The generation and distribution of martian impact melt/glass: A computational study with implications for the nature of dark surface materials. K. E. Wrobel and P. H. Schultz, Department of Geological Sciences, Brown University, Box 1846, Providence, RI 02912 (Kelly_Wrobel@brown.edu).

Introduction: Recent studies [1-2] propose that widespread dark deposits across Mars could be the result of well-preserved impact products accumulated since the late Hesperian (distal tektite-like glasses and lower velocity melt-matrix breccias). The relatively low impact velocity on Mars (compared to Earth) along with the sedimentary nature of the martian crust, however, has led to the assumption that significant impact melts may not be produced on Mars [3-4]. In contrast, Schultz and Mustard [1] found, based on spectral reflectance and the TES instrument, that accumulated distal deposits would be substantial enough to suggest an alternative interpretation for glassy andesitic materials.

The present study re-examines the possible contribution of melt across Mars by incorporating the CTH hydrocode [5] into a global ejecta dispersal model that includes Coriolis effects. The results confirm that substantial melt will be generated and widely distributed. Such materials may have a significant contribution to large concentrated regions of dark mobile deposits found on the surface.

Background and Procedure:

Effect of Rotation: Previous studies [2, 6-7] showed that accurate account of the Coriolis force is essential in detailed modeling of ejecta distributions; the Coriolis terms must be incorporated directly into the angular momentum equation of the spherical ballistics. In particular, the deposition locations of distal ejecta from high angle (closer to vertical) impacts are significantly affected, resulting in substantial concentrations of deposits at rather unexpected locations. The cumulative effects of such deposits over time could have global implications and thus accurate incorporation of the Coriolis force is crucial for the present study.

Computational vs. Analytical Models: Analytical ejecta-scaling models [e.g., 8-11], while indispensable and highly utilized, cannot provide a completely realistic, fully integrated model of ejecta mechanics (generation and distribution). Hydrocodes such as the CTH shock physics analysis package [5] allow more comprehensive tracking of specific impact cratering phenomena, including melt generation [e.g., 12].

Procedure: This study maps the distribution of impact melt across the surface from all large (>100 km in diameter) Hesperian-aged (or younger) martian craters using a series of detailed ballistic equations that have been altered to include rotational effects [see 6]. Actual melt fractions (along with melt generation velocity distributions) were calculated using a CTH computational model of a 10 km/s impact under martian conditions (melt fractions obtained were scaled accordingly for each crater based on diameter).

Ejecta mass estimates were obtained from an impact simulation that modeled the formation of a Lyot-sized crater – 220 km in diameter at ~30N, ~330W. Comparisons with previous analytical approximations show reasonable consistency (see Table 1). Differences stem primarily from the uncertainty in the empirical, material-dependent constants found in the analytical equations.

	Computational Model	Analytical Model
Total Ejecta Melt Mass (g)	2.57E+19	5.00E+19
Total Ejecta Mass (g)	1.60E+21	4.76E+21
Global Melt Thickness (cm) (If equally distibuted across Mars)	18.8	36.8

Table 1. Comparison between computational results (from a CTH martian impact simulation) and analytical results (from ejecta-scaling models [e.g., 8-11]) regarding melt production during a 10 km/s Lyot-sized impact (220 km diameter crater at ~50N, ~330W).

Results and Discussion: Figure 1 shows the cumulative thickness of distal impact melt (ejection velocities above 3 km/s – primarily pure melt) from a series of 22 martian craters, illustrating a widespread dispersal of substantial deposits. Many of the regions with considerable melt (tens of centimeters thick) coincide well with concentrations of dark materials found on the surface, such as Syrtis Major Planum and Hesperia Planum.

The preservation history of these distal ejecta products (Figure 1) will differ across the surface, eventually leading to more focused/concentrated regions of melt and glass. For example, impact glass deposited within the thick sediments of Arabia would have become buried and trapped (hidden as layers within deposits), but then later subjected to exhumation, deflation and redistribution [1]. Anything deposited in such locales should thus still be present today due to the lack of severe weathering occurring since the Hesperian [1]. Such deposits may account for the dark dunes trapped on the floors of large exhumed craters.

Impacts can generate complex assemblages of melted ejecta, not just tektite-like glasses: e.g., melt-matrix breccias and impact-melt breccias. As a result, the term 'impact melt' as applied here can be misleading. In fact, such melt breccias formed from unconsolidated sedimentary targets can contain as little as ~10-20% melt [13] due to incorporation of mineral clasts during ejection. Consequently, hydrocode estimates for the total volume of dispersed melted (partially and fully) materials could be underestimated by a factor of 5 to 10. With this in mind, the net impact melt accumulations presented in Figure 1 could (and should) be viewed as a highly conservative estimate.

Conclusions: The strong effect of the Coriolis force on the distal distribution of ballistic ejecta across Mars has previously been demonstrated [2, 6]. This new study combines those earlier results with melt generation estimates based on CTH-hydrocode calculations. When considering the total contribution of ejecta from a series of large craters, the Coriolis effect becomes substantial leading to large concentrations of materials at unexpected locations.

