MULTI-RING BASINS: MODELING TERRESTRIAL ANALOGUES.

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Introduction: History of the lunar surface is a part of the early evolution of terrestrial planets. Important footprints of the early lunar history are impact multi-ring basins. Similar giant impact structures are known on Earth. The aim of the presented project is the analysis of terrestrial giant impact structures origin as the starting point for the following analysis of origin and structure of lunar multi-ring basins and their role in formation of lunar surface.

Lunar and Terrestrial Basins: Lunar basins created ~3.8 Ga ago and earlier [1] definitely play an important role in formation of the modern lunar landscape [2]. Currently lunar basins may be studied by remote sensing only. Ancient impact basins on Earth have not survived. Only a few large impact structures are currently known including large impact craters Chicxulub, Sudbury, and Vredefort [3]. Following simple scaling rules [4] morphologic types of impact structures on different planets are similar for crater sizes with the same value of *gD* (g is gravity acceleration, D is the impact structure diameter). Hence, in the first approximation, terrestrial impact structures with diameters 100 to 300 km may resemble lunar craters with ~6 times larger diameters, i.e. craters with diameters 600 to 1800 km. The similarity definitely cannot be an exact one as target layering (crust thickness, for example), thermal profile and other important parameters may complicate the simple scaling. However, the study of largest terrestrial craters as possible analogues of small lunar basins looks attractive as we have a lot of data on crater subsurface structure [3].

Numerical Modeling: In the presented project numerical modeling of formation of selected terrestrial impact structures is carried out with following comparison of model results (predictions) with available geological and geophysical data accumulated for known largest terrestrial craters. SALEB hydrocode is used to model the vertical impact of a spherical projectile into a target, presented with 2 or 3 layers of different materials (e.g. upper crust, lower crust and mantle) initially balanced in a gravity field. ANEOS equation of state in tabulated form is used to describe thermodynamics of model rock materials such as limestone, granite, basalt, dunite. Mechanical model of rock behavior include brittle/ductile shear strength [5] and a possibility for a temporary internal friction reduction (an acoustic fluidization model [6]). The best fit models are chosen after several model runs with the variation of projectile sizes for the impact velocity of 12 to 15 km s^{-1}.

Chicxulub. The target is modeled as ~3 km limestone layer over granite basement over mantle below depth of 33 km (Fig. 1). The fit is targeted to reproduce the subsidence of the sedimentary layer revealed by geophysical investigations [7]. The model predicts the pristine crater of ~160 km rim diameter for a projectile diameter of 14 km for density 2700 kg m^{-3} and impact velocity of 12 km s^{-1}. Predictions include also estimates for the initial position and shock state of ejecta deposited at radial distance of 60±5 km from the center, approximate location of the Yax-1 drill hole [8].

Popigay. Reconnaissance modeling of Popigay crater in a simplified target of granite over mantle at depth of 40 km is shown in Fig. 3. Model results will be compared with available observational data [9,10]. Assumed projectile has diameter ~9 km and the impact velocity of 15 km s^{-1}.

Vredefort and Sudbury. Reconnaissance modeling reveals that in the first approximation one can assume similar projectiles for both structures. As Sudbury is tectonically deformed structure, the most comparisons may be done for Vredefort with a proper account for the estimated erosion level of 7 to 10 km (e.g. [11,12]). The model target include the upper crust (12 km), lower crust, and mantle at depth of 48 km. Fig. 4 show the modeled target structure with the characteristic “neck” of middle crust granitic rocks with the diameter of ~50 km at the assumed erosion level. The primary comparison of predicted structural features (Fig. 5) reveal the close similarity of the granitic “neck” and annular syncline diameters with previously published geologic maps. It is interesting that the best fit of the central structure at the assumed erosion level is found for the modeled pristine crater with the model rim diameter of 180 to 200 km only, what is much less than previously assumed diameter of ~300 km. The model output allows us to produce a set of testable predictions such as decay of structural deformations and post-impact temperatures with radial distance.

Perspectives: The presented results of the numerical modeling proved the basis to generate a set of predictions, which may be compared with observations. An iterative process of the model improvements to fit (and explain) observations allows us in a close future to find the best fit to each of investigated impact structures. The best model approaches will allow us to make more or less robust estimates with the following numerical modeling of lunar impact basin formation.

