RECONSTRUCTION OF THE ORIGINAL IMPACT-CRATER RELIEF FOR MJØLNIR, CHICXULUB AND BOSUMTWI IMPACT CRATERS REVEALS SURPRISINGLY SHALLOW STRUCTURES: DID WE MISS SOMETHING? Filippos Tsikalas and Jan Inge Faleide, Department of Geosciences, University of Oslo, Oslo, Norway (filippos.tsikalas@geo.uio.no, j.i.faleide@geo.uio.no)

Reconstruction of the original, immediately-after-impact, crater is performed for Mjølnir, Chicxulub and Bosumtwi craters by decompaction and fault restoration, as the three craters represent upper and lower range cases in the aspect of the experienced level of post-impact overburden.

The Mjølnir crater currently lies beneath ~50-800 m of post-impact sediments (Fig. 1f) [e.g. 1]. Of major importance in the reconstruction analysis is the fact that about 1.5-2 km of siliciclastic sediments were deposited during Cretaceous-Tertiary times (Fig. 1d) [e.g. 2] and were later removed, including the top of the central high (Fig. 1e), during the Late Cenozoic glacial erosion. Reconstruction suggests that the impact resulted in a very shallow structure with an average crater depth of only ~30 m (Fig. 1a).

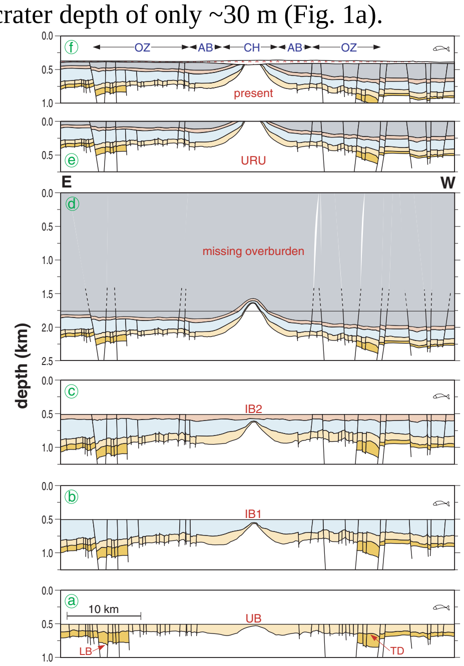

Fig. 1. Reconstruction of the Mjølnir original crater relief along an E-W trending profile by decompaction and fault restoration of the entire post-impact sedimentary succession. Time steps (a-f) correspond to the main unit boundaries. CH, central high; AB, annular basin; OZ, outer zone (modified from [3]).

Furthermore, the original crater exhibits a narrower-than-present central high, 4.5-5 km in diameter, that stands ~80 m above the surrounding platform level, in comparison with the present 8-km-diameter width and 250-m-height (Fig. 1a, f). On the other hand, the annular basin is quite prominent with a maximum depth of ~70 m, while the peak ring is not well developed in the original crater (Fig. 1a, f). Furthermore, reconstruction suggests that the original thickness of the allochthonous breccia in the marginal fault zone was greatly reduced by compaction, while the rim faults were extensively reactivated [3]. In summary, the decompaction and fault restoration approach at Mjølnir (Fig. 1) clearly demonstrated that post-impact deformation considerably enhanced the structural expression of an originally subtle crater and that the present distinct crater expression is largely a post-impact burial phenomenon.

Backstipping reconstruction at Chicxulub was employed at two time-steps defined by the sequences bounded by reflectors R2 and R1 in which the deposition has been influenced by the underlying crater relief (Fig. 2). Reflector R2 represents the stratigraphic level above which the inherited original impact structure is minimal, while reflector R1 is the first continuous reflector to have surpassed the impact-induced relief. In order to include all alternative possibilities, numerous porosity-depth relationships (initial porosity, $Ø_o$, and compaction constant, *c*, combinations) ranging between siliciclastic (sand- and shale-dominated alternatives and mixtures), carbonaceous and dolomitic sequences were used to decompact the post-impact succession at Chicxulub (Fig. 2, models 1-3). A differentiated paleowater depth of 350 m and 100 m was used for the R2 and R1 time-steps, respectively (Figs. 2b-c), based on the estimates derived from the progradating clinoform geometries [4]. Reconstruction at Chicxulub, experiencing 1-1.5-km-thick post-impact overburden, shows that the current ~700-m-relief of the “inner-ring” was originally 300-450 m (Fig. 2). Similarly, the current ~550 m (range 535-575 m) relief of the peak-ring above the surrounding depressions turned to be originally ~500 (range 420-570 m). Note that currently the “inner-ring” stands ~150 m above the peak-ring (Fig. 2a), while reconstruction shows that immediately-after-impact this relation was reversed, and actually the peak-ring stood higher by ~100 m (Fig. 2c). Therefore, there is a cumulative relative vertical movement of ~250 m between the two prominent structural features. The reconstruction clearly suggests that the post-impact evolution is closely related to the structurally disturbed volume at Chicxulub, containing zones of weakness and a brecciated region of variable thickness at depth [e.g. 6-7]. In combination with a prograding sedimentary load this setting led to post-impact differential subsidence and compaction faulting above the impact structure.

