NEW DRILL-CORE DATA FROM THE LOCKNE CRATER, SWEDEN: THE MARINE EXCAVATION AND EJECTION PROCESSES, AND POST-IMPACT ENVIRONMENT. J. Ormö[1] and M. Lindström[2], [1]Centro de Astrobiología (INTA/CSIC), 28850 Madrid, Spain (ormo@inta.es), [2]Dept. of Geology, Stockholm University, Sweden (maurits.lindstrom@geo.su.se).

Introduction and aim of study: Studies of marine-target craters provide information on cratering processes in layered targets. This has implications for the reconstruction of paleoenvironments on Earth and Mars [1]. At the Lockne crater, Sweden, the target water strongly affected the cratering and, thus, the geology and morphology of the final crater [2;3;4]. Three core-drillings were performed in August 2004 at different sites at the crater (Fig. 1). Six core-drillings have previously been performed at Lockne [5], hence the new drillings are numbered 7, 8, and 9. The previous drillings and extensive mapping together with numerical modeling have shown that the crater has a well preserved ejecta layer with a distribution reflecting the trajectory of the projectile [3;6].

The main scientific objectives of each of the 2004 drillings:

·"Lockne 7": Enigmatic massive calc-micrite megalenses (henceforth "CMM"). These structures represent a previously unknown carbonate depo-sitional environment in the Ordovician sea, apparently strongly linked to the crater depression that formed in the seafloor.

·"Lockne 8": Ejecta dynamics and energies. Large bodies of crystalline ejecta occur with great thicknesses and clast sizes at distances that by far exceed what is calculated for standard land-target craters of the same size. The drilling aims to constrain the volume, the interior stress during ejection, and the effect on the substrate from the deposition of the largest of the known coherent ejecta occurrences outside one crater radius from the basement crater rim. (Fig. 1).

·"Lockne 9" Definition of the outer crater and overturned rim-flap. The existence of a anomalously large overturned flap indicates that the crater excavation at a marine impact may differ significantly from the standard land-target impact. Shock levels within the flap may show if it was ejected by a shock-driven ejecta flow or by a low shock, hydraulic flow as suggested by numerical simulation [6;7]. To understand the distribution of the overturned flap and the shallow excavation flow preceding its deposition (Fig. 2) it is necessary to investigate its contact to the underlying strata on which it rests.

The Lockne crater. The impact occurred in an epicontinental sea about 455Ma. 2D [4] and 3D [6;7] modeling combined with geological observations of crater infill and morphology have given that the water depth must have slightly exceeded the impactor diameter. The water overlaid 80 m of limestone and semiconsolidated, bituminous mud that rested on the weathered Precambrian crystalline peneplain. The difference in strength between the water and the rocks generated a concentric shape of the transient cavity (Fig. 2) with an at least 14 km wide crater in the water mass, and a 7.5 km wide crater in the basement. A flap of ejected crystalline rock surrounds the crater (Fig 1), but structural rim uplift is absent [8]. The flap rests on top of a surface stripped from much of the sediments by the water cavity excavation flow (Fig 2). The water resurge used rip-apart openings formed by tangential stresses during the deposition of the semi-rigid flap to enter the basement crater [3]. The additional resurge erosion expanded the openings to form large gullies through the rim with extensive polymict deposits of reworked ejecta and rip-up material. The CMMs are visible at a few locations along the western rim of the basement crater, one of which was drilled in this study. These bodies can be at least several tens of meters in length and width, but their thickness and stratigraphic position (i.e., the relation with the crater formation) has been hitherto unknown. The CMMs lack stratification and are practically empty on both macroskopic fossils as well as microfossils. Some rare arthropod fragments are visible, but no stromatolites, stromatoporoids, corals, bryozoans, crinoids, or other reef-building or reef-living organisms. Significant is the high content (up to a few percent) of micro-crystals (< 100 microns) of quartz and feldspar with surface depressions that show they have grown within the micritic sediment, apparently during rapid deposition.

Preliminary results "Lockne 7": The drill core is 7.44 m long. The CMM is about 2.5 m thick, but has a gradual transition downwards into the more nodulous, bioturbated limestone known from elsewhere in the crater to constitute the first post-impact secular sediment after the end of the resurge deposition. From the drilling it is clear that the CMM is part of the secular sedimentation. However, it is still mysterious why this facies is known only from a few localities. The deeper drillings "Lockne 1&2" have, so far, not showed an existence of a similar facies. We are currently investigating this by analyzing the inorganic carbon (IC) content and stable isotopes (O18; C13) from different CMMs and drill cores. In "Lockne 2" there is

an approximately 8 m thick, black mudstone without nodules just after the last, silt-size resurge deposit at 120 m depth. The IC values in nodules increase downwards (2-9.5%) towards the mudstone, which, however, has a much lower value (0.5%) than samples from a CMM west of Tandsbyn (9-11%). The CMM has significantly lower O18 and higher C13 than the carbonate nodules in "Lockne 2". Hence, we have not yet been able to correlate the CMMs with any part of the secular limestones in the infill of the inner parts of the crater depression. The CMMs represent a unique type of carbonate sedimentation and are clearly linked to the geochemical environment that formed by the impact, possibly due to sudden convection of a stratified water body within the crater.

