DYNAMICS OF THE WATER RESURGE AT MARINE-TARGET IMPACT CRATERS ANALYZED WITH A COMBINATION OF LOW-VELOCITY IMPACT EXPERIMENTS AND NUMERICAL SIMULATION.

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Introduction: The term marine-target crater denotes the preserved crater in the seafloor after an impact in an aquatic environment [1]. Many marine-target craters are no longer covered by the sea in which they formed. Instead they can be recognized on their special geology, geomorphology, and geochemistry that are consequences of the aquatic target environment [1, 2]. Among the special features for marine-target craters are the resurge deposits that form when sediment-loaded water surges back to fill the newly formed crater in the seafloor [3]. The sedimentology of these resurge deposits depends greatly on the water velocity that in its turn depends on the depth and width of the water crater. It also depends on the amount and kind of solids available for transportation and subsequent deposition. The viscosity and density of the fluid are further controlling factors, mainly influenced by the quantity of easily suspended fines per volume water. Sedimentary features of the resurge sediments of the Lockne and Tvären marine-target craters were described by [4]. These craters are excellent examples of impacts where the target water had a strong influence on the cratering and modification processes. Both craters formed about 460 My ago in the Baltoscandian epicontinental sea with seawater and mainly limestones covering a crystalline basement. The resurge deposits are several tens of meters thick in the central parts of the craters and can visually be distinguished as single normally graded beds, although the study by [4] shows that the granulometry and composition of the deposits hold much more information. The target water depth for Tvären (apparent basement crater diameter D=2 km) is currently estimated to have been about 100 m, and for Lockne (D = 7.5 km) it was 500-700 m [4].

From the sedimentological information gathered at Lockne and Tvären Ormö et al. [4] concluded that there are identifiable differences between deposits laid down by flow that they call the “resurge proper”, and sediments deposited during and after the formation and collapse of a “central water plume” (here CWP) that evolves into an “anti-resurge” with an outwards-moving flow. They notice how the shallower water depth at Tvären causes a less pronounced development, or even absence, of the CWP. As the anti-resurge fades out the water movements in the interior of the crater transforms into what can be characterized as an “oscillating resurge” with no unique movement direction. At both Lockne and Tvären the resurge proper continues, and dominates, the flow over the inner crater rim during the whole process of resurge filling of the crater.

The Chesapeake Bay impact structure is, like Lockne and possibly Tvären, a concentric crater with a deep inner crater in the crystalline basement surrounded by a wide outer crater in the sediments. For the Chesapeake Bay impact structure, however, the apparent concentricity is, essentially, a secondary effect caused by extensive collapse of the sedimentary strata surrounding the basement crater [5]. The Chesapeake Bay impact structure formed about 35.4 My ago [6] in a coastal environment with a relatively shallow water depth that varied over the structure from a few tens of meters depth on the landward side to just over 300 m on the seaward side [7]. The shallow water in combination with the huge size of the structure and the loose sediments caused a water-charged debris flow [8] interacting with a set of rock avalanches during crater collapse [9]. The great variation in water depth over the target site at the Chesapeake Bay impact structure may have affected the entry of the resurge into the inner crater, and thus the development of a CWP and anti-resurge.

Methods: Here, we use a combination of laboratory impact experiments and numerical simulation of highly simplified Lockne-, Tvären- and Chesapeake Bay -type impact events to better understand some of the details from the previous sedimentological investigations as well as illustrate the general context of the dynamics of the water resurge at craters such as these. Understanding the evolution of the resurge flow is of great importance for later reconstructions of the paleoenvironment at the time of impact as well as ejecta distribution and tsunami generation.

Low-velocity impacts were carried out with a modified paintball marker of the brand WDP Ltd. Angel Speed06. The marker’s electronic triggering is modified to enable simultaneous projectile launch and highspeed camera recording. The marker uses compressed air and can launch projectiles of any chosen composition. In our experiments we used standard paintballs (17.5 mm) which weigh approximately 3 grams, as well as slightly smaller (16.4 mm) glass balls that weigh approximately 5.8 grams. The test bed is a 125x125x60 cm polycarbonate tank partially filled with the target material, i.e. saturated sand covered by a layer with freshwater. Experiments were carried out under 1 atm air pressure. The results from the laboratory experiments are combined with results from numerical simulation of Lockne- and Tvären -type impact events in order to facilitate the analysis of certain processes during the cratering and modification. Here, we use the iSALE and SOVA codes.

