**NEXT STEP IN MARINE IMPACT STUDIES: COMBINING GEOLOGICAL DATA WITH NUMERICAL SIMULATIONS FOR APPLICATIONS IN PLANETARY RESEARCH.** J.Ormö[1] [1]Centro de Astrobiologia (CAB), Instituto Nacional de Técnica Aeroespacial, Ctra de Torrejón a Ajalvir, km 4, 28850 Torrejón de Ardoz, Madrid, Spain. (ormo@inta.es)

**Introduction:** Baltoscandia is favourable for geological studies of marine-target (M-T) craters. One reason is the relatively dense population of craters of different diameters, of approximately the same age, and with different target water depths. This allows comparative studies of the effects of a target water layer on the lithologies and morphologies of the resulting craters [1]. Baltoscandian craters like Kärdla [2] and Lockne [3] are well documented. Today, a considerable number of the documented craters and impact sites on Earth are known to have formed at sea. All but one, the Eltanin impact site west of Chile, have formed in epicontinental seas. This circumstance is mainly a result of higher probability of both formation and preservation in such areas [1]. Famous craters as Chicxulub, Chesapeake Bay, and Mjölnir were also formed at sea [e.g. 4, 5, 6]. Marine impact cratering is an important topic within impact research. The fact that our planet is mostly covered by water must be taken into consideration when evaluating consequences and hazards from impact events. In addition, M-T craters may have applications in the exploration of our Solar System.

**Definition:** An M-T crater forms from an impact into a target with an upper layer of water. In its transient stage, an M-T crater consists of a water cavity and, in some cases, a seafloor crater. Only the latter may be preserved. How much of the crater that develops in the seafloor depends on the amount of expended energy in relation to the depth of the sea. This relation has been analysed both experimentally [7] and numerically [8]. Studies by Ormö and Lindström [1] show a strong link between the water depth and the geology of the seafloor crater. At relatively shallow water depth the crater resembles a “land-target” crater, although sometimes with stronger collapse of the rim. At deeper water the crater is concentric with a deep crater in the basement surrounded by an outer crater, apparently formed by a shallow excavation flow in connection with the development of a wide water cavity [1, 8, 9]. The outer crater may in these cases be cut by gullies eroded by the resurge of debris-loaded water.

**The potential of numerical simulation:** Geological studies of the Lockne crater have improved our understanding of water related features to such an extent that they can be used as constrains not only for a rough simulation of the impact, but for modeling specific parameters. The codes have likewise developed so that they now better can simulate the complex process of an impact into a layered target. This development led to an attempt to make a detailed numerical modeling of the 455 Ma Lockne crater [9]. The aim was primarily to find the target water depth, which was an unknown variable, but also to better understand the processes behind some of the special features of the crater (e.g. the development of a wide overturned flap). The model also gave the opportunity to test the code on a full-scale impact in a layered target. Main geological constraints in the Lockne modeling were (1) the occurrence of a 7.5 km wide inner crater in the crystalline basement with a slightly elevated rim, (2) a shallow outer crater with no obvious rim, (3) an about 3 km wide, overturned flap of basement rock outside the basement crater rim, (4) strong stripping of an initially 80 m thick sedimentary cover prior to the deposition of the flap, and (5) evidence for a forceful resurge. The simulations were done at various water depths of the likely depth interval (200-1000 m). Impactor size, mass, and velocity were also varied. It was concluded that for a 400 m radius asteroid striking at 20 km/s, the target water depth was slightly less than 1000 m. The study is continued with more sophisticated software (3D) to analyse the effects of impact angle and ejecta/water interactions [10].

**Perspectives:** Knowledge of M-T craters can be used when analysing planetary paleoenvironments and surface properties where remote sensing may provide the only information. Ormö and Muinonen [11] propose that Martian M-T craters could reveal paleo-water depths and, hence, the climatic evolution of the planet. Any low-strength material in the upper part of a layered target may respond as a water layer. Craters from impacts into hydrocarbon and nitrogen seas have indeed been suggested to exist on Titan [12]. Cassini radar data may reveal their features. Future studies of M-T craters should focus on the mechanics of the concentricity, and the influence of obliquity on the ejecta distribution, resurge flow, and how they affect tsunami formation. This is currently pursued by the new impact research group at CAB by combining experiments, fieldwork, planetary research, and numerical modeling.

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