Introduction: The presence of giant impact basins on the Moon is important to understand its early thermal and magnetization state. The impact basin formation is still poorly known process mainly interpreted from geophysical data (e.g. [1]). Despite the presence of numerical modeling of impacts at all scales [2], 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. The presented work is devoted to the reconnaissance study of a giant basin formation on the Moon.

The numerical model consists of the material motion equations solver (SALEB hydrocode is used here [3, 4]), a set of equations of state (ANEOS code is used here [5, 6]), and a set of assumptions about the thermal state of the target. The resolution is constant through the grid and equal 10 km. Projectile is resolved with 13 to 20 cells per projectile radius (CPPR).

Mars model. Spherical Moon 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) shockwave derived equation of state to the real lunar rocks should be refined in the future. The same is valid for the unknown lunar core material, modeled here preliminary with the available EOS for pure iron. The thermal profile has been estimated for various geological periods by many authors Here we use temperatures profile [7], close to estimates for 0.5 Ga after the Moon formation.

The target initially is balanced in the field of gravity. The gravity potential is solved from the Poisson equation at the same grid and is updated for heavy material redistribution. The general view of the target is shown in Fig. 1. The model simulates the Moon with radius 1740 km, mass 7.47 x 10^22 kg, and surface gravity of 1.62 m s^-2.

Model runs have been done for vertical impacts of (basaltic) asteroids with velocities of 18 km s^-1. The typical outcome is shown in Figs 2 and 3. The final shape of the planet returns close to the sphere. 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 (due to “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.

Current relatively low resolution model can not predict precise surface expression of the final basin. It needs much more sophisticated modeling. However a few important issues may be clearly illustrated. The presented model run generate the transient cavity of approximately 1600 km in diameter. This is close to 2100 km “excavation cavity”, estimated in [1] for South Pole–Aitken basin. The zone of crust removal (Fig. 3) has diameter of ~1200 km due to “splash back” material during the central uplift oscillation. This central region presents the surface of the mantle melt pool. Area around the crater is heavily covered with ejecta, including melted mantle and crust material. The question is what one see on the surface now. The pristine distribution of material around the basin may be covered with ejecta from later formed basins [8]. Deep mantle material more easier survives in ejecta. In the central area surface may be changed by secondary melt differentiation.

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Fig. 2. Selected time frames for modeling of 262-km asteroid (basalt) impact with $v_{imp} = 18$ km s$^{-1}$. Top plate is for the initial geometry, bottom plate is for 800 seconds after impact when transient (excavation) cavity is reached ($D_{tr} \approx 1600$ km).

Fig. 3. The thermal state for 16,000 s (~4.4 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 1600 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 1800 K (black lines with numbers) depict the general geometry of the impact "hot spot". The "melt pool" has a diameter of ~700 km with a depth of ~400 km. The central melt cylinder may be an artifact due to axial symmetry of the problem solved.