Melting of Surface Ice Deposits on Mars by Hot Impact Ejecta. D. K. Weiss and J. W. Head, Department of Earth, Environmental, and Planetary Science, Brown University, Providence, RI 02912, U.S.A. (david_weiss@brown.edu)

Introduction: A wide variety of fluvial features are present on the surface of Mars. Of these features, fluvial features associated with impact craters and impact ejecta [e.g., 1, 2] are of particular interest because they may offer insight into the ancient martian climate and its relationship to the impact cratering process. The high spatial and temporal frequency of both impact events and surface ice [e.g., 3, 4] on Mars raises the possibility that an impact cratering event into regional surface ice deposits could have been a relatively common occurance throughout martian geologic history. We examine two mechanisms by which impact ejecta may cause melting of surface ice deposits in this scenario, wherein an impact occurs into regional surface snow and ice deposits (Fig. 1A):

Contact melting [1]*:* Ejecta is at elevated temperatures due to a combination of pre-impact geothermal heating at the depth from which it is excavated, and shock heating during the impact. When the ejecta is emplaced on the surface snow and ice deposits (Fig. 1B), the hot ejecta radiates heat outwards and conducts heat downwards into the icy deposits, thereby generating meltwater which may lead to fluvial erosion (Fig. 1C).

Basal melting [5]*:* Ejecta deposition on top of regional surface snow and ice deposits inhibits geothermal heat diffusion through the ice (Fig. 1C and E). As a result, following the impact event the 273 K ice melting isotherm within the shallow crust is predicted to rise to the base of the ice sheet given sufficient ejecta thicknesses (Fig. 1E). This causes the ice sheet to melt from the bottom-up, supplying a potential source of liquid water for fluvial erosion proximal to the impact crater (Fig. 1F).

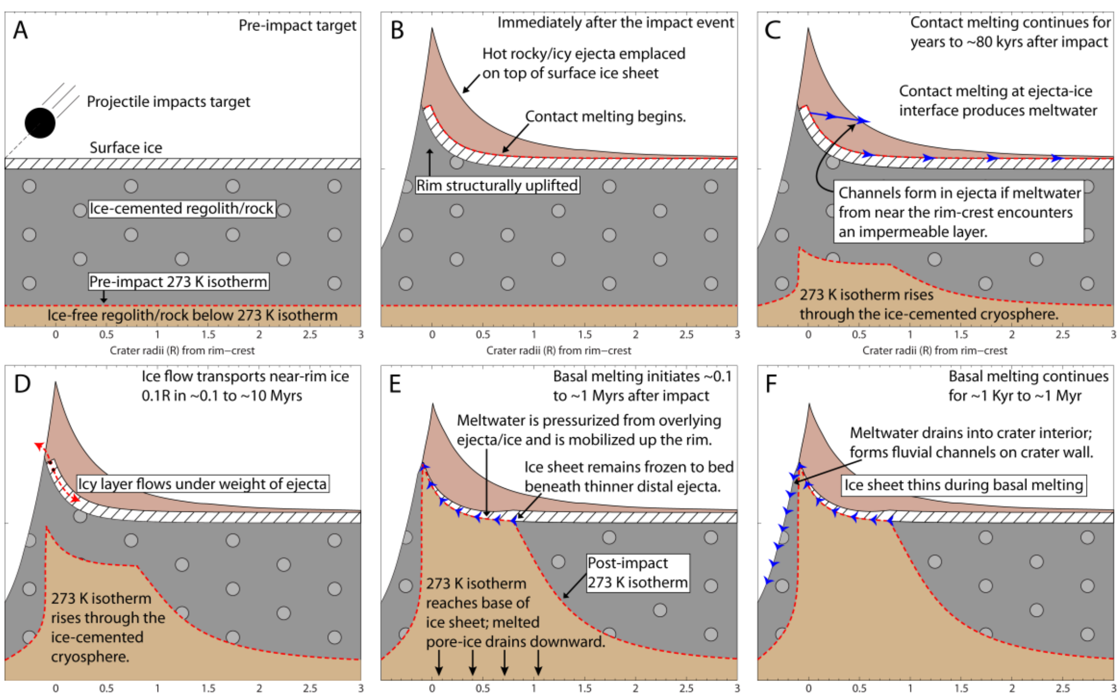

Figure 1. Post-impact melting configuration used in our models. A) The pre-impact target is composed of a surface ice layer overlying ice-cemented regolith/rock. The pre-impact ice-melting isotherm (273 K) (dashed red line) defines the base of the cryosphere (the zone cold enough for pore-ice stability). B) The impact occurs, and hot ejecta is deposited on top of the surface ice; contact melting of the surface ice begins. C) Contact melting continues and meltwater drains out of the ejecta; meltwater derived from near the topographically high rim-crest may form chan-

