IMPACT CRATERING AS A MODIFICATION PROCESS IN THE NOACHIAN HISTORY OF MARS: MAJOR PROCESSES AND WEAKNESSES.

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Introduction: A major candidate for periodically raising atmospheric and surface temperatures and causing rainfall and surface runoff during the Noachian is the process of impact cratering [e.g. 1-4]. The higher impact cratering flux in early planetary history not only increased the frequency of impact 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-surface 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 [1,2,4]. However, how this process operates is not well understood.

Analysis of the Impact Cratering Mechanism: In this work, we explore the effects of impact cratering on the atmosphere and surface, documenting the "Impact Cratering Atmospheric/Surface Effects" (ICASE) scenario as originally put forth by Segura et al. [1-2]. We highlight the important steps in the mechanism to create an illustrative timeline for qualitative understanding of the sequence (Fig. 1) while discussing the geological implications predicted by the ICASE scenario at each step, including atmospheric heating and rainfall. We illustrate the schematics of these steps and the global/regional implications through a series of descriptive diagrams (Fig. 2). Our goal is to offer an improved understanding of the atmosphere and surface effects related to impact cratering to set the stage for future modeling.

Important Factors: When modeling the regional and global temperature effects and rainfall associated with an impact event, initial model conditions will change depending on the circumstances of the impact event itself. Parameters which must 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. After the event, vaporized material will rise and expand as a plume and, upon reaching transparency temperature, will begin radiating heat down toward the surface and up through the top of the atmosphere.

The global extent of the vapor plume growth will depend directly on the amount of vaporized material injected into the atmosphere and the nature of the ambient atmosphere. Previous work [e.g. 1-4] has assumed global growth of the plume under all circumstances as an initial condition for predictions of the resultant rainfall and surface runoff rates and distributions. However, 3-dimensional plume growth modeling is necessary to quantify this variable and make reliable predictions on an impactor size relationship to global plume growth under early Mars atmospheric conditions. The early martian atmosphere was likely much thinner than Earth's current atmosphere, forcing the plume to expand differently, and likely more rapidly, than shown through Earth-based calculations and models.

As the plume grows and releases heat through expansion and thermal radiation, temperature decreases.

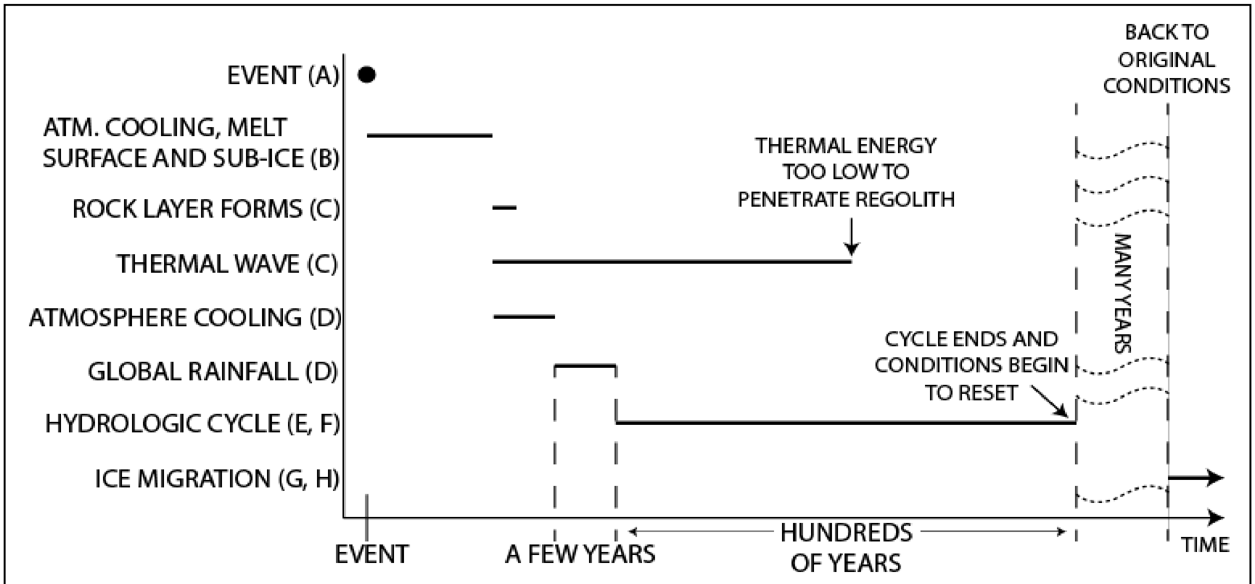

Figure 1. ICASE Sequence Timeline

Eventually, the plume will cool to condensation temperature for the vaporized rock silicate in the atmosphere, forcing it to condense and rain down at extreme temperatures, as high as ~1600 K [1-3]. The geomorphology of similarly-aged regions adjacent to Noachian craters can provide insight into the nature of the condensed rock silicate layer. Because the temperature of the condensed material is potentially near the liquidus temperature for basalt, the material may interact with the surface in one of two ways: (1) it may form a solid layer trapping heat beneath and forcing it to escape through specific conduits, for example, producing pseudocraters, or (2) buried heat might be lost to the atmosphere due to enhanced porosity in a particulate layer. Here, we explore both aforementioned hypotheses and discuss potential surface features that would result from either case.