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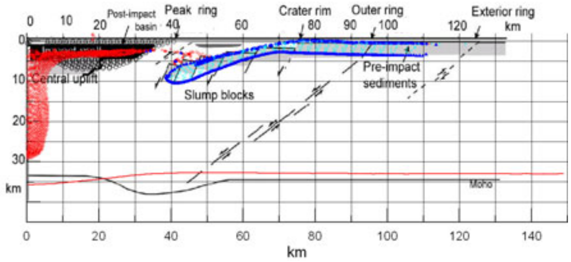

Fig. 1. Chicxulub. The comparison of the "best fit" model and geophysical model [].

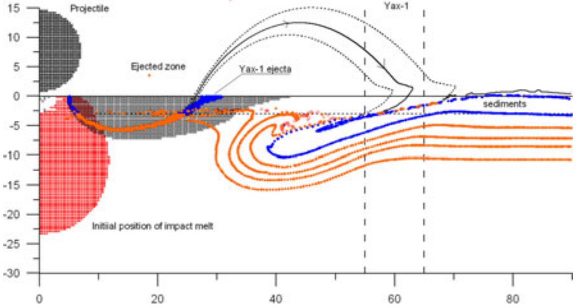

Fig. 2. Chicxulub: modeled geometry of melt and ejecta zones (initial position of Lagrangian tracers) and final position of initially horizontal layers of sediments (blue) and crystalline rocks (brown). Also the stream tube of ejecta deposited at the distance of Yax-1 drillhole is shown.

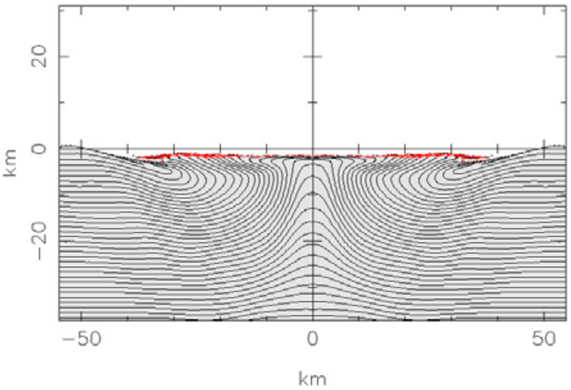

Fig. 3. Popigay: 100-km in diameter crater in crystalline rocks. Computed position of impact melt is shown as red dots.

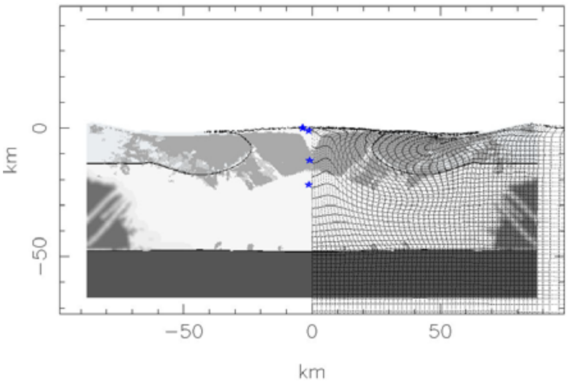

Fig. 4. Vredefort: The proper diameter of the middle crust "neck" at the assumed erosion level of ~10 km corresponds to the rim basin diameter of 180 km

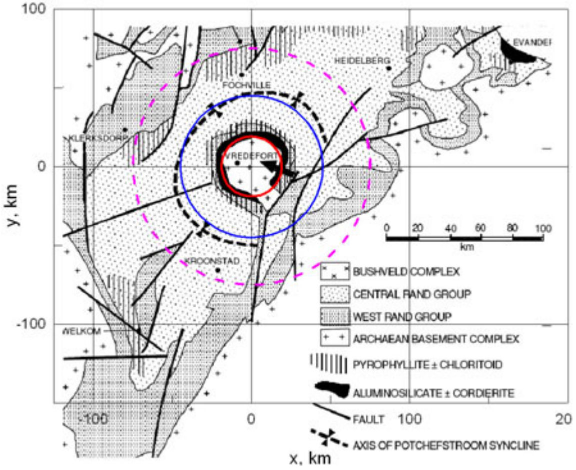

Fig. 5. Vredefort: the comparison of computed diameters of middle crust rock "neck" at ~8 to 10 km erosion level (red circle) and annual syncline (blue circle) with the simplified geological map [13]. Pink dashed circle is for estimated rim position