MORPHOMETRY AND STRUCTURE OF ERODED COMPLEX IMPACT CRATERS: A PARAMETER STUDY USING HYDROCODE MODELING. A. T. Kurta, K. Wünnemann, T. Kenkmann, Museum für Naturkunde, Leibniz Institute at the Humboldt-University Berlin: alex.kurta@museum.hu-berlin.de

Introduction: Most impact structures on Earth are modified by erosion. First order structural features of impact craters such as the crater diameter, the size of the central uplift, and ring syncline can be measured in field campaigns [e.g. 1] or by geophysical explorations [e.g. 2,3]. However, these quantities deviate from the original crater diameter or other morphological features of the pristine crater. Here we present first results of a systematic numerical modeling parameter study of crater formation addressing the question how these structural features develop as a function of depth for a range of crater sizes. Our objective is to determine size-ratios between features such as the diameter of the ring syncline and the rim-to-rim diameter and how they vary with depth at complex impact structures. By comparing the model-derived ratios with observed structural data of natural craters it may be possible to better constrain the amount of erosion of terrestrial impact craters.

Model Setup: We used the iSALE 2D hydrocode [4,5] to simulate complex impact craters in the size range between 10 and 50 km. Projectile sizes were varied between 600-3000 m. Other model parameters were kept constant for all modeled crater sizes. We made the models as simple as possible (vertical impact, g = 9,81 m/s^2, impact velocity U = 15km/s) and assumed both projectile and target composed of granite. The thermodynamic state was calculated with Tillotson's equation of state [6]. The strength behavior of the material was described by a Drucker-Prager model, where strength Y is linear function of pressure P ($Y=C+\mu P$, where μ is the internal friction coefficient, and C the cohesion). To simulate a temporary strength degradation of the target during crater formation we applied the acoustic fluidisation model [7,8,9].

Methods: In a first step we calibrated our models to find the "right" set of acoustic-fluidisation parameters [9]. We chose two relatively well preserved terrestrial impact structures on Earth with different size and tried to reproduce crater morphometry by keeping the acoustic fluidisation parameters constant. The best fit was found for a decay time of β = 120 and a viscosity of γ = 0,004. Note that these parameters represent a compromise to enable modeling of impact craters over a considerable range of size. For the calibration we chose the Bosumtwi (Ghana) [1] (crater diameter ~ 12 km, width of central uplift ~ 1.8 km, max. high of central uplift ~ 200 m) and Chesapeake Bay (USA) [2] (crater diameter ~ 40 km, width of central uplift ~ 10 km, max. high of central uplift ~ 2000 m) impact craters. Note that we modeled only the inner crater of Chesapeake Bay and neglected the extensive enlargement of the crater due to an extremely weak, water–saturated sediment layer as the uppermost unit [10]. In a second step we modeled craters in a size range between 10 and 50 km by varying the projectile diameter between 600 m and 3000 m in steps of 200 m so that we finally got 13 numerical models. For each model we determined the apparent crater rim diameter and ring syncline diameter as a function of depth. The trace of the crater rim with increasing depth (Fig. 1) is defined by a sudden change in dipping of marker lines and an increase in plastic strain. The ring syncline is defined here as a local depression of a marker line between the central uplift and the crater rim. The ring syncline axis is located at the deepest point of the depression. The trace of the ring syncline with increasing depth connects the deepest points of each marker line (Fig. 1).

First results: Fig. 2-4 show the course of the apparent crater diameter and ring synclines as a function of depth for different crater sizes. As expected, all models show a decrease of the apparent crater diameter (D_r) with depth (at different levels of erosion) in a similar manner (Fig. 2). The

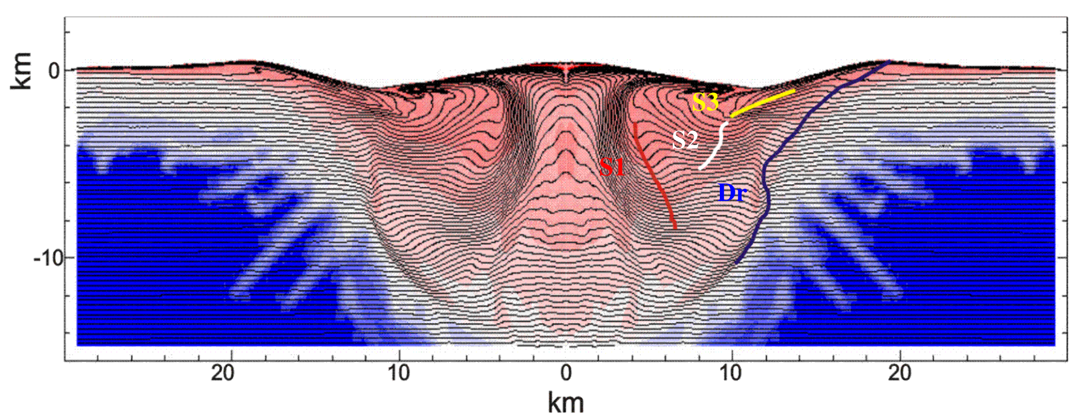

Fig.1: Numerical model of the Chesapeake Bay impact. The traces of the apparent crater rim (D_r) and of the ring syncline axes S1, S2, and S3 are visualized

