CRATER RIM DEVELOPMENT OF THE RITLAND IMPACT STRUCTURE – FIELD OBSERVATIONS AND POSSIBLE MECHANISMS. Fridtjof Riis[1], Elin Kalleson[2] and Henning Dypvik[2], [1]Norwegian Petroleum Directorate, Professor Olav Hanssens vei 10, P.O.Box 600, 4003 Stavanger, Norway (Fridtjof.Riis@npd.no), [2]Department of Geosciences, University of Oslo, P.O.Box 1047 Blindern, 0316 Oslo, Norway (elinkal@geo.uio.no, henning.dypvik@geo.uio.no).

Introduction: Field observations in the Lonar, Barringer and other craters suggest that the processes of crater rim formation may be complex and involve large scale movement of ejecta along the ground surface ("fluidized ejecta") [1]. In the Ritland structure (Fig. 1), such processes have been studied in the field in well exposed geological sections. The Ritland structure is the remnants of a 2.7 km diameter, simple crater [2]. Formed in a shallow sea setting, the crater was infilled by Cambrian sediments and later covered by Caledonian thrust nappes. It is now partly re-exposed due to Cenozoic uplift and erosion, and there are continuous exposed sections from the crater floor, through the walls, rim and ejecta. Large parts of the crater rim are preserved and exposed to the east and north of the Ritland structure (Figs. 2 and 3).

Fig. 1. Location of the Ritland and other recognized impact structures in Scandinavia (positions indicated by black dots).

The target area consisted of a peneplanated surface of Precambrian crystalline basement, flooded by the epicontinental sea covering large areas of Baltica/Scandinavia [3] and covered by about 10-20 m of Cambrian sandstone and clay. Studies of the sedimentary succession within and outside the crater suggest that the sea was shallower than 100 m at the time of the impact. A shallow sea would not significantly modify the formation of the crater and rim [4]. The thin layer of Cambrian sediments acts as a marker horizon, aiding the interpretation of the geological structures.

Field observations: Based on the field observations, the rim and associated area has been divided in 4 zones (Fig. 2).

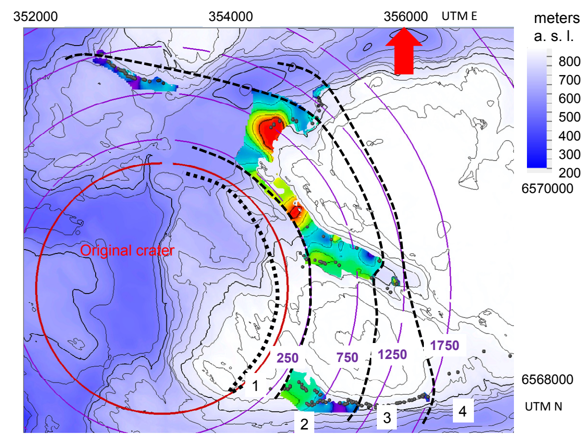

Fig. 2. Map of study area, illustrating the thickness of the rim; red color where thickness exceeds 50 m. White color in mountain areas covered by thrust nappes. Dark blue in crater depression and eroded areas. Zones indicated on the figure are discussed in text. Purple lines show distance from the interpreted crater rim crest.

Zone 1 extends from the inner side of the crater rim and 200 to 300 m outwards from the position of the original rim crest. In this zone the pre-existing peneplain has been elevated about 50 m, and basement gneisses with a varying degree of brecciation are exposed. The original sedimentary contact between basement and Cambrian sandstone has been deformed and cannot be recognized. The top of the initial rim is not preserved due to erosion. Measurements of strike and dip of the gneiss foliation in zone 1 show different orientations of foliation relative to the outside of the crater structure. At the two well-exposed rim locations, Stropastøl and Svodene, the gneiss foliation is close to vertical (Figs. 3 and 4) in contrast to the general trends outside, dominated by low and moderate dips. This indicates that the basement rocks at the crater margin were wrenched up relative to their original position, in accordance with general impact theory [5] and recent numerical modeling of the formation of the Ritland structure [4].

