GIANT MARTIAN IMPACT BASINS - NUMERICAL MODELING. B.A Ivanov, Institute for Dynamics of Geospheres, RAS, 119334, Moscow, Russia, baivanov@idg.chph.ras.ru.

Introduction: The presence of several giant impact basins on Mars (e.g. Hellas, Utopia, Argyre, Isidis), open a scientific window into early years of Mars geology. For example, the count of these basins has been used for the one of the first chronology system for Mars [1]. Recent data from gravity and magnetic fields give the basis for important speculations about early thermal and magnetization state of Martian crust and core (e.g. reviews [2-4], and papers [5-7]) when all giant basins have been formed. The impact basin formation is still poorly known process mainly modeled from geophysical data (e.g. [8]). Despite the presence of numerical modeling of impacts at all scales [9], the specific modeling of giant crater formation at a spherical planet with the specific thermal profile is still the unresolved problem due to many lacunas in our knowledge of material strength and thermodynamic properties of crustal and mantle rocks as well as the material of the Martian core. The presented work is devoted to the reconnaissance study of giant basin formation on Mars.

The numerical model consists of the material motion equations solver (SALEB hydrocode is used here [10, 11]), a set of equations of state (ANEOS code is used here [12, 13]), and a set of assumptions about the thermal state of the target.

Mars model. Spherical Mars is modeled at the rectangular grid of cells filled with 3 materials: basalt models crust, dunite models mantle, and iron models core. All 3 materials are described with ANEOS equation of state. The problem of fitting of (mainly) shock-wave derived equation of state to the real Martian rocks should be refined in the future. The same is valid for the unknown Mars core material, modeled here preliminary with the available EOS for pure iron. The thermal profile of Mars has been estimated for various geological periods by many authors as reviewed in [2-3]. Here we use crust/mantle and core/mantle temperatures close to estimates in [14]. The general view of the target is shown in Fig. 1. The model simulates the planet with radius 3400 km, mass 6.44 10^{23} kg, and surface gravity of 3.69 m s^{-2}.

Model runs have been done for vertical impacts of (basaltic) asteroids (diameters from 400 to 800 km) with velocities of 8 to 12 km s^{-1}. The typical outcome is shown in Figs 2 and 3. The final shape of the planet returns close to the sphere, however the mantle uplift and remote stresses are visible in the small-scale analysis. The main (so far) result we see in the evidence that the "melt pool" at the basin center is the inevitable consequence of basin-forming impacts. It means that the crust/mantle boundary estimated from geophysics is the "new crust/new mantle" boundary as the solidification of the «melt pools» repeats the primary crust separation process with possible geochemical peculiarities (such as "depleted mantle"). This is a valuable input model for possible further geochemical speculation about mineralogy of "new" crust and mantle inside basins.

Discussion. The model results give an opportunity to estimate the size of basin-forming impactors by the direct comparison of mantle uplift profiles, modeled numerically and geophysically. However it needs the solution of another model problem of solidification of the "melt pool" with stress field in the crust and mantle. The most similar problem is analyzed in [15, 16] with simplified initial conditions (hemispheric heated volume) but with the whole planet mantle convection. It is shown that magmatic activity in the impact site may exists for 100 Ma and longer depending on mantle viscosity. This activity may be enough intensive to produce the Tharsis rise.

For smaller impacts the solidification of "new" crust and "new" mantle is inevitable. It means that the interpretation of MGS gravity anomaly data for Mars (as well as for lunar basins) should take into account possible geochemical "novelity" of crust and mantle in originally molten zone, which may occupy areas of n*1000 km across (like in Fig. 3).

Conclusion and outlook. Analizing the data obtained with MEX, MGS and Odyssey spacecrafts, the modeling of impact cratering on Mars allows us to understand better Martian geology and geophysics.

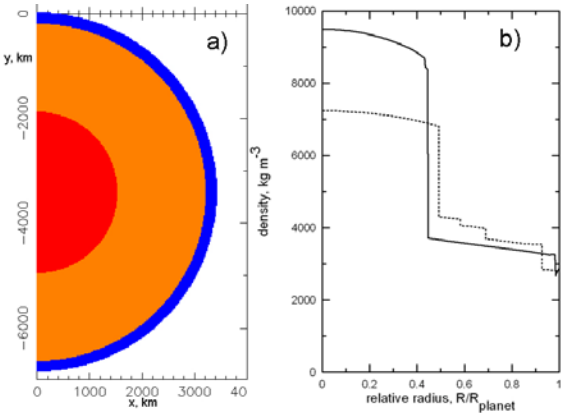

Fig. 1. (a) Modeled Mars with core (red), mantle (brown) and crust (red). (b) density profile for modeled with ANEOS basalt/dunite/iron Mars (solid line) compared with one of geophysical models [2].

