THE SOUTH POLE IMPACT CRATER ON VESTA: NUMERICAL MODELING. B. A. Ivanov[1], H. J. Melosh[2], E. Pierazzo[3], [1]Institute for Dynamics of Geospheres, RAS, 119334, Moscow, Russia (baivanov@idg.chph.ras.ru), [2]Departments of Earth and Atmospheric Sciences, Purdue University, Civil Engineering Building, Room 3237, 550 Stadium Mall Drive, West Lafayette IN 47907 (jmelosh@purdue.edu), [3]Planetary Science Institute, 1700 E. Ft. Lowell Rd., Ste. 106, Tucson, AZ 85719 (betty@psi.edu).

Introduction: The Dawn mission to the largest asteroids Vesta and Ceres promises valuable new data about these differentiated bodies (see the review [1] and references therein). The link between the largest South Pole impact crater (SPIC) on Vesta and its corresponding asteroid family is an important issue for modeling efforts and to understand large scale cratering processes on small bodies [2, 3, 4]. Here we present some 2D numerical models of SPIC formation with self-gravity [5] and the acoustic fluidization model [6].

Numerical Model: The SALEB hydrodynamic solver [5] is used to model the solid material motion due to impact. The Poisson equation for the gravitational potential allows us to compute the components of the gravity acceleration in each computational cell vertex. The boundary conditions associated with the gravitational potential are updated at 100s time intervals (this is the most time-consuming procedure).

Target. Geochemical analysis and modeling of HED meteorites allows us to estimate the probable structure of a differented Vesta [1, 7, 8, 9]. Before an analysis of all possible structural parameters, we follow the choice in [3, 4] by treating Vesta as a spherical body 540 km in diameter with an iron core of 240 km in diameter. Its crustal thickness is assumed to be 20 or 40 km – close to the range estimated in [7]. ANEOS-based tables for basalt, dunite, and pure iron are used as a proxy to represent the equations of state for crust, mantle and core respectively. Details of EOS usage and the assumed strength/friction properties are published elsewhere [5]. Additional fits to specific HED parameters as well as to a non-pure iron core have not been done yet: With our assumed asteroid diameter, crust thickness and core size, the *GM* value of 20.9 km^3/s^2 is slightly above the best astronomical and Mars influence estimates of ~17.4±0.3 km^3/s^2 [9]. Our model's surface gravity is about 0.27 m/ s^2 with an average density of 3.8 g/cm^3 – slightly above the best current estimates of 3.36 to 3.38 3.8 g/cm^3. For simplicity, a constant twmperature of 293 K is assumed. The spherical target is equilibrated in its self-gravity field in a special pre-modeling run without a projectile.

Projectile and spatial resolution. Dense basalt projectiles (density of 2.858 g/cm^3) with an impact velocity of 5.5 km/s have various radii ranging from 40 to 96 km (mostly larger than ~40 km assumed in [2, 10]). Our spatial resolution varies from 10 to 30 cells per projectile radius (CPPR) with a cell size of 2x2 km in cross section. Consequently, Vesta's radius is covered with ~135 cells. The present resolution is a compromise between accuracy and the need to made dozens of variants to cover multiple combinations of parameters. For future, more detailed models, the resolution may be easily improved by a factor of two.

Preliminary Results: The first runs with 40 to 50 km diameter projectiles and standard rock strength/dry friction properties [5] produced a simple crater (Fig. 1) dissimilar to the SPIC (as revealed by modeling from from HST imaging [11], 1996 version http://sbn.psi.edu/pds/asteroid/EAR_A_5_DDR_SHAPE_MODELS_V2_0/data/vesta.tab). The impact shatters the asteroid, accelerates it to 2 to 30 m/s velocity, causes plastic deformation in the iron core, but does not dramatically disturb the initial spherical shape. Moreover, the vertical impact of such a projectile seems unable to eject enough of the mantle material at escape velocity – in disagreement with the observed deep crust/upper mantle "chips" among Vesta family asteroids and HED meteorites [12,13]. In this case, the widely cited "spallation model" (eg. [2]) does not appear to be an attractive explanation for material ejected from a depth of 10 km and more—the crater excavation flow may do the job better.

