LATE NOACHIAN VALLEY NETWORK FORMATION ON MARS: AN ASSESSMENT OF THE IMPACT CRATER-RELATED FORMATION MECHANISM. A. Horan[1] and J. Head[1], [1]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02908 USA (Ashley_Horan@brown.edu).

Introduction: The martian valley networks (VN) [1] and associated open- and closed- basin lakes (OBL/CBL, e.g. [2, 3]) are related to fluvial features indicative of the flow of liquid water in the southern uplands and adjacent areas, during the Late Noachian and Early Hesperian [4]. Highland impact craters from this period are also highly degraded, possibly assisted by fluvial activity. The LN-EH climate is potentially much different than both today and throughout most of the Amazonian, time periods during which liquid water is not stable in the atmosphere [5] and is metastable on the surface [6]. During the LN-EH, due to a younger and less luminous Sun [7] approximately 75% of the present value, the mean annual temperature (MAT) of Mars was unable to reach the triple point of water solely by incoming solar radiation [8, 9], even with the addition of greenhouse gases to the atmosphere [8-15]. This has led to two candidate end-member early climate scenarios: 1) "warm and wet" [16], during which MAT were high enough to produce conditions permitting rainfall, or 2) "cold and icy" [9] during which the southern uplands of Mars were dominated by snow accumulation and temperatures were significantly below 273 K. The formation of the fluvial features observed on Mars may not require continuous clement conditions throughout the Noachian, however, suggesting that occasional periods of warmth could have generated melting of surface and subsurface ice to cause runoff and valley network formation.

A major candidate for periodically raising atmospheric and surface temperatures and causing rainfall and surface runoff is the process of impact cratering [17-20]. The higher impact cratering flux in early planetary history not only increased the frequency of events, but also increased the number of large-magnitude (basin scale) events. Therefore, one can anticipate the importance of impact events in the Noachian: the intense kinetic energy transfer resulting from the projectile collision is predicted to cause vaporization, melting, and ejection of all projectile and significant volumes of target material, heating the atmosphere and surface to produce conditions appropriate for significant rainfall and runoff [17, 18, 20].

Analysis of the impact cratering mechanism: We explore the effects of impact cratering on the atmosphere and surface, documenting the "Impact Cratering Atmospheric/Surface Effects" (ICASE) scenario as put forth by Segura et al. [17-18]. We highlight the important steps in the mechanism to create an illustrative timeline for qualitative understanding of the sequence (Figure 1) while discussing the geological implications predicted by the ICASE scenario at each step. We illustrate the schematics of these steps and the global or regional implications through a series of descriptive diagrams (Figure 2).

Important Factors: When modeling the regional and global temperature effects and resultant rainfall associated with an impact event, initial model conditions will change depending on the circumstances of the impact itself. Parameters which should be considered include impactor size, impacting velocity, and angle of incidence. All of these values correlate directly with the amount of energy transferred by the impacting event, influencing the amount of vaporized projectile and target material. Following this, the vaporized material will expand as a plume releasing no heat until it reaches transparency temperature, which is uncertain for the atmosphere of early Mars.

The global extent of the vapor plume growth will depend directly on the amount of vaporized material injected into the atmosphere. Previous work [e.g. 17-20] has assumed global growth of the plume under all circumstances as an initial condition for predictions of rainfall and surface runoff rates. However, 3-dimensional plume growth modeling is necessary to quantify this variable and make reliable predictions on impactor size relationship to global plume growth under early Mars atmospheric conditions.

As the plume grows and releases heat through expansion and thermal radiation, it decreases in temperature. Eventually, the plume will cool sufficiently for the vaporized rock silicate in the atmosphere to condense and rain down at extreme temperatures, possibly above 1500 K [17-19]. The geomorphology of regions adjacent to craters can provide insight into the nature of the condensed rock silicate layer. In one option, it might form a solid layer trapping heat underneath and forcing the heat to escape through specific conduits, for example, producing pseudocraters. In another option, buried heat might be lost to the atmosphere due to enhanced porosity in a particulate layer. Following the global rock silicate fallout, vapor in the atmosphere is predicted to cool sufficiently for water vapor to condense and rain out, producing regional or global rainfall and surface runoff and inducing a hydrologic cycle.

Relationship To Valley Network Formation: With the more detailed understanding of the ICASE model [17-20] and its general geologic implications (Figures 1, 2), we now assess the model predictions in terms of VN formation. The rainfall events proposed by the ICASE scenario predict average global rates equivalent to that of Earth in tropical rainforests, approximately 2 m/year, at much higher temperatures and with no plant life to naturally absorb water. Large-scale impact events will induce a hydrologic cycle, allowing these intense rainfall periods to continue for two to four hundred years for an impact event the size of the Argyre basin [20]. The 1-dimensional model used by Segura et al. [17-18] assumes the initial condition of a fully saturated regolith, forcing all of the rainfall into runoff. In a more realistic situation, the porous regolith may absorb some of the rain, prohibiting immediate surface runoff and making the runoff values predicted in this model a maximum. Consequentially, ICASE water accumulation totals imply rains equal to that of a significant deluge effect. We conclude that the water from the initial rainfall and subsequent hydrologic cycle predicted by ICASE to be induced by impact events would produce too much erosion and surface runoff to carve the valley networks. Clearly, impact cratering during this period was a significant process, and the effects may have contributed to smoothing of plains and degradation of crater rims, but the effects seem too global and intense to produce the delicate and widely-spaced valley networks [1].

Conclusions: Our goal is to set the stage for an improved ICASE model and provide testable hypotheses and predictions. Areas that appear to be most productive include: (1) improving knowledge of the importance, applicability, and validity of the initial conditions used in the Segura et al. [18] impact cratering model; (2) determining whether or not impact events on Late Noachian Mars produced local, regional, or global effects; (3) assessing predictions of geomorphological effects caused by the immediate post-impact ~1600 K global condensed-silicate-rock layer; and (4) continuing discussions on moving forward by focusing on the youngest of the large impact basins, Argyre, as a model for studying the global and regional effects of large impacts [21].

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Figure 1: ICASE Sequence Timeline

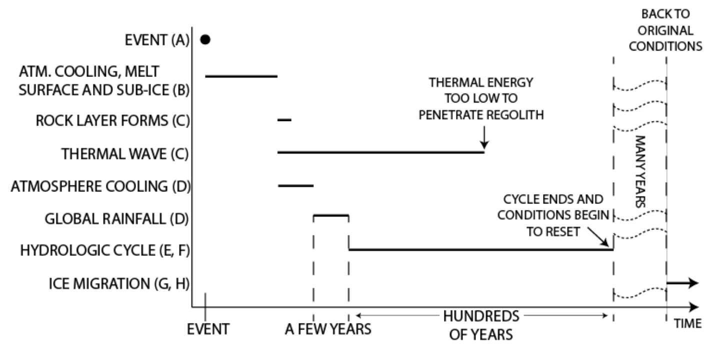

Figure 2: ICASE Sequence Diagram