plateau is defined by a laterally extensive basaltic caprock that overlies Borealis Basin ejecta, underlying megaregolith and bedrock [6]. Researchers have noted morphologic similarities between the ampitheatre-headed tributaries of Mamers and groundwater sapping channels on Earth [4, 5]; uncertain is the effect of resistant volcanic bedrock forming the capping unit of the AT plateau. Terrestrial "sapping" channels in basaltic material have been shown to involve a significant component of overland flow due to the difficulties of incision and removal of erosion-resistant material [7].

Observations and Interpretations: The morphology of Mamers Valles has three major features that may provide clues as to its origin: 1) Mamers gradually expands in channel width from ~2-5 km at the head in the south to ~25 km in the north where it opens into the FT; 2) numerous examples of incision of channel walls by amphitheater-headed tributaries along its course, and 3) incision and removal of material from ~4-5 craters buried by Noachian flood lavas along the channel path (Fig. 1a, inset). Additionally, large portions of the floor of Mamers Valles are occupied by Amazonian-aged debris-covered glacier deposits [8, 9]. Our investigation utilized 128 m/pixel MOLA topography [10] and high-resolution CTX images from the Mars Reconnaissance Orbiter [11] to assess changes in channel profile downsection as well as across incised craters.

One particular area of interest is located near the head of the channel, where the main channel is only ~2 km across and appears to have experienced minimal Amazonian glacial modification. In this region the channel crosses and incises multiple craters from rim to rim without disruption by the rim topography, and the channel itself crosses the interior of the crater floor continuously with no evidence of filling of the crater and overtopping at the exit breach (Fig. 2). This morphology is unique. At locations where valley network channels flow into and out of craters (open-basin lakes, [12]), a channel signature is not preserved across the deeper part of the crater floor. Instead, water from the inlet channel ponds within the crater until it reaches the level of the outlet valley [12]. Topographic profiles of the Mamers channel (Fig. 2) in its upper reaches as it bisects multiple crater rims and floors illustrate the lack of correlation between channel incision and surface topography. For example, the channel floor occurs at a consistent level (~-2,400 m as defined by MOLA) regardless of the intervening crater elevation. Additionally, within the craters the channel remains wide (~2-4 km) but shallow (>100 m deep), while when traversing the crater rim the channel retains the same constant width, but increases in depth by several hundred meters. This behavior is inconsistent with overland flow of water carving the channel. Instead, we interpret this behavior to be indicative of the presence of subsurface water flow and collapse assisting in channel formation.

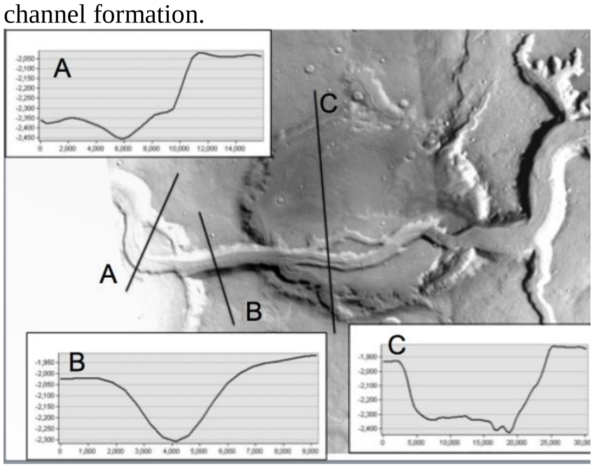

Fig. 2. Subset of Mamers Valles in CTX images, with topographic profiles of the channel derived from MOLA topography. The width of the channel varies, but the base level to which the channel incises remains constant in both inter- and intracrater settings. Location within Mamers indicated in Fig. 1a.

What insight does the geologic context of AT provide about possible subsurface water flow? The VN watershed area within Arabia Terra is not commensurate with the amount of water required to form large-scale hydrological features [12]. If the climate was warm and wet, groundwater upwelling and surface seepage may have permitted surface water to persist [13]. In the case of Mamers, such subsurface water flow is suggested by the collapse of sub-channel sections of crater floors and rims to the same level in multiple craters (Fig. 2). Subsurface focus of water flow appears to have facilitated slumping of the crater rim and floor sections immediately above the subsurface channel (topographic lines A and C). For groundwater flow to mobilize on the scale of the remaining parts of Mamers Valles requires significant volumes of subsurface groundwater flow. Furthermore, the basaltic capping unit must be weakened sufficiently, or material beneath this capping unit must be fairly porous.

What is the origin of enhanced water flow in this region? Previous work has addressed the origin of the fretted channels by invoking the melting of pore ice in the upper subsurface to enhance mass wasting at the local scale [e.g. 4, 5]; however, this mechanism may be insufficient for the scales required in both regional area and volume of water produced [2, 14]. An alternative explanation is the contact (top-down) and deferred melting of buried snow and ice caused by the widespread emplacement of Late Noachian flood lavas [15], which are ~150-200 m thick and cover ~3.5 x 10^6 km^2 of the AT plateau in the Mamers region [14]. In this scenario contact melting of exposed ice/snow may produce glacial outburst floods [14] while deferred melting disrupts the cryosphere, which may drive flow in the vertical rather than horizontal direction [15]. For Mamers, full emplacement of the lava thickness in the region may melt/disrupt pore ice/snow in the subsurface for several hundred meters depth.

Conclusions and Outstanding Questions: Our observations of Mamers Valles suggest that the erosive activity that facilitated the formation of the fretted channel was localized in the subsurface, potentially through the migration of large amounts of liquid water. The basic structure of the initial phases of the channel analyzed here is inconsistent with overland flow, as the channel structure does not deviate when encountering topographic obstacles such as crater rims. These observations suggest that significant volumes of liquid water were mobilized in the subsurface to generate flow and collapse on a large scale; it is possible that the proliferation of fretted channels in Arabia Terra is the result of this process activating on a regional scale. However, while this collapse model may describe the initiation of the channel's upper reaches, the increase in width and depth in the lower reaches of the channel may be the result of additional subaerial flow into the channel from groundwater or fluvial sources. We are currently assessing the role of groundwater flow in the formation of fretted channels through top-down heating and deferred melting mechanisms [15].

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