EJECTA DISTRIBUTION AND STRATIGRAPHY – FIELD EVIDENCES FROM THE RITLAND IMPACT STRUCTURE. Elin Kalleson[1], Fridtjof Riis[2], Ronny Setså[1] and Henning Dypvik[1], [1]Department of Geosciences, University of Oslo, P.O.Box 1047 Blindern, 0316 Oslo, Norway (elinkal@geo.uio.no, ronny@geo.as, henning.dypvik@geo.uio.no), [2]Norwegian Petroleum Directorate, Professor Olav Hanssens vei 10, P.O.Box 600, 4003 Stavanger, Norway (Fridtjof.Riis@npd.no).

Introduction: The Ritland structure is the remnants of a marine Cambrian impact crater, 2.7 km diameter [1] (Fig. 1). During Cambrian it was buried by crater infill sediments and later covered by thrust nappes during the Caledonian orogeny. At present it is partly re-exposed due to Cenozoic uplift and erosion. East of the crater, an ejecta layer from the impact is well preserved within a succession of Cambrian shales [2]. Below the ejecta, ten m of siltstone and shale record the Cambrian transgression, when the peneplanated surface of Precambrian basement was flooded by the epicontinental sea covering large areas of Baltica/Scandinavia [2, 3]. A shallow, epicontinental sea, with a general, low-energy regime is suggested at the time of impact.

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

These settings have proved favorable for preserving the ejecta layer, which today can be studied in field in many outcrops from the proximal crater rim area to the more distal localities several km farther out. The lithological contrast between the shales in the target area and the basement gneisses in the ejecta makes it easy to estimate the volumetric contribution of ejected material in geological sections. This gives a unique possibility to study both the lateral and stratigraphical developments of the ejecta layer. Relative to geomorphological studies of ejecta [e.g. 4] the field outcrops at Ritland offers valuable data regarding possible depositional mechanisms.

Methods: The field studies are based on the high resolution topographic maps of Statens Kartverk (Norwegian Mapping and Cadastre Authority – NMCA, scale 1:5000, 5 m contour distance). The model in Fig. 2 was created with Petrel software. The ejecta layer has been studied in several sections, ranging in distance from approximately 2 to 6 km from the crater center (Fig. 2). Some well exposed ejecta sections are presented in this study; Raudkleiv and Rekkjebråtet (Fig. 2).

Microscopic structures and textures of the rocks have been inspected in thin section, in particular quartz grains in the search for planar deformation features (PDFs) [5].

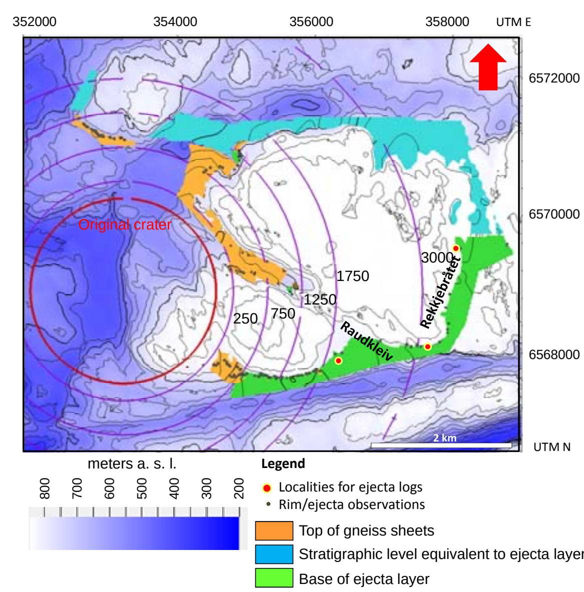

Fig. 2. Map of study area. Distribution of rim and ejecta and localities discussed in this study. Numbers 250, 750, 1250 and 3000 indicate distance from crater margin. White color in mountain areas covered by thrust nappes. Dark blue in crater depression and eroded areas.