Preliminary results "Lockne 8": Mapping of the occurrence of brecciated crystalline rock south of Ynntjärnen has revealed an approximately 1 km^2 area with basement ejecta that has ended up with a stratigraphic position on top of younger sedimentary target rock (Fig. 1). However, its thickness in the central parts was unknown, and, hence, if it there also rests on sediments, or if it has managed to penetrate to the basement. The drilling showed that the thickness at the drill site is about 50 m and that the ejecta rests directly on top of fractured basement, however with possible remnants of dark sediments injected between clasts. It shows that, at this location, the deposition of the crystalline ejecta excavated through the sediments, but not significantly below the calculated top of the basement peneplain as calculated by [8].

Preliminary results "Lockne 9": The drill site was located at a part of the western flap with an appearance similar to known dolerites in the area. The upper 2.27 m were strongly weathered and caused core loss. The drilling was terminated at 31.04 m depth after having passed the calculated level of the basement peneplain [8]. At a depth of 11.4 m the strongly brecciated dolerite is either interrupted or has a rapid transition into a dark greenish, fine-crystalline, slightly "nodular" variety that continues to a depth of about 22.9 m. The green surfaces of this basalt are dotted with small (<1mm) ochre-colored spots. Thin sections reveal that the basalt is largely a micro-breccia and SEM-EDX analysis shows that the spots possibly are Ilmenite (opaque with high Fe, Ti, and O contents). The basalt is different from other known dolerites in the area and we aim to reveal its origin by future studies including XRD and geochemistry.

References: [1] Ormö J. et al. (2004) *Met. Planet. Sci., 39*, 2, 333-346. [2] Ormö J. and Lindström M. (2000) *Geol. Mag., 137*, 67-80. [3] Lindström M. et al. (2005) *Impact Studies* (Springer), in press. [4] Ormö J. et al. (2002) *JGR, 107*, E11. [5] Lindström M. et al. (1996) *GFF, 118*, 193-206. [6] Lindström M. et al. (2005) *PSS*, in press. [7] Shuvalov V. et al. (2005) *Impact studies* (Springer), in press. [8] Sturkell E. and Lindström M. (2004), *Met. Planet. Sci.,39*, 1721-1731.

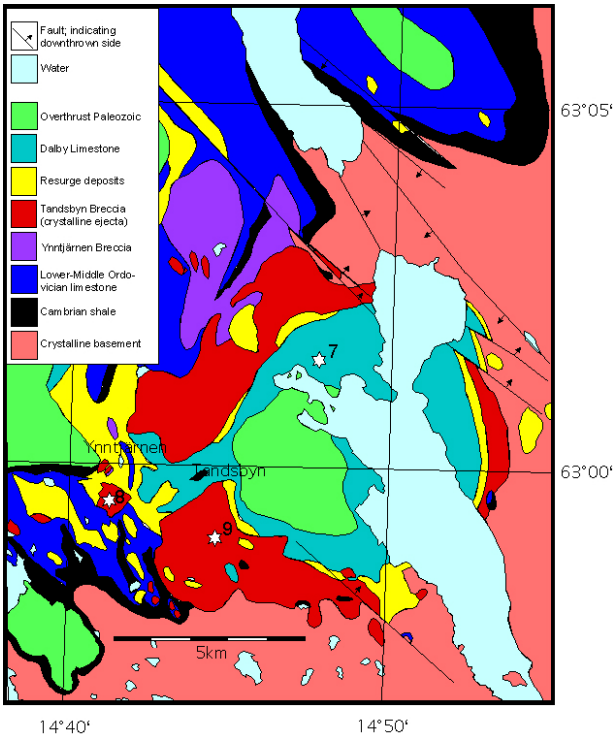

Figure 1. Geology of the Lockne crater. Stars indicate the drill sites of this study.

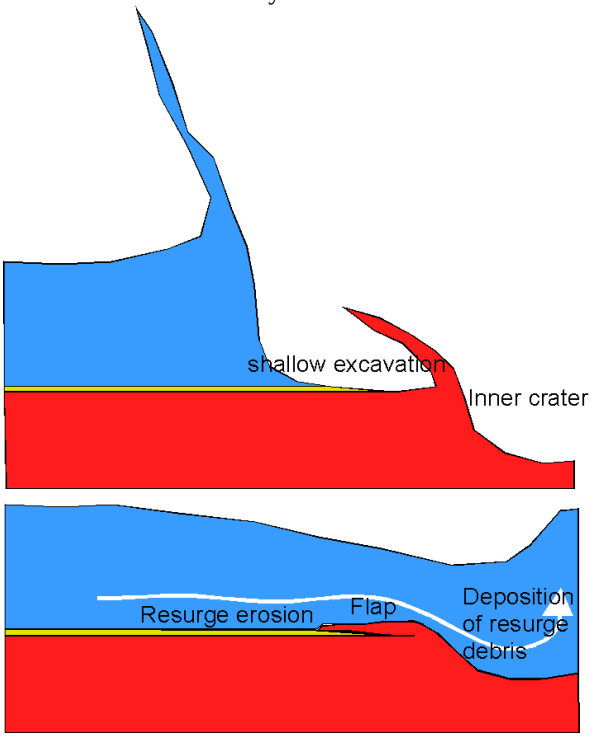

Figure 2. Schematic illustration of excavation and modification of the Lockne crater.