maximum depth down to which the apparent crater rim can be traced increases with crater size, e.g. for a ~10 km crater the crater rim can be traced 3 km deep whereas for a 50 km crater the apparent crater rim goes down to a depth of 12 km. The depressed region between the central uplift and the crater rim shows three sub-depressions, each of them is defined by a ring syncline axis that can be traced in certain depth-intervals (Fig.3). The ring syncline axis (S1) borders the central peak and is caused by the rise of material into the central dome. Its inner limb comprises of the steeply dipping marker lines of the central uplift. For craters of 10-20 km diameter the diameter of this ring syncline S1 approximately remains constant with depth (Fig. 3) but for larger craters the S1 diameter increases with depth. At shallow erosion levels this inner ring syncline disappears due to a broadening and collapse of the central uplift (Fig. 1). The diameters of the ring synclines S2 and S3, located in the central and outer areas of the morphological depression between central uplift and crater rim, decrease with depth and are restricted to shallower erosion levels. Like S1 the ring syncline S2 is caused by the material deficit due to the uplifting of the central dome. The ring syncline S3 is initiated by the overturned flap that shifts into the crater depression in the course of crater collapse. The ring synclines S1 and S2 coexist at a depth interval of 1-6 km. Craters formed by 600 to 1000 m projectiles and final crater sizes of 10-20 km deviate in their structural characteristics because the central uplift does not collapse outward. For these craters Fig. 4 shows a weak positive correlation between apparent crater diameter and ring syncline diameter S1, whereas for larger craters a negative trend is typical.

Discussion: We tried to systematically determine first-order structural features of complex impact craters as a function of depth using 2D numerical models of crater formation. We are aware that the models are oversimplified. This is especially attributed to the fact that we used a very simple, uniform material model (Drucker-Prager + acoustic fluidisation) for all crater sizes (10-50 km) to keep the parameter study as simple as possible. The amount of central uplift formation and subsequent collapse is strongly controlled by these parameters and affects the position of the ring synclines. Other shortcomings that likely limit the direct comparison of our numerical models with natural craters are the 2D axial symmetry of the models, the uniform rheology of the targets, and the limited localization behavior of deformation. Nevertheless, this study may assist field geologists investigating the structural inventory of natural craters. Our next step will be a comparison of field data of terrestrial impact structures with our numerical results. Measurements of the apparent crater diameter and ring synclines of natural craters may allow to better estimate the amount of erosion of these craters since their formation.

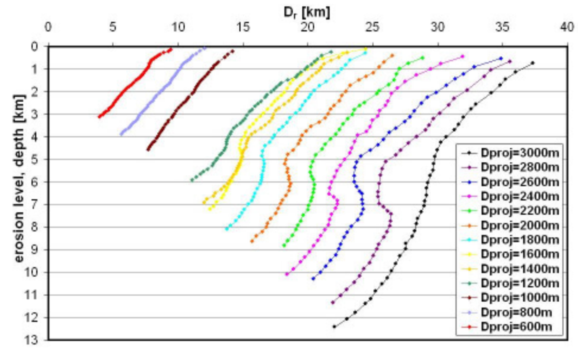

Fig.2: Diameter of apparent crater rim (D_r) vs. depth.

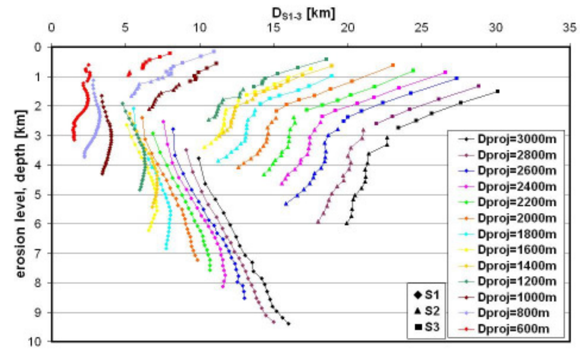

Fig.3: Diameter of ring synclines S1, S2 and S3 vs. depth.

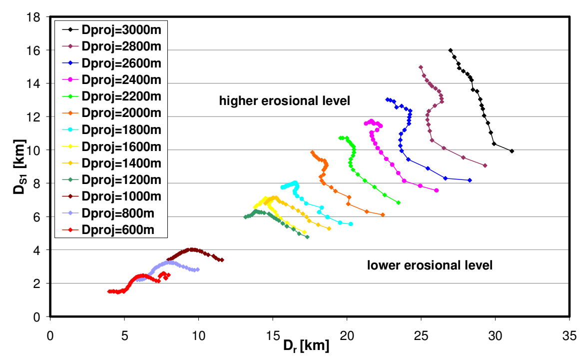

Fig.4: Diameter of apparent crater rim (D_r) vs. the diameter of S1.

References: [1] Kenkmann, T. (2002) *Geology*, 30, 231-234. [2] Karp T. et al, (2002), *Planet. Space Sci.* 50, 735-743. [3] Poag C.W., Koeberl C., Reimold W.U. (2003), In: The Chesapeake Bay Crater, Springer. [4] Wünnemann K. et al, (2006), Icarus 180, 514-527. [5] Collins et al (2004) *Met. Planet. Sci.,* 39, 217-231. [6] Tillotson, J.H. (1962), *Report GA-3216, General Atomic, San Diego, CA.* [7] Melosh H.J., Ivanov B.A., (1999), *Annu. Rev. Earth Planet. Sci.* 27, 385–415. [8] Melosh H.J., (1979), *JGR* 84, 7513-7520. [9] Wünnemann K., Ivanov B.A. (2003) *Planet. Space Sci* 51, 831-845. [10] Collins G.S., Wünnemann K. (2005), *Geology*, 33, 925-928.