The accumulation of melt-rich ejecta products dispersed across Mars should be significant and thus must be accounted for. Some of this material may be trapped in successive layers within sedimentary deposits or redistributed by aeolian processes. On the other hand, the absence of melt products in certain regions could be an indicator of weathering processes through time [1]. Differences between the distribution of distal impact products (as shown in Figure 1) and the dark material regions evident on Mars albedo maps may be the result of weathering, burial, and/or impact angle effects. Regardless, the build-up of well-preserved impact melt should be substantial in regions of dark deposits across the surface.

Future studies will incorporate the effect of impact angle on the pattern of melts.

References: [1] Schultz P. H. and Mustard J. F. (2004) *JGR, 109*, doi:10.1029/2002JE002025. [2] Wrobel K. E. and Schultz P. H. (2003) *6th Int. Mars Conf.*, Abstract #3242. [3] Artemieva, N. A. (2001) *LPS XXXII*, Abstract #1216. [4] Kieffer S. W. and Simonds C. (1980) *Rev. Geophys. Space Phys., 18*, 143-181. [5] McGlaun, J. M. et al. (1990) *Int. J. impact Eng., 10*, 351-360. [6] Wrobel K. E. and Schultz P. H. (2004) *JGR, 109*(E5), doi:10.1029/2004JE002250. [7] Dobrovolskis A. (1981) *Icarus 47*, 203-219. [8] Housen K. R. et al. (1983) *JGR, 88*(B3), 2485-2499. [9] Schultz P. H. et al. (1981) *Proc. LPS XXII*A, 181-195. [10] Schultz P. H. and Gault D. E. (1985) *JGR, 90,* 3701-3732. [11] O'Keefe J. D. and Ahrens T. J. (1977) *Proc. LPS VIII*, 3357-3374. [12] Pierazzo E. et al. (1997) *Icarus, 127*, 408-4. [13] Schultz P. H. et al. (2004) *EPSL, 219*, 221-238. [14] Edgett K. S. et al. (1997) *JGR, 102*(E9), 21,545-21,568.

Acknowledgements: This material is based on work supported by NASA Grant No. NAG5-11538 and a 2004-2005 Rhode Island Space Grant Fellowship.

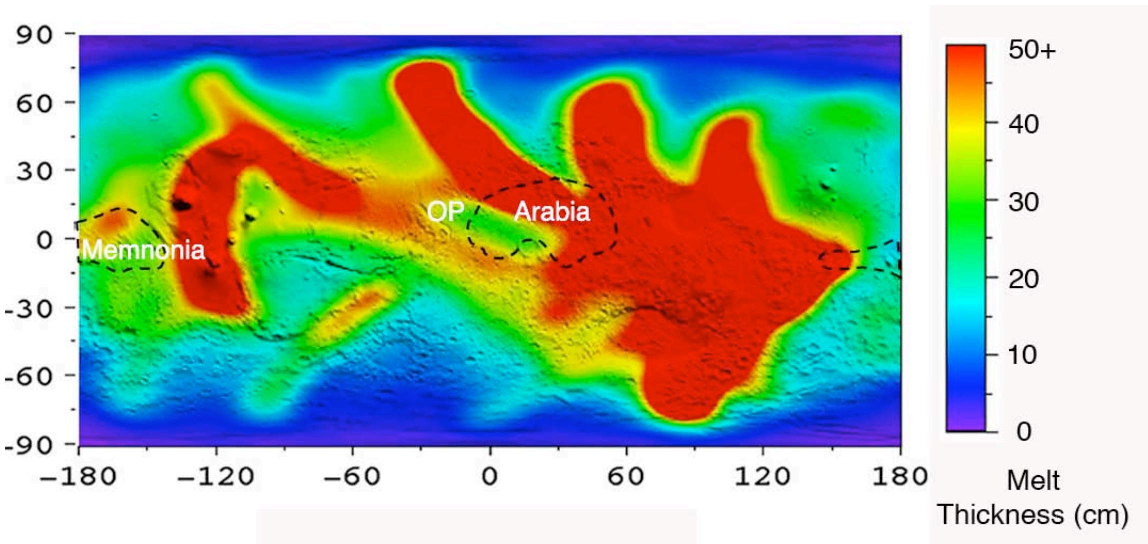

Figure 1. Map of the cumulative distribution of distal melt from all large (≥100 km in diameter), Hesperian-aged (or younger) martian craters. A series of detailed spherical ballistic equations (directly incorporating the effect of planetary rotation – the Coriolis force) were used to map deposition locations [6-7]. The melt fraction contributions were found computationally using a CTH Martian impact model. Circled regions (dashed lines) highlight examples of prominent surface areas [see 14] (OP stands for Oxia Palus) where impact melt/glasses may have been trapped and sustained within sediments.