Probing the Giant Impact Hypothesis of the Martian Crustal Dichotomy. S. H. Hart[1], F. Nimmo[1], D. Korycansky[1] and C. Agnor[1], [1]University of California Santa Cruz, Earth and Planetary Sciences 1156 High St. Santa Cruz, CA 95064 shart@pmc.ucsc.edu

Introduction: The Martian crustal dichotomy is a first order feature of Martian topography whose origin has yet to be adequately explained. Both internal and exogenic mechanisms have been proposed [1-3], invoking either large-scale mantle dynamics or giant impact events. This study uses numerical simulations to test the viability of a single giant impact [1,3] causing the large scale difference in crustal thickness between the northern and southern hemispheres of Mars.

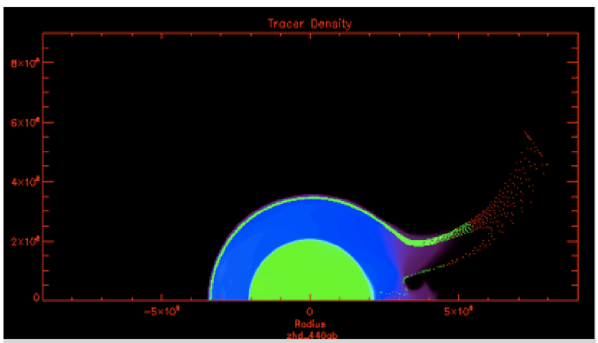

Figure 1. An example of a screenshot of an impact simulation run at time 1020s, impactor radius = $3x10^7$cm, impactor velocity = $2.5x10^6$ $^{cm}/_{s}$, and a kinetic energy of ~$1.04x10^{36}$ergs. Graphical representation of tracer particles at the surface overlaying background density contours.

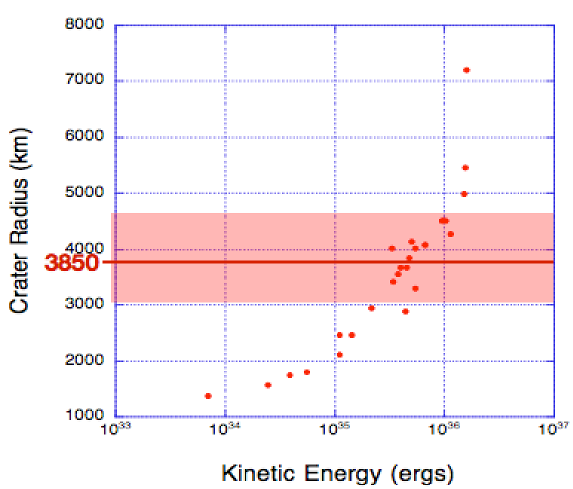

Figure 2. Plot representing the relationship between the kinetic energy of the impactor with the resulting excavated crustal region. Shaded region denotes impactors creating basins comparable to the present size of the northern lowlands.

A modified version of the numerical hydrocode Zeus MP [4] has been used to simulate these large impacts into a two layer differentiated target body using the Tillotson equation of state with an anorthosite mantle and iron core. The code employs a variable Eulerian grid on a 2-D axi-symmetric polar grid, while also embedding an array of lagrangian tracer particles in the top 50km of the target body. These tracer particles track the evolution of the crustal material that occurs in each of the impact runs, allowing the region of crustal excavation to be calculated for each impact event. An important part of this process was to benchmark the results of the model with previously derived scaling relationships [5,6], verifying that our shockwave speeds and depth of impactor penetration were consistent.