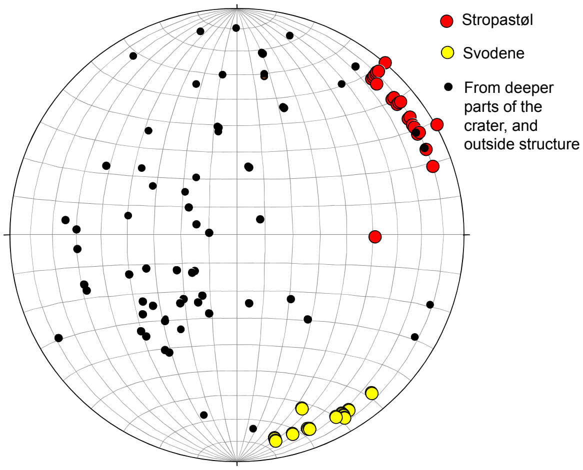

Fig. 3. Stereoplot showing strike/dip measurements of gneiss foliation in the area. Most places the dip is low to moderate (black dots), but at the rim locations (Stropastøl = red circles and Svodene = yellow circles) the foliation is close to vertical.

Zone 2, extending from 300 m to about 1000 m away from the crater wall consists of 20 to 50 m thick sheets of brecciated basement gneiss which rest on a few meters thick layer of Cambrian sediments (Fig. 4). Zone 3, extending from about 1000 to about 1400 m is characterized by broken-up sheets and gigantic blocks of gneiss, and marks a transition from the area of gneiss sheets ("fluidized ejecta") to the distal ejecta in zone 4. In zone 4, a continuous ejecta layer consisting of a mixture of gneiss clasts and shale can be mapped out to about 5 km away from the crater margin. The gneiss clasts are interpreted to originate from the ejecta curtains [6].

The thick brecciated gneiss sheets in zone 2 have a locally erosive lower boundary to the Cambrian sediments, and their internal structure resemble the brecciated basement gneiss of the crater wall. Thin dikes of Cambrian shale occur locally at the base of the gneiss sheets. In zone 3, the gneiss sheets are broken up into blocks 10-50 m thick and 10 to a few hundred meters wide. Here, the gneiss sheets are overlain by the ejecta layer, showing that the sheets were emplaced immediately after the impact. The Cambrian shale underneath and between the brecciated basement slabs in zone 2 is generally deficient of crystalline debris, while in the outermost part of zone 3, the slabs appear to have been mixed with shale and ejecta.

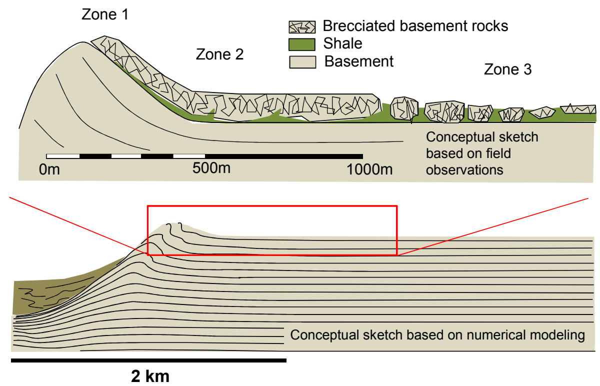

Fig. 4. Model of the crater rim. The lower figure is based on the numerical modelling of the Ritland structure [4], illustrating how the basement rocks are deformed along the crater margin. The upper figure (vertical axis 3x exaggregation) shows a model of the brecciated basement rocks, partly resting on pre-impact shale, and how this is developed with distance from the crater margin.

Between zone 3 and zone 4, the Cambrian shale underlying the ejecta rapidly increases in thickness from a few meters up to 10 meters. In zone 4, the ejecta layer with crystalline debris lies stratigraphically on top of an approximately 10 m thick shale succession generally deficient of any crystalline debris, with the exception of a few large boulders found embedded within the shale [6].

Implications on rim formation: The field evidence suggests that in zone 2 and 3 large slabs of brecciated basement were sourced from the crater rim and emplaced during and immediately following the impact. The underlying clay was partly eroded, partly squeezed into the gneiss sheets, suggesting movement along the ground surface and possibly pressure build-up. Emplacement prior to the deposition of ejecta indicates high velocities of the basal glide. The distal ejecta (disintegrated crystalline debris) travelled ballistically, although the ejecta bed may have been modified by bottom currents [7].

References: [1] Maloof A.C. et al. (2010) *GSA Bull. 122*, 109-126, [2] Riis F. et al. (2011) *Meteoritics & Planet. Sci., 46*, 748–761. [3] Lidmar-Bergström K. and Näslund J.O. (2002) *In: Doré, A.G., et al. (eds.) Geological Society, London. Special Publication 196*, 103-116. [4] Shuvalov et al. (in prep.) *J. Geophys. Res.,* [5] Melosh J. (1989) *Oxford Monographs on Geology and Geophysics 11*, 253p, [6] Kalleson E. et al. (2012) *43rd LPSC* (abstr.).