Results and discussion: Our experimental and numerical results illustrate the geological reconstructions of concentric crater formation, water cavity collapse and resurge generation, formation of a resurge proper, central water plume (CWP), anti-resurge, slack-water zone, and their reciprocal relations at marine-target impacts. In addition, it has been possible to observe detailed analogues of the evolution of the CWP, as well as how obliquity of projectile trajectory and variations in water layer thickness from one end of the target area to the other (e.g., seawater deepening away from the coast) affects the cratering and subsequent water resurge. The results are exemplified by Figures 1 and 2.

References: [1] Ormö J. and Lindström M. (2000) *Geol. Mag 137,* 67–80. [2] Dypvik H. et al. (2003) *Sed. Geol., 161,* 309-337. [3] Lindström M. et al. (1996) *GFF 118,* 193–206. [4] Ormö J. et al. (2007) *Met. Planet. Sci. 42,* 1929-1943. [5] Horton J. W. et al. (2006) *Met. Planet. Sci. 41*, 1613-1624. [6] Gohn G. S. et al. (2008) *Science 320*, 1740-1745. [7] Horton J. W. (2005) *USGS Prof. Pap. 1688*, A1-A24. [8] Ormö J. et al. (2009) GSA Spec. Pap. (in press). [9] Gohn G. S. et al. (2009) GSA Spec. Pap. (in press).

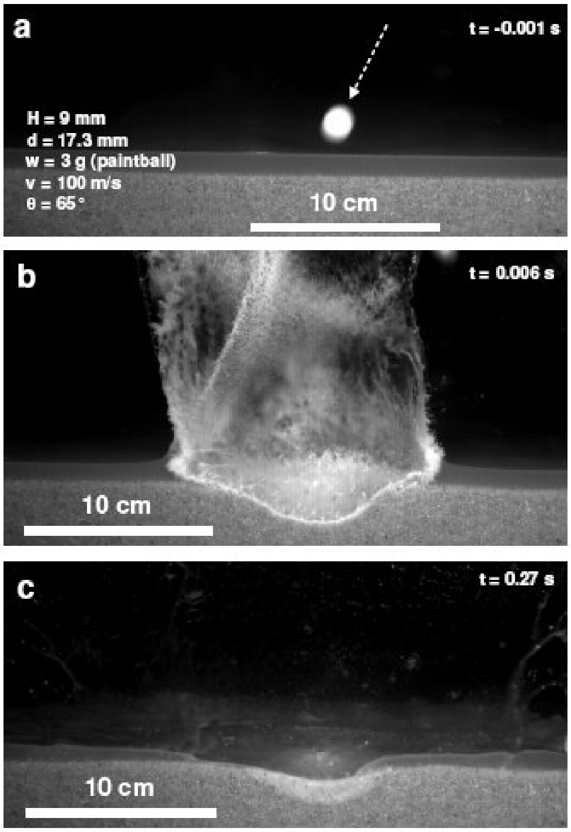

Fig. 1. Low-velocity laboratory experiment of oblique impact into a target of water (dark grey) over saturated sand (light grey). Note the irregular uprange and downrange crater development and the earlier uprange resurge intrusion. H signifies water depth, d projectile diameter, w projectile weight, v projectile velocity, and θ the impact angle over the horizontal plane.

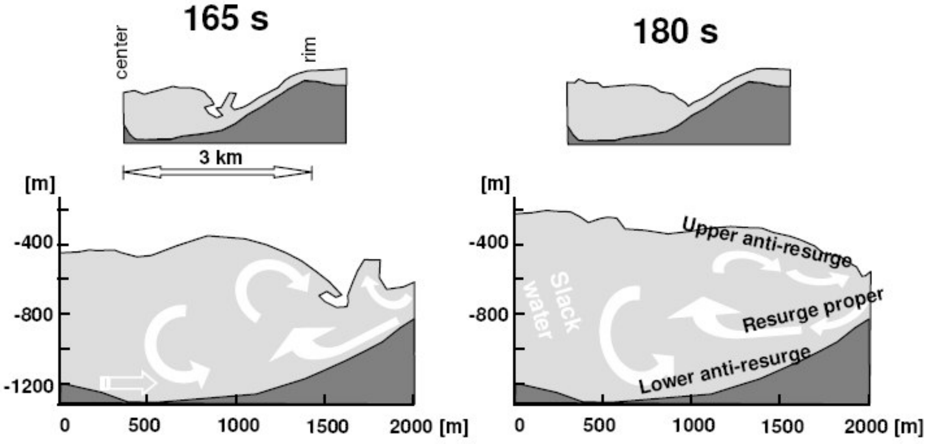

Fig. 2. Schematic illustration of water movements during the late stage of collapse of CWP and anti-resurge development based on 2D iSALE numerical simulation of a Lockne-type impact event. The results are consistent with the sedimentological analysis by [4].