TOWARDS A BETTER UNDERSTANDING OF MARINE IMPACT PROCESSES: WHAT A POTENTIAL DRILLING OF THE MJØLNIR CRATER (BARENTS SEA) HAS TO OFFER. F. Tsikalas[1], H. Dypvik[1], J. I. Faleide[1] and M. Smelror[2], [1]Department of Geosciences, University of Oslo, Oslo, Norway (filippos.tsikalas@geo.uio.no, henning.dypvik@geo.uio.no, j.i.faleide@geo.uio.no), [2]Geological Survey of Norway, Trondheim, Norway (Morten.Smelror@ngu.no)

The 40-km-diameter Mjølnir Crater in the central Barents Sea is one of the very few cases globally where an intactly-preserved source-crater and ejecta-layer correlation has been established [1-6]. Both geophysical and geological data unequivocally substantiate an asteroid impact at about 142 Ma (Jurassic-Cretaceous boundary) into a sedimentary platform with 300-500 m paleo-water depth. A total of ~2100 km of seismic reflection profiles clearly image the impact-related and post-impact structure and stratigraphy (Fig. 1). In addition, free-air gravity, seismic velocity, and porosity anomalies exhibit close correspondence to the impact-induced structure and physical property distributions [7-10]. Two shallow boreholes, one near the center (7329/03-U-01, 121-m-long core) and another ~30 km from the crater periphery (7430/10-U-01, 51.1-m-long core) (Figs. 1-2) have confirmed the impact origin of the structure and offer a seismic stratigraphic correlation [1-6].

Potential Deep Drilling: We now propose a transect of three drill-sites that require riser drilling (Figs. 1-2) and comprises two crater sites (MJOL-1A and MJOL-2A) and one reference site (MJOL-3A). The transect drilling, complemented by the two existing shallow drillholes and the extensive geophysical database, will address the following three themes:

(1) Marine Impact Cratering Mechanics: Through the proposed Mjølnir drilling a better stratigraphic control on the target and impact-induced lithologies will be reached. Combined with the entire spectrum of seismic reflection profiles better constraints on the amount of excavated (allochthonous) breccia volume, structural uplift, gravitational collapse, and infilling will be reached. Due to the well-established Barents Sea stratigraphic framework and the stratigraphic control obtained by the proposed drilling, we will be able to map/follow the displacement of the originally horizontal platform target-layers during the course of the cratering processes.

The proposed drilling aims to resolve the pressure and temperature distribution occurring during the Mjølnir impact. This work will, initially, include detailed geochemical (inorganic/organic) and mineralogical analyses (optical, electron-microscopical) of shocked mineral grains along with authigenic formations. The mineralogical analyses will provide peak shock pressure and temperature zonations along the cores, as well as the compositional contamination of the projectile material. When comparing pressure/temperature distribution to theoretical models, a testable framework for increased understanding of the impact cratering physics will be achieved.

The nature of the cratering processes depends, to some extent, on whether the target is crystalline or sedimentary. Numerical simulations for Mjølnir [11] have documented the importance of the target lithology for the cratering processes. In particular, the low-strength sedimentary target layer leads to a modification crater stage that deviates considerably from the more typical scenario of modification for large com-

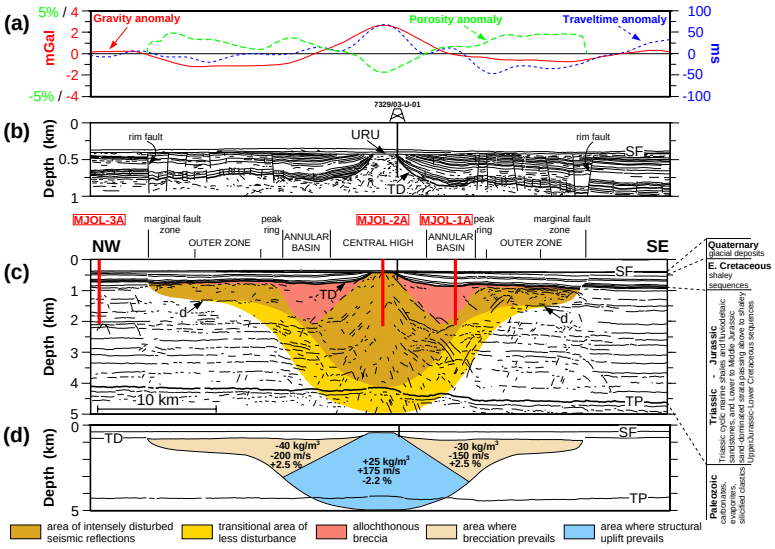

Fig. 1. Geophysical type section: (a) free-air gravity, seismic traveltime, and porosity anomalies, (b-c) interpreted single-channel and multi-channel profiles, and (d) impact crater model with calculated physical property distribution (modelled density contrasts in kg/m^3, seismic velocities in m/s, and porosity anomalies in %). SF, sea floor; URU, late Cenozoic upper regional unconformity; TD (top disturbance, impact horizon); TP, Top Permian; d, low-angle décollement.