nels within the ejecta facies if the meltwater encounters an impermeable layer (e.g., a spring). D) The surface ice sheet may flow, enhanced by the weight of the overlying ejecta. E) The thermally insulating ejecta layer inhibits heat conduction, which raises the melting isotherm (273 K) (dashed red line) up through the cryosphere; the melted pore-ice then drains downward and is a source for groundwater recharge. The 273 K isotherm is raised up to the base of the ice sheet near the rim, where the ejecta is thickest. This allows for basal melting of the ice sheet; the meltwater is predicted to be transported up the crater rim (blue arrows) and towards the crater interior due to the pressurization from the overlying ejecta and ice. F) The meltwater transported into the crater interior could form fluvial channels on the crater walls.

Methods: We implement thermal models to test whether the presence of ejecta on top of surface ice can produce substantial contact melting at the ice sheet surface, or raise the geotherm sufficiently to induce melting at the base of an ice sheet (Fig. 1) [6]. We model the cooling of ejecta and melting of surface ice using the one-dimensional heat equation [6], where the initial ejecta temperature (Fig. 2) is found as the combined effects from pre-impact geothermal heating and post-impact shock heating [7].

Results: We find that the heat flux and surface temperature conditions required to produce contact melting are met throughout martian history for craters larger than ~40 km in diameter (Fig. 2), whereas the heat flux and surface temperature conditions to produce basal melting are met only under currently understood ancient martian thermal conditions. For an impact into a regional ice sheet, the contact and basal melting mechanisms are predicted to generate melt volumes between ~10^{-1} and 10^{5} km^3, depending on crater diameter, ice thickness, surface temperature, and geothermal heat flux. *Contact melting* is predicted to occur immediately following ejecta emplacement over the course of hundreds of years to tens of kyrs. *Basal melting* initiates when the 273 K isotherm rises through the crust and reaches the base of the ice sheet ~0.1 to ~1 Myrs following the impact.

Fate of meltwater: We find that contact melting is predicted to produce fluvial features on the surface of ejecta and the interior crater walls, whereas basal melting is predicted to produce fluvial features only on the interior crater walls (Fig. 1C and F). Before basal melting initiates, the ice-cemented cryosphere underlying the crater ejecta is predicted to melt

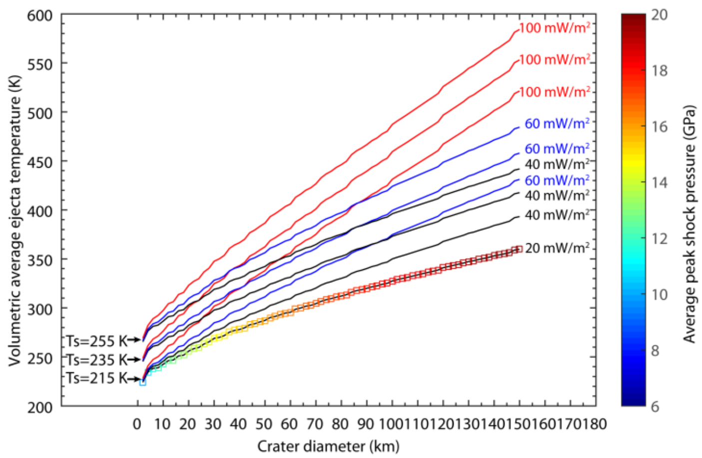

Figure 2. Volumetric average ejecta temperature (T_E) as a function of crater diameter for surface temperatures (*Ts*) of 215, 235, and 255 K, and surface heat fluxes of 20 mW/m^2, 40 (black lines), 60 (blue lines), and 100 mW/m^2 (red lines). Color bar indicates volumetric average peak shock pressures corresponding to each crater diameter (shown on the 20 mW/m^2 line).

and drain downwards through the substratum (Fig. 1C-E), generating a source of water for chemical alteration and possibly subsurface clay formation.

The contact and basal melting mechanisms appear attractive within the constraints of the current 3D climate models for the Late Noachian [e.g., 4] because they do not require warm atmospheric temperatures (e.g., the rainfall hypothesis for Late Noachian craters [8]). For example, contact and basal melting could operate as a background landscape/crater degradation processes in a cold and icy early Mars [5] even in the absence of punctuated warming events [e.g., 9, 10].

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