FLUVIAL GEOLOGY OF THE NORTHWEST HELLAS REGION, MARS: EVIDENCE FOR LOCALIZED DRAINAGE AND TERRAIN INVERSION. Benjamin D. Boatwright and James W. Head, Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, RI 02912 USA (benjamin_boatwright@brown.edu; james_head@brown.edu).

Introduction: The Northwest Hellas Region (NHR) is composed of cratered Noachian highland terrain in Terra Sabaea and Noachis Terra, forming a high-standing plateau centered ~1300 km northwest of the Hellas basin rim with elevations generally in excess of 2 km [1]. This particular area has attracted interest for its low drainage density relative to nearby areas of similar age [e.g. 2-3]. Craters generally display sparse fluvial dissection on their rims and are surrounded by etched intercrater plains material.

The most distinctive fluvial morphology in the NHR is inverted channels, which often form branching tributary systems within degraded crater floors (Figs. 1a-b). We compare these inverted channels to ones previously described in Arabia Terra [4-5] (Fig. 1c) and hypothesize that they are aggradational remnants of valley networks that fed into crater basins from nearby intercrater plains. Several examples of channel systems transitioning from negative to positive relief suggest that these morphological differences may be controlled by breaks in slope [5] (Figs. 1e-f). Other evidence of topographic inversion may instead point toward infilling and differential erosion of a fine-grained mantling deposit [4]. We interpret the lack of incision within much of the intercrater plains as potential evidence for a localized source of runoff, such as snowmelt from an ice sheet.

Fluvial geology: There are dozens of examples of previously undescribed inverted channel systems within NHR craters, all of which have a similar appearance and relative location near the base of crater walls. Smaller channels appear ridge-like (Fig. 1a), while larger ones may be significantly wider with flat tops and complex braided morphologies, continuing uninterrupted for several kilometers (Fig. 1b). The inverted channels are distinct both geographically and morphologically from the distributary features described within crater basins elsewhere in the southern highlands [e.g. 6-7]. Instead, these inverted channels often appear to head at alcoves in crater walls, and can occasionally be traced as negative relief valleys beyond crater rims a short distance into the surrounding uplands.

The closest analog we find to the NHR channels is the inverted channels described in Arabia Terra [4-5]. The geology of Arabia Terra is similar in many ways to that of the NHR: there is generally low drainage density, and both inverted channels and an etched mantling unit are present. Inverted channels in both regions occur in the dissected unit (Npld) of the Noachian plateau sequence, although others in the NHR also occur in the cratered unit (Npl1) [8]. The etched unit in the NHR is mapped as part of Npl1, but its morphology is very similar to the etched unit (Nple) identified in Arabia Terra [8].

Most of the inverted channels in Arabia Terra are thought to have formed through inversion of a later indurated mantle fill, particularly in association with other inverted topography [4]. When associated with an upslope valley, however, channel inversion has also been explained through differential erosion of aggraded fluvial sediment at slope breaks, where the steeper valleys have been preserved as erosional features [5]. The mantling unit is then deposited unconformably on top of the valleys and channels [5].

Interpretation: Both regional inversion and preserved aggradational sediments are present within the NHR. In Arabia Terra, there are clear examples of inverted channels originating from other inverted topography such as craters (Fig. 1c), but such examples are generally absent in the NHR. While some inverted craters are visible, they are most often downcut at sharp boundaries by fluvial or eolian erosion, leading to a chaotic "island and pit" texture in much of the intercrater areas (Fig. 1d). The inverted channels appear either where upslope valleys have incised into crater walls and debouched onto floors (Fig. 1e), or in isolation on crater floors when the upslope valleys have been completely infilled or removed. The transition appears to be correlated with slope, such that the inverted channels begin at a point where the slope has become shallower (Fig. 1f). This phenomenon is also observed in Arabia Terra [5], and we prefer this interpretation to explain the preservation and inversion of channel systems in the NHR.

Unlike traditional valley networks [e.g. 2], the valleys upslope of the inverted channels typically only extend several kilometers beyond the crater rim crest. The crater rims themselves are often so degraded that they are only distinguishable by their relatively steeper slopes compared to the surrounding terrain. As with the inverted channels, the preservation of valleys appears to be correlated with this slope change, as they rarely extend into the flatter intercrater plains beyond the immediate surroundings of the crater.

The low drainage density and lack of integration of valley systems beyond crater rims leads us to interpret the fluvial drainage in the NHR as being locally as opposed to regionally derived. This is consistent with previous interpretations of fluvial geology elsewhere in the region [3].We additionally propose that the mechanism for this limited drainage could have been snowmelt, such that individual melt channels originated from ice sheet margins positioned at higher elevations, resulting in limited integration as the channels drained downward into nearby crater floors.

3-D GCM simulations of the early Mars climate have shown that higher atmospheric pressures would lead to increased thermal coupling between the atmosphere and surface, causing preferential accumulation of ice in the southern highlands [e.g. 9]. Under supply-limited conditions with a Noachian near-surface water budget and geothermal heat flux, the ice sheet would achieve an equilibrium line altitude that falls near the elevation of many of the valley heads within the NHR [10]. Top-down melting off the ice sheet and into crater basins is thus a possible formation mechanism for the valleys and inverted channels.

