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Introduction

Cosmic impacts on Earth often take place at sea. The majority of all marine impacts are still covered by the sea and are thus less accessible for investigations. So far a very limited amount of work has been carried out looking at the aftermath of marine impacts. In particular the facies associated with the deposition in the crater as well as the patterns of faunal recovery in and around marine craters. The Ordovician of Baltoscandia is unique in that at least five well preserved craters with a good record of post impact sediments are preserved (Lockne, Tvären, Granby, Hummeln, Kärdla). On Earth they correspond to approximately one third of all known marine craters. Of these the Lockne crater in Jämtland (Sweden) is of particular interest since it is well exposed and gives excellent possibilities for a field-based study of the successions from the Dalby Limestone in and around the crater as well as from existing drill cores. Dealing with impact structures formed in a marine environment there is often a continuous sedimentation occurring directly after the impact event and the crater thus holds a greater possibility to be preserved rather than eroded. The Lockne crater owns its considerably good preservation to the continuous sedimentation of the Dalby limestone directly after the impact and more important by the protection from overthrusted Caledonian nappes.

Geological background

The Lockne impact crater was formed at 455 Ma when a meteorite hit a relatively deep marine environment, presumably with a minimum depth of 500 m. The targeted seabed consisted of sediments from the Cambrian and Ordovician, mostly lithified limestones and soft claystones as well as semi-lithified limestones, all resting on a crystalline basement. The transport of material from the seabed began with the impact ejection, followed by a gigantic catastrophic seawater resurge sweeping into the new, empty, and still hot crater. This resurge eroded deep channels into the crater margin. In addition great volumes of rocks from the seabed and the surrounding crater were ripped away by the resurge. Much of this eroded material became mixed with ejecta and contains structures indicating the involvement of water during deposition. After the impact event and the settling of the impact related rock material, deposition of sediments from the Dalby Limestone continued in and around the newly formed crater. The Dalby Limestone has the same biostratigraphic age as the youngest beds that pre-date the impact. The impact related rocks are thus under- and overlain by the marine sediments of the Dalby Limestone. Lithology and thickness of the Dalby Limestone vary accordingly to position in the seascape after the impact. The principal facies of the Dalby Limestone at Lockne is characterised by massive, light grey, hard calcilutite that occurs as ellipsoidal to irregularly rounded nodules with maximum diameters in the range 5-30 cm and vertical thickness in the range 2-15 cm. Morphologically the Lockne crater consists of a 7,5 wide inner crater that is surrounded by a 3 km wide outer crater. The inner crater is filled with more than 200 meters of resurge deposits and post-impact Dalby Limestone constitutes 88 m in the deepest part of the crater and 31 m just inside the rim of the inner crater. Furthermore, the ejecta and resurge products can be traced at least 40 km outward from the impact center.

Report

This project is intended to contribute to the understanding of how meteorite impacting affected the Ordovician sea; however the primary objective is to identify different facies in craters and further to identify patterns on faunal recovery in a marine crater. Dealing with impact structures formed in a marine environment there is often a continuous sedimentation occurring directly after the impact event and the crater thus holds a greater possibility to be preserved rather than eroded.

I conducted extensive field investigations in the Lockne area where the prominent Ordovician Lockne crater is located. Several different facies of the same limestone are evident in the crater. A characteristic faunal assemblage is associated to each facies. In co-operation with Dr. Jens Ormö (Centro de Astrobiologia Madrid, Spain.) and Prof. Maurits Lindström (Stockholm University, Sweden) the Dalby Limestone in the Lockne crater has been investigated through comprehensive fieldwork in the Tandsbyn gully and further through material from the Lockne 1 and Lockne 2 drill-cores. Deposits of the same post-impact secular deposits in the Tvären crater, Stockholm archipelago, (Sweden), are available through the Tvären 2 drill-core and erratic boulders. Rock samples were lithologically evaluated through thin sections and further processed for organic carbon (orgC) (Tvären 2) and inorganic carbon (IC) (Lockne 1, Lockne 2 and Tvären 2) in percent of the sample weight.

The Lockne and Tvären craters formed in the Upper Ordovician Baltoscandian epicontinental sea. Both craters demonstrate similarities concerning very near age, target seabed, and succeeding resurge deposits, however, the depth of the impacted sea and the sizes of the craters are unlike. The post-impact sedimentary succession of carbonates, i.e., the Dalby Limestone, deposited after the resurge sediments in the two craters are nevertheless similar. At least three main facies varieties of the Dalby Limestone (*rim facies*, *cephalopod facies* and *argillaceous facies*) were established in Lockne depending on sea-floor topography, location with respect to the crater, and local water currents. The dominating nodular *argillaceous facies*, represented by low values of inorganic carbon (IC), was distributed foremost in the deeper and quiet areas of the crater floor and depressions. At the crater rim, consisting of crushed crystalline basement, a *rim facies* with a reef-like fauna was established, most certainly due to topographical highs and nutritious substrate. In Tvären, the lower part of the succession consists of an analogous argillaceous facies, also showing similar low IC values as in Lockne, followed by calcareous mudstones with an increase of IC. Occasionally biocalcarenites with a distinctive fauna occur in the Tvären succession, probably originating as turbidites from the rim. They are evident as peaks in IC and lows in organic carbon (orgC). The fauna in these turbidites corresponds very well with those of the erratic boulders derived from Tvären; moreover they correspond to the *rim facies* of Lockne.

These results have recently been accepted for publication in *Meteoritics and Planetary Science*. Moreover the gastropod content in these facies has resulted in another paper, accepted in *GFF*. The results have further been presented as a poster and oral presentation at "*Impact craters as indicators for planetary environmental evolution and astrobiology*" in Östersund (Sweden), June 8-14, 2006 and "*Changing palaeogeographical and palaeobiogeographical patterns in the Ordovician and Silurian*", University of Glasgow, Scotland, UK, 30 August – 1 September 2006, respectively. IAS has been acknowledged in all of the above publications and presentations and I am most grateful for this grant.

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