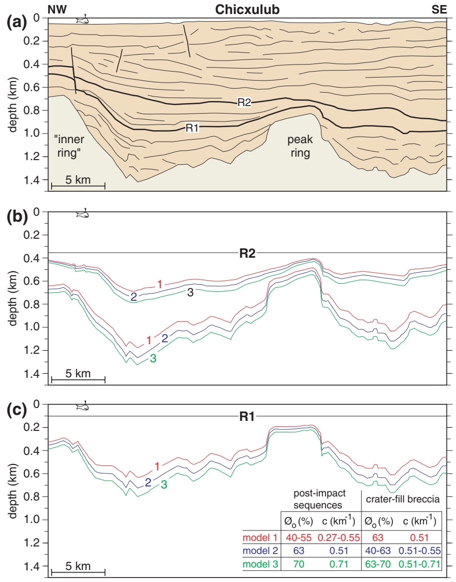

Fig. 2. Reconstruction of the Chicxulub original crater along **(a)** a re-interpreted depth-converted profile (part of profile Chicx-B [5]) by backstripping and decompaction utilizing paleowater depths of 350 m and 100 m for time-steps at reflectors R2 **(b)** and R1 **(c)**, respectively.

For Lake Bosumtwi crater, backstripping and fault restoration was performed at the post-impact stratigraphic level where the impact-induced morphologic relief was diminished. A similar, as Chicxulub, full-spectrum of porosity-depth relationships ($Ø_o$ and c combinations) were used to decompact the post-impact succession at Lake Bosumtwi crater (Fig. 3, models 1-3). Two attempts concerning uniform paleowater depth levels were conducted, one with a paleowater depth of 75 m that approximates the current water depth (Fig. 3a) and another with a paleowater depth of 200 m (Fig. 3b). Reconstruction at Bosumtwi shows that the current 110 m height (on this particular profile) of the central uplift/high measured from the base of the western depression was originally 95 m (range 85-105 m), while the current 101 m height of the central uplift/high measured from the base of the eastern depression was originally 103 m (range 95-110 m). On the other hand, the current 46 m depth of the western depression (measured from its base up to the relief on its right side) was originally 55 m (range 43-68 m), while the current 50 m depth of the eastern depression (measured from its base up to the small terrace on its left side) was originally 52 m (range 49-55 m) (Fig. 3). Reconstruction clearly reveals a differentiated post-impact lateral evolution at Lake Bosumtwi crater, exhibiting a central uplift/high that was pronounced, in average, during burial and a western depression that was subdued more that the eastern one.

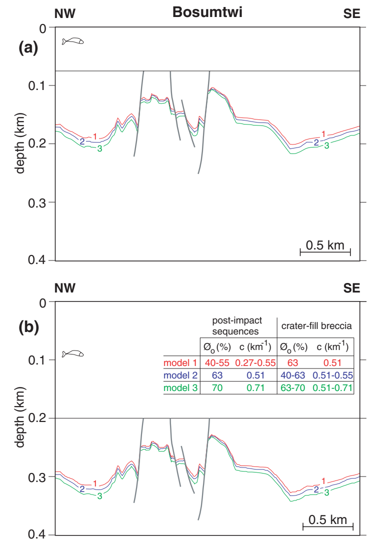

Fig. 3. Reconstruction of the Lake Bosumtwi impact crater (profile from [8]). A uniform paleowater depth of 75 m **(a)** and 200 m **(b)** was utilized, respectively.

The reconstruction results for the Mjølnir, Chicxulub and Bosumtwi craters are closely related to the impact-induced structurally disturbed target-rock volume and a brecciated region of both laterally-varying thickness and physical properties at depth. The observed lateral changes in physical property anomalies across these impact craters are the result of several counteracting impact cratering processes, but the primary effect is a porosity increase caused by extensive fracturing and brecciation. The impact event left a peripheral region in which porosity-increasing processes, such as fracturing, brecciation, and gravitational collapse, prevails over density-increasing ones. The opposite is the case at the central crater where higher densities and lower porosities are related to crater floor rebound and structural uplift of deeper rocks [9].

References: [1] Tsikalas F. et al. (1999) *GSA Special Paper, 339,* 193-204. [2] Dimakis P. et al. (1998) *Tectonophysics, 300,* 311-327. [3] Tsikalas F. et al. (1998a) *GSA Bulletin, 110,* 537-552. [4] Bell C. et al. (2004) *Meteor. Plan. Sci., 39,* 1089-1098. [5] Snyder D.B. and Hobbs R.W. (1999) *The BIRPS Atlas II: A second decade of deep seismic reflection profiling*, 3 CD-ROMs. [6] Christeson G.L. et al. (2001) *J. Geoph. Res. 106,* 21751-21769. [7] Morgan J.V. et al. (2000) *Earth Plan. Sci. Lett. 183,* 347-354. [8] Scholz C.A. et al. (2002) *Geology, 30,* 939-942. [9] Tsikalas F. et al. (2002a) *Deep-Sea Research Part II, 49,* 1103-1120.