In this work we study: (1) an increase of the SPIC projectile diameter to ~80 km at 5.5 km/s, and (2) the influence of a temporary frictional strength decrease (parameterized by the acoustic fluidization - AF- model). We find a systematic change of the impacted Vesta profile (Fig. 2) for projectile diameters from 70 to 90 km. All impacts create craters with conical "flat" slopes, and cover the hemisphere opposite to the impact point with a global ejecta layer. The ejected mass of "mantle" (originating from layers below 20 km depth) is of the order of (0.8 to 2.7)×10^6 km^3 which is enough to explain the presence of "mantle" asteroids in Vesta's family [13]. Our modeling demonstrates a complex interplay of deposited ejecta and crustal/mantle material that slides back into the crater—which can be compared with observations [14].

Conclusions and Outlook: Results of our reconnaissance modeling of the SPIC formation demonstrate the possibility that the projectile may be larger than the normally assumend 40 km. This implies that the assumed 1 Gyr age of SPIC, derived from estimates based on collision probability [10], may be larger, because larger projectiles are less abundant in the main belt. This deep excavation argument needs to be confirmed with 3D oblique impact modeling to understand how the depth of the escaped ejecta depends on impact angle. We should check also if the presence of a solid iron core may increase the collision strength of Vesta – the largest modeled projectile of 96 km in diameter strips out the crust from the hemisphere opposite to impact but does not destroy our model Vesta target at specific kinetic energy per mass ~0.66×10^5 J/kg (what is well below the catastrophic limit ~20×10^5 J/kg [15]).

Acknowledgements: Supported by PGG grant NNX10AU88G.

References: [1] McSween H. Y. *et al.* (2010) *Space Science Reviews*, *46*, in press (DOI 10.1007/s11214-010-9637-z). [2] Asphaug E. (1997) *MAPS*, *32*, 965-980. [3] Jutzi M. & E. Asphaug (2010) *LPSC*, *41*, #2129. [4] Jutzi M. & E. Asphaug (2010) DPS meeting, *BAAS*, *42*, 1033. [5] Ivanov B.A. et al. (2010) GSA Spec. Pap., 465, 29-49. [6] Melosh H.J. & B.A. Ivanov (1999) *AREPS*, *27*, 385-415. [7] Ruzicka A. *et al*. (1997) *MAPS*, *32*, 825-840. [8] Righter K. & M.J. Drake (1997) *MAPS*, *32*, 929-944. [8] Warren, P.H. (1997) *MAPS*, *32*, 945-963. [9] Konopliv A.S. et al. (2010) *Icarus*, doi:10.1016/j.icarus.2010.10.004, in press. [10] Marzari F. A. *et al.* (1996) *A&A*, *316*, 248–262. [11] Thomas P.C. *et al.* (1997) *Icarus*, *128*, 88-94. [12] Miyamoto M. and H. Takeda (1994) *EPSL*, *122*, 343-394. [13] Reddy V. *et al.* (2010) *Icarus*, doi: 10.1016/j.icarus.2010.11.032, in press. [14] Reddy V. *et al.* (2010) *Icarus*, *210*, 693–706. [15] Melosh H.& E.V. Ryan (1997) *Icarus*, *129*, 562-564.