Ejecta distribution: A well defined ejecta layer is observed in the green areas of Fig. 2, beyond about 2 km from the crater center (750 m from crater wall, which is drawn as a red line in Fig. 2). The largest crystalline clasts are observed 700 - 1800 m from crater margin. Boulders, sometimes exceeding 5 m in diameter, are found embedded in the dark shale (Fig. 3). With the exception of these occasional large boulders, the ejecta layer generally appears as a mix of crystalline rock clasts and shale with varying clast content (50 to 90 %), overlying a 10 m interval of shales without crystalline debris, although occasional boulders which have penetrated the clay have been observed. A general upwards-fining trend may be present, with the largest boulders commonly found in the lowest part of the ejecta layer and the clast size decreases upwards whereas the sand content increases upwards. Within the ejecta layer, repeated upwards-fining developments separated by possible sub-horizontal planes have been observed (Fig. 3). Within the green area of Fig. 2, the ejecta bed appears to be continuous, with a thickness variation from almost 0 and up to maximum thickness of about 4 m. At some localities a thin unit of moderately sorted sand to gravel is draping the main ejecta bed.

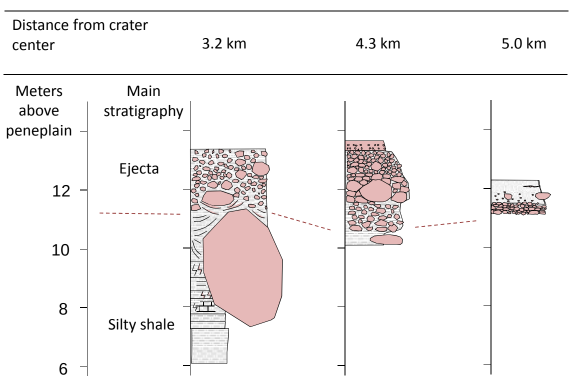

Fig. 3. Correlation between some of the studied sections, illustrating the developement of the ejecta layer at proximal and more distal sites. Crystalline clasts in pink color.

About 5 km from the crater center in the green area (Figs. 2, 3), the amount of ejecta material decreases rather abruptly and the ejecta layer becomes thin and discontinuous. Crystalline clasts up to 10 cm occur dispersed, and the ejecta layer consists of moderately to well sorted, coarse sand.

In the blue area of fig. 2, the stratigraphic level equivalent to the ejecta bed is generally covered by vegetation, and the bed itself, if existing, is believed to be thin.

Shock features: PDFs were observed in quartz grains of the ejecta bed from several localities. An assemblage of shatter cones was found within the ejecta layer at Raudkleiv. The shatter cones consist of almost pure calcite, with a few quartz grains. The shatter cones exhibit the typical diverging striations (horse-tail pattern), and the structures are penetrating; a diagnostic feature separating shatter cones from other non-impact structures like slickensides or wind ablation [4].

Conclusions: The presence of shatter cone clasts and quartz grains with PDFs in the ejecta confirms its impact origin.

The position of the ejecta layer within the Cambrian sedimentary succession gives information of both the age and paleoenvironment at the time of impact, suggested to be a shallow sea. It probably represents the best possibility for dating the Ritland impact.

The lack of observations of ejecta in the northern area compared to the abundance south-east of the crater structureis suggested to reflect an asymmetry in the ejecta distribution.

The main depositional mechanisms suggested are ballistic travel of material, combined with some surge-like flow set up by the horizontal velocity component of the ballistically travelling debris. Large boulder-sized clasts arriving early had sufficient energy to penetrate into the upper part of the soft, unconsolidated shales, which prevented further movement. The main part of the ejecta consists of dominantly crystalline debris from the ejecta curtain mixed with various amounts of local material (clay). The mixing with sea floor clays and indications of ejecta stacking into lumps/heaps, suggest some horizontal movement of material along the seafloor away from the crater. The ejecta layer and the scattered clasts in distal locations appear at the same stratigraphic level in the study area. This indicates that erosion during deposition was modest, and could explain the relatively low amount of local shale mixed into the ejecta layer compared to dominantly crystalline debris.

The upper, sandy beds may be the products of post-impact reworking by (tsunami?) waves or density currents.

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