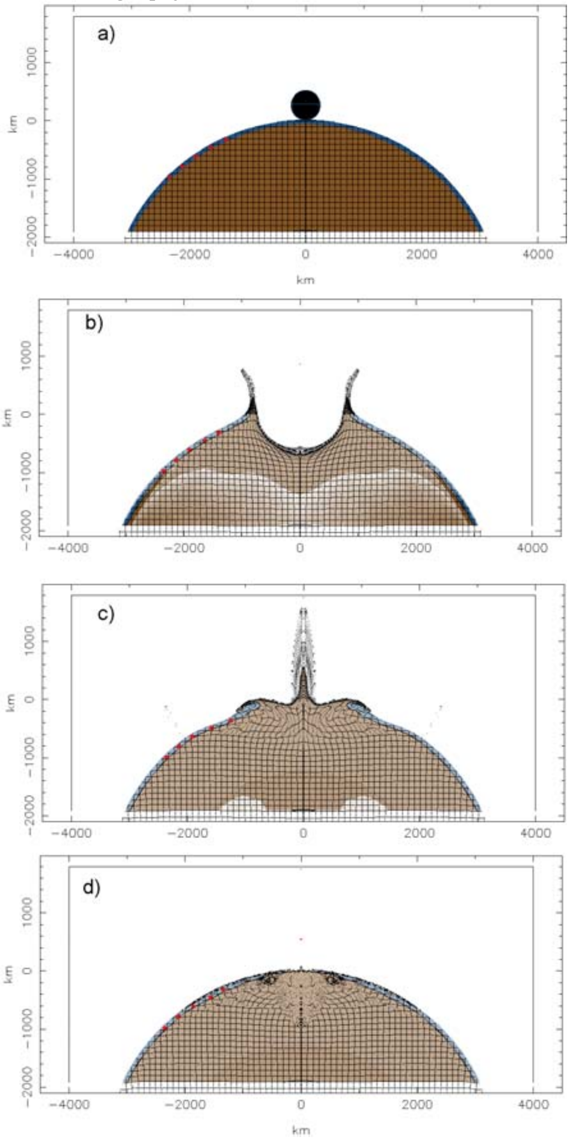

Fig. 2. Selected time frames for modeling of 500-km asteroid (basalt) impact with v_{imp}=8 km s^{-1}. Top to bottom: 0, 450, 2300, and 10000 seconds after impact. Note the giant “splash” due to central dome collapse in (c) delivered a lot of melt a top of the crust around crater.

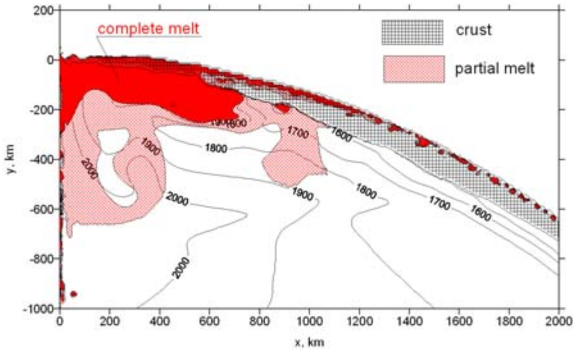

Fig. 3 The thermal state for 10,000 s (~2,7 hours) after the impact shown in Fig.2. While the current equation of state does not reproduce exactly solidus and liquidus for mantle, we estimate the melted state as partial melt at a given solidus (raised with pressure as for KTB peridotite), and complete melt as material overheated 200K above solidus for a local pressure. The melted zone is in an eddy motion in the computations. The thick layer and remote patches of ejected melt are visible up to 2000 km from the axis of symmetry. The fate of this (invisible now) mantle melt is unclear: (1) it may be heavily mixed with local crust material during the ballistic deposition, or/and (2) it may sink down through the heated crust (which deserve the further model analysis). Isotherms 1600 to 2000 K (black lines with numbers) depict the general geometry of the impact “hot spot”. The “melt pool” has a diameter of ~600 km with a depth of 200 to 600 km.

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