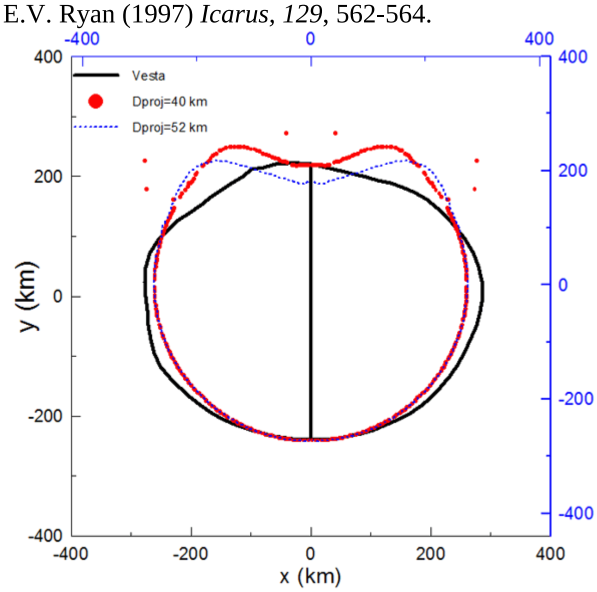

Fig. 1. Meridional (80°+260° lat.) profile of Vesta (black axis) in comparison with two model profiles for spherical basaltic projectiles with diameters 40 and 52 km (blue axis). Models results are linearly scaled down (factor of 0.95) to fit model and real Vesta sizes

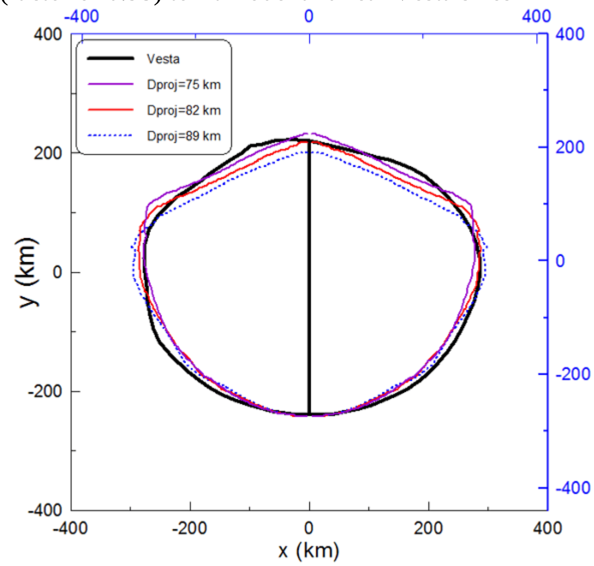

Fig. 2. Meridional (80°+260° lat.) profile of Vesta (black axis) in comparison with three model profiles for spherical basaltic projectiles with diameters 74, 82, and 89 km (blue axis). Model results are linearly scaled down (factor of 0.95) to fit model and real Vesta sizes.

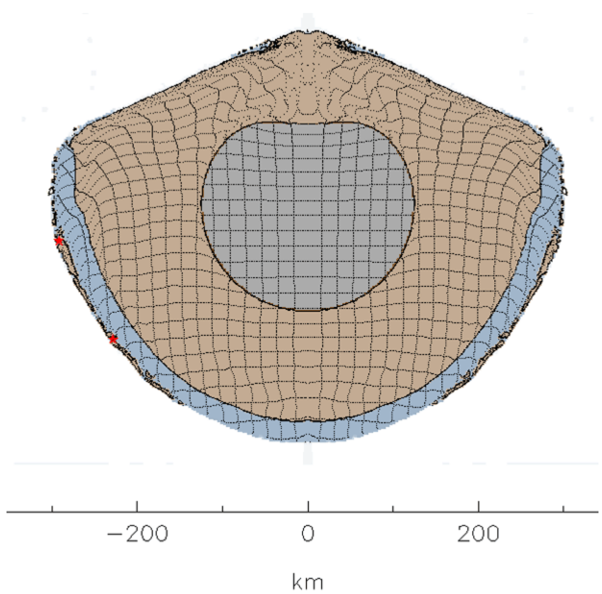

Fig. 3. Model cros-section of Vesta after impact of a projectile D_{proj}=82 km (red profile in Fig. 2). The iron core is slightly deformed, crustal material (initial crust thickness of 20 km) partially fills back the conical crater floor as a thin veneer. Transient crater diameter (along the curved surface) is about 550 km (radial distance of 230 km).