VOLATILE-RICH CRATER INTERIOR DEPOSITS ON MARS: AN ENERGY BALANCE MODEL OF MODIFICATION. Patrick S. Russell[1], James W. Head[1], Michael H. Hecht[2], [1]Dept. of Geol. Sci., Brown Univ., Providence, RI 02912 USA, [2]Jet Propulsion Laboratory, Pasadena, CA, USA. Patrick_Russell@Brown.edu.

Introduction: Several craters on Mars are partially filled by material emplaced by post-impact processes. Populations of such craters include those in the circum-south polar cap region, in Arabia Terra, associated with the Medusae Fossae Formation, and in the northern lowlands proximal to the north polar cap. In this study, crater fill material refers to an interior mound, generally separated from the interior walls of the crater by a trough that may be continuous along the crater's circumference (i.e. a ring-shaped trough), or may only partially contact the crater walls (i.e. a crescent-shaped trough). The fill deposit is frequently off-center from the crater center and may be asymmetric, (i.e. not circular) in plan view shape.

Such craters associated with the Medusae Fossae Formation are likely partially exhumed and contain remnants of Medusae Fossae material that may be ignimbrites [1], eolian materials [2, 3], true polar wander deposits [2], volatile-rich deposits [4], or volcanic ash accumulation [5]. In Arabia, such crater fill has also been interpreted as polar layered deposits associated with true polar wander [2] or lacustrine sedimentary deposits [6]. The fill of craters around the south pole is contiguous with south polar layered material, which argues for a similar process of deposition [7] with possible later exhumation of or flow into the crater [8]. Two craters at high northern latitudes contain fill material but are well separated from the north polar layered terrain: Korolev (73°N, 195°W) and an unnamed crater (77°N, 145°W). This configuration suggests this fill material was also deposited in a similar manner to the polar cap materials [7] and may or may not be remnants of a formerly more extensive polar cap [9].

An alternative origin is that impact disruption of the subsurface cryosphere allowed effusion of sub-cryosphere confined groundwater into the crater under artesian-like conditions [10, 11]. This process would be aided in a globally interconnected hydrosphere-cryosphere system [10] by the low planetary elevation of the northern lowlands craters [12]. By the same reasoning, such an explanation would not be likely for filled craters in high-elevation, circum-south polar regions. However, filling by groundwater effusion seems a less likely explanation than polar-like depositional processes because the only large craters (> 40 km diameter) in the northern lowlands containing significant fill material are the two most proximal to the north polar cap [12]. Given these theories of crater fill formation, fill material in the north and south polar regions is almost certainly rich in volatiles, and even the fill of equatorial craters may contain significant volatiles.

Volatile-rich deposits have the property of being modifiable by the local stability of the solid volatile, which is governed by local energy balance. Here we test the hypothesis that asymmetries in volatile fill shape, profile, and center-location within a crater result from asymmetries in local energy balance within the crater due mainly to variation of solar insolation and radiative effects of the crater walls over the crater interior. We first focus on Korolev crater [13] in the northern lowlands. We can then apply this model to other craters in different regions. If asymmetry in morphology and location of crater fill are consistent with radiative-dominated asymmetries in energy budget within the crater, then 1) the volatile-rich composition of the fill is supported (this process should not be effective at shaping volcanic or sedimentary deposits), and 2) the dominant factor determining the observed shape of volatile-rich crater fill is the local radiative energy budget within the crater (and erosive processes such as eolian deflation are not necessary).

Korolev Crater: Korolev crater (~80 km diameter) is superposed on Amazonian mantle material surrounding north polar terrain [7]. While the crater is circular, rim height is not uniform around its circumference (Figs. 1-3). The rim is highest in the northeast (-3.4 km) and lowest in the west (-4.2 km). The lowest elevation of exposed floor is in the southwest (–6.2 km) (Fig. 1). The smooth-surfaced, roughly circular fill deposit within Korolev does not extend completely to the interior walls of the crater, leaving an intervening ring-shaped trough (Figs. 1-3). Relative to the crater's center, the fill deposit is displaced to the north and east (Fig. 1), where it reaches closer to and higher up the crater walls (Figs. 2, 3). The highest point of the fill deposit (-4.7 km, roughly equivalent to the surrounding plains) is also displaced in the same sense (Figs. 1-3). The rim-to-floor depth expected at a fresh, unfilled crater of Korolev's diameter based on morphometric relations of martian craters is 2.3 km [14] to 2.9 km [15]. This range corresponds well with the observed range of maximum and minimum rim-to-floor depths (2.8 km and 2.0 km) using the floor elevation of the greatest exposed depth and the maximum and minimum rim elevations. This consistency in observed and predicted fresh depths suggests that the actual deepest point of the crater is not much deeper than the observed elevation, -6.2 km. The maximum thickness of the fill mound is then ~1.5 km [15].

Preliminary Model: Initial model development demonstrates the relative role of incident solar radiation on differently-facing slopes. As expected at the high northern latitude of Korolev, south facing slopes receive more total yearly insolation. Asymmetry in insolation is clearly a candidate for being the major control on volatile fill asymmetry. This is supported by observation in a north-south profile across Korolev (Fig. 2) showing a strong asymmetry in which fill is concentrated to the north, consistent with more energy input from southerly insolation.