Future work: In order to understand better the complex nature of drainage patterns and sediment transport off an ice sheet, we are currently developing an extension of the MARSSIM landform evolution model [11] that would allow us to test point sources of fluvial discharge and sediment flux, as might be present at an ice sheet margin with top-down melting. With additional input parameters from the University of Maine Ice Sheet Model [12], we hope to determine under what, if any, conditions snowmelt from an ice sheet might have produced the amount of fluvial erosion and deposition that is observed in and around craters in the NHR. These results would have implications for the climate history of early Mars, particularly as it relates to the prevalence and mode of fluvial erosion and sediment transport in the southern highlands during the Noachian.

A comprehensive account of the geologic history of the Northwest Hellas Region is difficult. Evidence for fluvial erosion and deposition is comingled with later emplacement of one or more mantling units that have been variably inverted by fluvial and eolian erosion. There is evidence of both modification of channels by later infilling alongside what appears to be fluvial dissection of mantling materials. This could point toward multiple episodes of alternating erosion and deposition in the region throughout the Noachian and Hesperian periods. By investigating the new possibility of locally derived drainage from snowmelt with numerical modeling, we will be better able to describe the geologic history of this interesting region of Mars.

References: [1] Smith D.E. et al. (2001) *JGR* 106; [2] Hynek B.M. et al. (2010) *JGR* 115; [3] Irwin R.P. et al. (2018) *JGR* 123; [4] Fassett C.I., Head J.W. (2007) *JGR* 112; [5] Davis J.M. et al. (2016) *Geology* 44; [6] Moore J.M., Howard A.D. (2005) *JGR* 110; [7] Di Achille G. (2009) *GRL* 36; [8] Greeley R., Guest J.E. (1987) *USGS Misc. Invest. Map* I-1802-B; [9] Wordsworth R. et al. (2013) *Icarus* 222; [10] Fastook J.L., Head J.W. (2015) *PSS* 106; [11] Howard A.D. (1994) *Water Resources Res.* 30; [12] Fastook J.L. et al. (2012) *Icarus* 219.

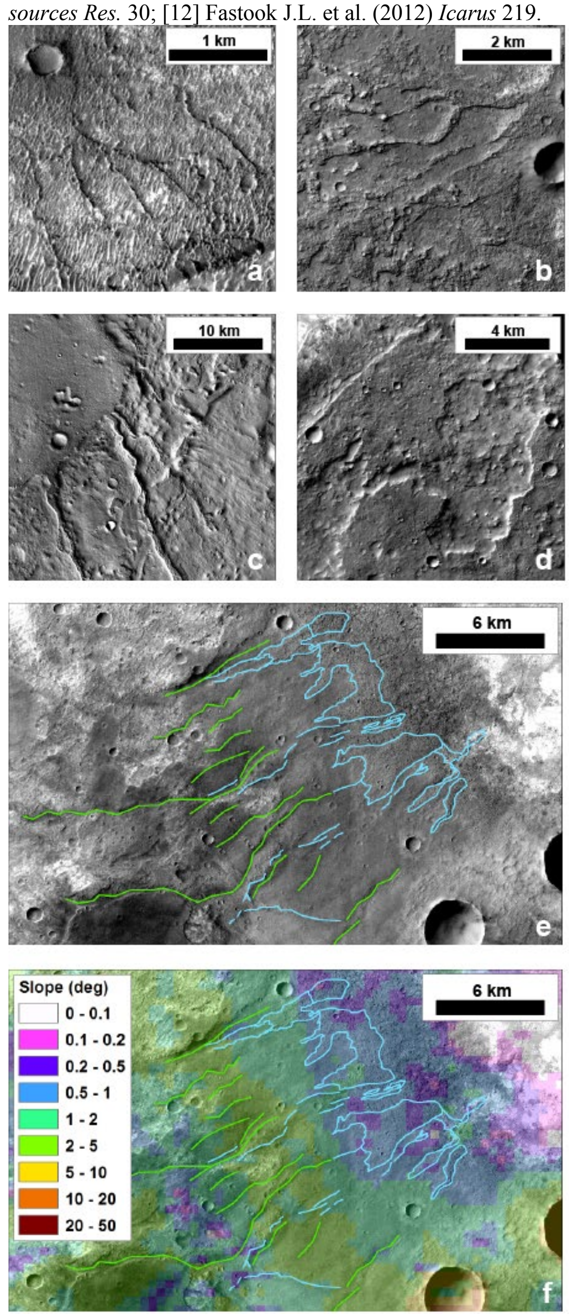

Figure 1. a) Smaller, ridge-like inverted channels in crater, -21.493 48.261; b) larger, flat-topped inverted channels in crater, -22.463 46.186; c) inverted channels in Arabia Terra associated with inverted crater, 16.255 49.820; d) diagnostic “island and pit” texture in intercrater plains, -23.825 47.345; e) valley (green) to channel (blue) transition on degraded crater rim, -23.062 48.234; f) MOLA slope map of same region showing correlation between channel morphology and slope break at crater floor. All images from CTX.