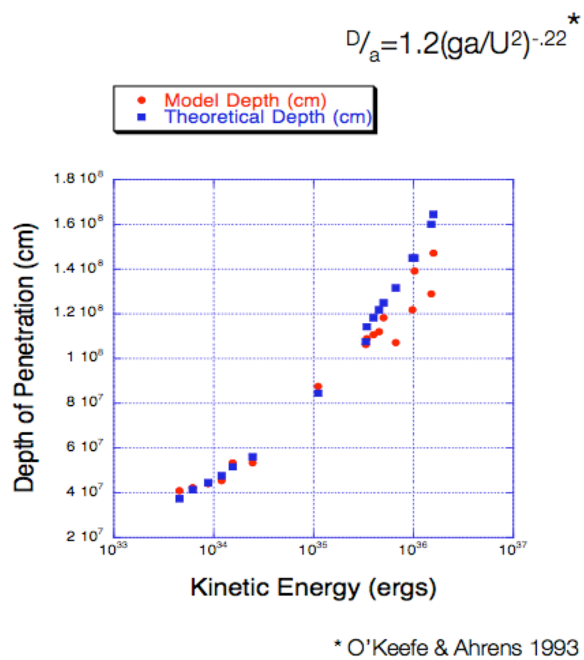

Figure 3. Plot representing one of the benchmarking techniques in which the maximum depth of penetration of the impactor is compared to a scaling relationship developed by [6].

It was found that in order to create a region of crustal excavation large enough to explain the dichotomy an impact kinetic energy of ~$7x10^{35}$ergs is required (figure 2), which is comparable to the energy estimated by [1]. This amount of energy is enormous, equal to several percent of the gravitational binding energy of the planet. We estimated the mass of melt produced by tracking the total mass of material that underwent a shock pressure between 42GPa and 102GPa [5]. (fig. 4). The minimum mass of melt produced by impacts large enough to create the dichotomy was ~$5x10^{24}$g. If redistributed globally, such a melt layer will be ~14km thick, sufficient to erase the present-day topographic step associated with the crustal dichotomy.

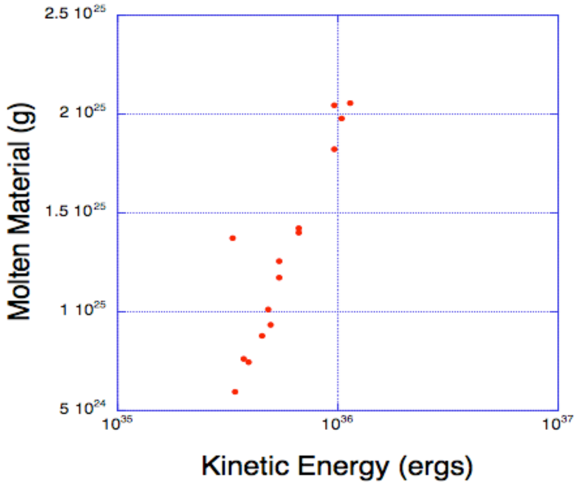

Figure 4. Mass of material (g) that underwent a pressure between 42-102GPa, forming melt in the target body. All of the impactors represented in the red region of figure 2 are shown.

These preliminary results require further investigations. In particular, the effect of oblique impacts and the actual pattern of ejecta redistribution need to be determined. Nonetheless, our initial results suggest that, while an impact energy of ~10^{36}ergs can excavate a crustal basin comparable in size to the dichotomy, melt generation and redistribution is unlikely to allow the initial dichotomy to be preserved. We therefore conclude that a single, giant impact is unlikely to have directly caused the Martian dichotomy.

References:

[1] Willhelms D.E. and Squyres S.W. (1984) *Nature,* 309, 138-40. [2] Zuber M.T. (2001) *Nature,* 412, 330-27. [3] Marinova M.M. et al (2005) *AGU* P42A-06. [4] Norman M. (2000) Introducing Zeus-MP: a 3D, parallel, multiphysics code for astrophysical fluid dynamics. *Instituto de Astronomia, Universidad Nacional Autonoma de Mexico.* [5] Melosh H.J. (1989) Imact cratering: a geologic process, *Oxford Univ. Press, New York*. [6] O'Keefe J.D. and Ahrens T.J. (1993) *JGR,* 98, 17011-17028.