Following the global rock silicate fallout, the atmosphere continues to cool and, eventually, the water vapor condenses and rains out, producing regional or global rainfall depending on the final distribution of the vaporized material in the atmosphere. In cases that introduce a large quantity of water to the atmosphere, some rainfall will be forced into surface runoff and a temporary hydrologic cycle is induced, during which the water is cycled through the atmosphere many times, further eroding the surface with each interraction.

Relationship to Fluvial Erosion and Valley Network Formation: With the more detailed understanding of the ICASE model [1-4] and its general geologic implications (Fig. 1,2), we extend our study to assess modelled predictions relating this process to Noachian valley network formation [1,2]. The rainfall totals proposed by ICASE predict average global rates equivalent to tropical rainforests on Earth, 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 [4].

The 1D model used by Segura et al. [1,2] assumes the initial condition of a fully saturated regolith, forcing all 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 therein a maximum.

Consequentially, ICASE water accumulation totals imply rains equal to that of a significant deluge effect, with intense rainfall and large volumes of water flowing on the surface. We conclude that the water from the initial rainfall and hydrologic cycle predicted by ICASE 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 sinuous and widely-spaced valley networks [6].

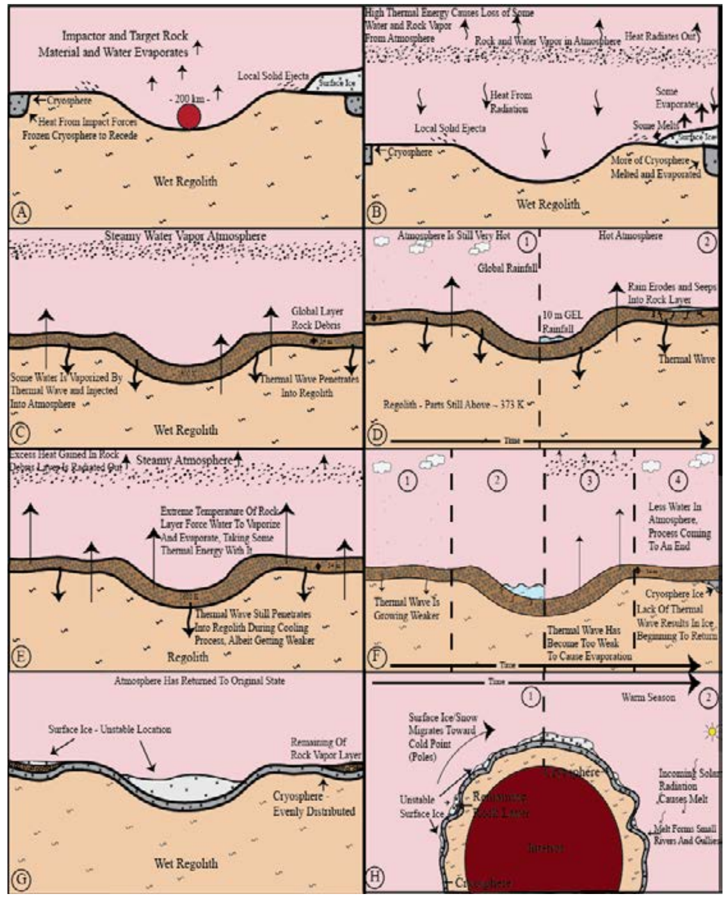

Figure 2. ICASE Sequence Diagram

Conclusions: We set the stage for an improved ICASE model and provide testable hypotheses and predictions. Areas that appear to be most productive for future investigation include: (1) improving knowledge of the importance, applicability, and validity of the initial conditions used in the Segura et al. [2] 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 rock silicate 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 [5].

References: [1] Segura et al. (402), *Science* **298**, 377-80. [2] Segura et al. (408), *J. Geophys. Res.***113**, E11007. [3] Segura et al. (412), *Icarus* **24**, 144-148. [4] Toon et al. (410), *Earth Planet. Sci.* **38**, 303-322. [5] Horan and Head (415), *6th Moscow Solar System Symposium* **Session 2**, 6MS3-MS-05. [6] Hynek et al. (410), *J. Geophys. Res. Planets115*, E09008.