plex craters on land, as intensive slumping and gravitational collapse counteract the crater floor uplift. Furthermore, only dispersed character melts are expected to have formed during Mjølnir impact due to the sedimentary and water-rich target. Magnetic modeling shows that such melts are most probably located at the periphery of the structure [9], and site MJOL-1A will test this model (Figs. 1-2). Therefore, the proposed Mjølnir drilling will contribute to the understanding of the actual impact processes by providing, for the first time in impact crater research, a direct calibration to both empirical relationships and numerical simulations.

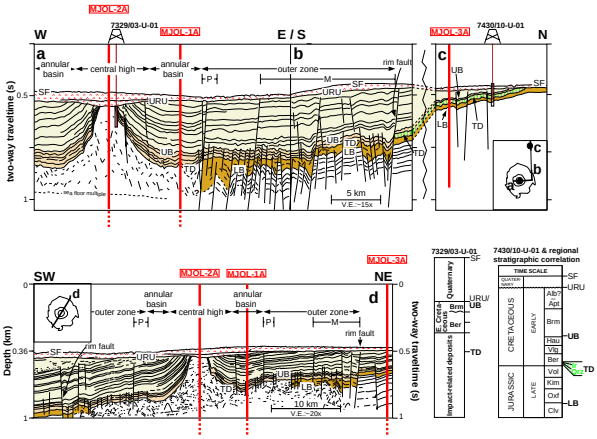

Fig. 2. Interpreted examples of shallow multi-channel profiles (a-c) and a single-channel profile (d) crossing the structure. Reflectors UB (upper boundary) and LB (lower boundary) bound the time of impact. UB, lower Barremian; LB, base Upper Jurassic. Vertical-bars raster denotes the uncertainty in the seismic tie of the impact horizon. Qrz/Ir, position of shocked quartz grains and iridium peak, respectively. P, peak ring; M, marginal fault zone. Other annotations in Fig. 1.

(2) Impact Magnitude and Impact-induced Perturbations: Refined geological/physical constraints on the impact cratering processes derived through the proposed drilling may constrain estimates of the energy release during impact. Energy release dissipation determines the distribution of ejecta and tsunami, which may have induced short-term perturbations/environmental stress in the Barents Sea and adjacent regions. In particular, palynological studies of the ~80-cm-thick ejecta-layer of borehole 7430/10-U-01 (Fig. 2) have revealed a high abundance of marine prasinophyceae algae and a minor abundance peak of freshwater algae attributed to the extensive impact-induced water-column disturbance [12]. Sites 1 and 3 may recover thicker ejecta deposits allowing further analysis on the effects on marine organisms. The analysis will also involve high-precision dating. The existing biostratigraphic age for the Mjølnir impact (142±2.6 Ma, Jurassic-Cretaceous boundary) [3] will be refined by absolute dating derived both from the paleomagnetic study and ^{40}Ar-^{39}Ar/U-Pb datings on possible melts (macro-/microscopic). Furthermore, Mjølnir dimensions approximate the 45-km-diameter marine Montagnais Crater in Canada which was placed at the threshold of a regional/global extinction initiation. Therefore, micropaleontological/paleontological studies will test the lower crater-size boundary, and thus impact-released energy, required for regional and/or global extinctions to occur.

(3) Quantification of Post-impact Modifications: Integrated geophysical modeling at Mjølnir demonstrates a close correspondence of geophysical anomalies to the radially-varying distribution of structural and morphological units, and to the physical-property distribution [9-10]. The impact-induced substratum suffered differential compaction triggered by a considerable overburden that alternated the impact crater morphology and geometry. Indeed, at Mjølnir the brecciated periphery compacted more that the denser central crater resulting to a central high standing higher that the surrounding platform (Figs. 1-2) [9-10]. Post-impact modifications may have obscured or blurred many marine impact craters in sedimentary targets whereas the quantification of post-impact effects may be difficult in the subaerial impact record. The proposed drilling, core analyses, and well-log measurements will contribute to the assessment of petrophysical properties within the impact structure. It will, thus, contribute to an understanding of post-impact operating compaction-processes and evolution, and to the identification and recognition of marine impact craters on sedimentary targets.

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