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Kärdla impact crater – transitional from simple to complex based on reflection seismics

Argo Jõeleht, **Jüri Plado**, Kaidi Sarv
Department of Geology, University of Tartu, Estonia (argo.joeleht@ut.ee, juri.plado@ut.ee, kaidisarv@gmail.com)

Abstract

Based on drillings, the 4 km Kärdla impact crater is considered as one of the smallest complex craters on Earth in crystalline target. We present results of reflection seismic profiling indicating only a small hill near the crater center. Weakly developed central uplift is likely related to incomplete collapse of crater cavity.

1. Introduction

Kärdla impact crater, Estonia, is known as one of the smallest complex craters on Earth that was formed in crystalline rocks. The crater, rim-to-rim diameter about 4 km, was formed in shallow marine environment [3]. Crater rim was partly eroded by resurging sea, but in general it is well preserved. The complex nature of the Kärdla crater is based on three boreholes inside of the crater. A drillhole K18, located near its center (Fig. 1), revealed existence of the central uplift as suevitic breccia and strongly fractured crystalline basement rocks lie more than 150 m higher in comparison to boreholes K1 and K12 in the annular moat. We present results of reflection seismic survey that provides more information on the size and location of the central uplift.

2. Methods

Internal structure of the Kärdla crater was studied using 24-channel system. In total about 20 km of profiles covered both central part and rim area of the crater (Fig 1). Geophone spacing was 10 m. Limited number of channels available (relatively short receiver line) and variable burial depth (<100 m at rim, >300 m at central part) created acquisition configuration challenges in order to illuminate both rim and central areas of the crater. In the rim area, where the crystalline rocks were not deep, the source (8 kg sledge hammer) was applied in-line at 10 m spacing with maximum near-offsets ranging 10-120 m, after which receiver line was moved by 12 channels. In the central part and some parts with lower crystalline rim, the source was applied every 20 m at near-offset range 10(20) to 230(240) m. Thus, the maximum offsets were 350 or 470 m.

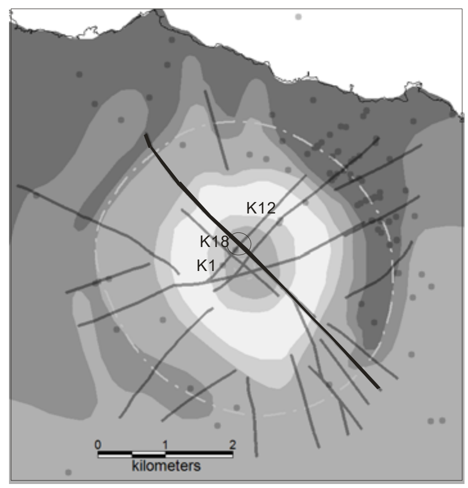

Figure 1: Location of seismic profiles (gray lines) and boreholes (dots). Crater rim and its small projection in the center are marked by dot-dash line. Central mound on Fig 2 is marked with black circle. Black line marks the profile on Fig 2. Background is bedrock geology map.

Data were processed using SeismicUnix package [1]. Apart of typical reflection seismic processing flow, the Kirchhoff pre-stack depth migration was applied.

3. Results

Seismic profiles suggest that the crater is not quite symmetric in many aspects. The central uplift is laterally rather small feature that is located 300–400 m northward from its expected location at the center of the crater (Fig. 2). This mound is visible only on two crossing profiles near borehole K18 whereas other profiles in the central part of the crater show no uplifted basement rocks or bending of overlaying strata. Small central uplift is in agreement with gravity data. The lack of positive gravity anomaly in the center was attributed to small density contrast between uplifted rocks and surrounding crater fill [2].

The crater is also asymmetric in the shape and height of the rim. The rim is slightly elongated in NW-SE direction (diameter 4.5 km in NW direction versus 4.1 km in NE). A high rim occurs extensively only in the (north)eastern side whereas there are some smaller peaks in southwest and northwest. Low rim in northern and southern parts have been interpreted as resurge gullies [3]. Drillings at western rim show also erosional features, but no gully-like cut-in features which might suggest that the rim has never been high there. Rim height variations might be related to changes in rock types as amphibolitic and granitic rocks prevail in the western and eastern rims, respectively.

4. Summary and Conclusions

Seismic reflection profiles indicate only a small central uplift in the Kärdla crater. The uplift is 300–400 m off the center. It is interpreted as result of partial collapse of crater resulting in under-developed central uplift. Variable collapse of crater cavity might have been controlled by lithological changes in crystalline basement.

Acknowledgements

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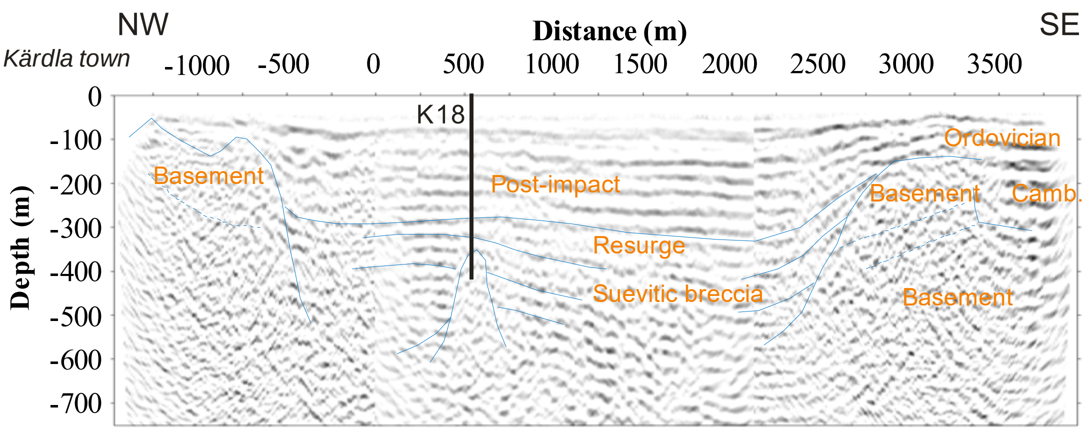

Figure 2: Reflection seismics profile with interpretations. Location is shown in Fig. 1.