However, because insolation from the west and east are similar, it is evident from the asymmetry in an east-west profile of Korolev fill (Fig. 3) that other factors are influencing fill morphology. In this case, a strong east-west asymmetry in rim height (Fig. 3) suggests that shadowing a high rim may be a secondary, or possibly locally primary, influence on volatile fill stability. A nearby high rim, however, will also decrease radiative heat loss by reducing the angle of sky seen by a surface [16]. A more detailed model to sort out relative effects on crater fill morphology is outlined below.

Further Model Development: Our approach to determine where and how much modification of an assumed existing water-ice crater-fill occurs is to calculate the main energy input and output pathways for a patch of the surface and assume any excess input energy is available for sublimation. The main processes involved are as follows: 1) solar insolation, incremented by 5 minute intervals over a martian year, including the slope and slope direction of the surface and the shadowing effects of the crater walls, 2) temperature-dependent re-radiation from the surface, including the geometric effects of the crater walls on reducing emittance to the sky, 3) diffusion of heat into or out of the body of ice below the surface, and 4) energy, if any, available for phase change and sublimation [16]. By iteratively calculating the energy balance of these processes at different points within the crater, we can determine the relative amount of sublimation at each point. For simplification and for ease in comparison with observed fill topography (e.g. Figs 2, 3), these calculations will be done along one center-to rim transect at a time. While absolute amounts of sublimation may be attainable in the future, we are currently mainly interested in what factors control the asymmetry of the deposits, for which relative differences around the crater are sufficient. By modeling Korolev with both a uniform rim and a more realistic approximation of varying rim height, the role of rim height in combination with azimuth orientation of fill material slope will be assessed.

References: [1] Scott, D. H., and K. L Tanaka (1982) *JGR 87*, 1179-1190. [2] Schutlz, P. H., and A. B. Lutz (1988) *Icarus 73*, 91-141. [3] Forsythe, R. D., and J. R. Zimbelman (1989) *Nature 336*, 143-146. [4] Head, J. W. (2001) *LPSC XXXII*, Abstract #1394. [5] Hynek, B. M. et al. (2002) *LPSC XXXIII*, Abstract #1408. [6] Malin, M. C., and K. S. Edgett (2000) *Science 290*, 1927-1937. [7] Tanaka, K. L., and D. H. Scott (1987) USGS Map I-1802-C. [8] Head, J. W. (2001) *JGR 106*, 10,075-10,085. [9] Fishbaugh, K. E., and J. W. Head (2000) *JGR 105*, 22,455-22,486. [10] Clifford, S. M. (1993) *JGR 98*, 10,973-11,016. [11] Russell, P. S., and J. W. Head (2002) *GRL 29*, 17, doi:10.1029/2002GL015178. [12] Russell, P. S., and J. W. Head (2002) *Eos Trans. AGU Suppl.* F849. [13] Head, J. W. et al. (2002) *Microsymposium 36*, Abstract #MS031, Moscow, Russia. [14] Pike, R. J. (1988) in *Mercury*, F. Vilas et al., eds., Univ. Arizona Press, 165-273. [15] Garvin, J. B. et al. (2000) *Icarus 144*, 329-352. [16] Hecht, M. H. (2002) *Icarus 156*, 373-386.

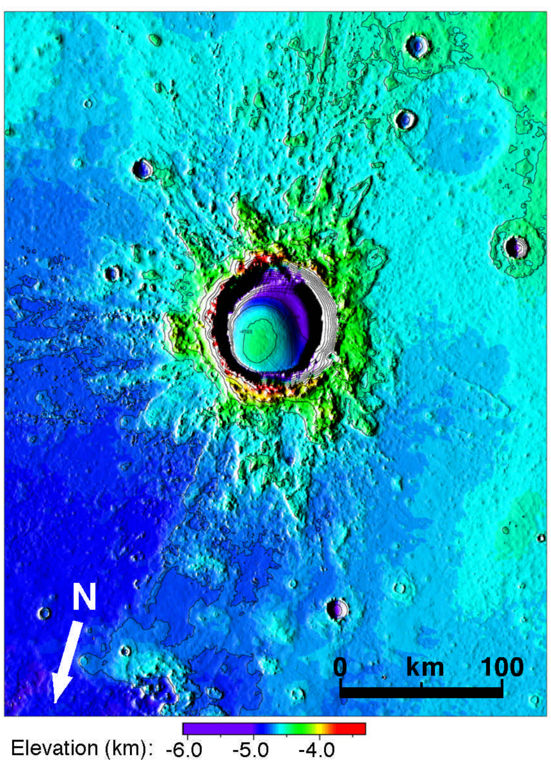

Figure 1. Gridded MOLA topography of Korolev Crater.

Figure 2. South-north altimetric profile of Korolev Crater.

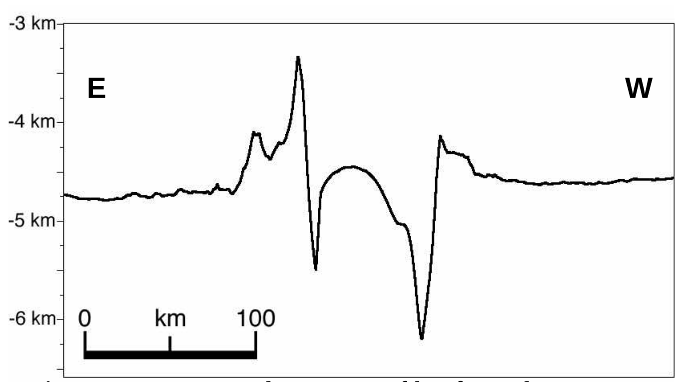

Figure 3. East-west altimetric profile of Korolev Crater.