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An age of both Ilumetsa structures – support of their impact origin

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Abstract

Two Ilumetsa craters are listed as a proven meteorite impact site in the Earth Impact Database, but neither remnants of the projectile nor other identification criteria (e.g., PDFs) have been found up to this point [1]. Also, until now, the temporal relation between two Ilumetsa craters has not been established, as only larger structure was dated by determining ^{14}C age of gyttja (containing charcoal and silty sand) present within it [2]. In the present study we have established an age of both Ilumetsa craters by the ^{14}C dating of charcoal present within their ejecta blankets (similar method was used recently to date Kaali crater [3]). Both craters were formed between 7170 and 7000 cal. BP. Such temporal relation supports impact origin of those features.

1. Introduction

The Ilumetsa crater field in SE Estonia consists of two structures with diameters of 75-80 m (Ilumetsa Large - IL) and ~50 m (Ilumetsa Small - IS) with true depths of about 8 and 3.5 m, respectively [1, Fig. 1]. Both structures are surrounded with a rim up to a few meters high, which is highest in the eastern parts (max. rim heights are 4.5 and 1.5 m, respectively). The target rocks consist of Middle Devonian weakly cemented light-yellow to reddish silt- and sandstones, overlain by up to ~2.5 m thick layer of brown basal till and glaciofluvial sand. The rim consists of Devonian and Quaternary sands mixed with numerous till-like clayey sediment lenses. Deformed sedimentary beds and small thickness of glacial sediments favor an impact rather than a possible glacial (e.g., kettle- or sink-hole) origin of Ilumetsa.
Structures were previously dated by the ^{14}C analysis of gyttja and peat from the very bottom of IL [2]. The lowermost organic beds date back to 6030±100 14C years (7170-6660 cal. years BP; recalibrated with IntCal13). About 600 years older age (6542±50 14C years or 7570-7320 cal. years BC; IntCal13) of Ilumetsa was proposed by [4]. This date was based on peat with glassy spherules found in a depth of 5.7 m from the Meenikunno bog, ~6 km SWW from the structures. The spherules were reported as being up to a few millimeters in size and interpreted as dissipated melt or condensed vapor however their chemical composition (that could show relation to extraterrestrial material) was not reported.

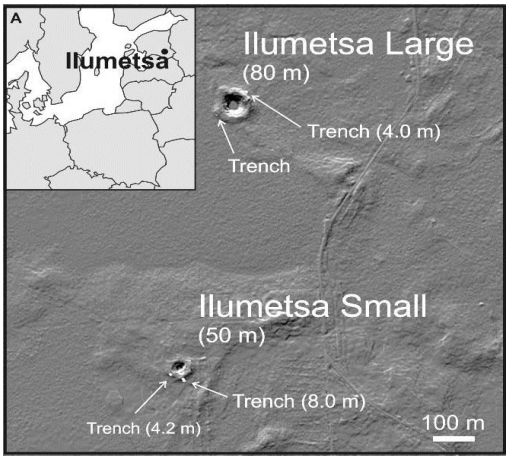

Figure 1. A) Location of the Ilumetsa craters. B) Digital elevation model of two Ilumetsa structures with location of the trenches (lengths of trenches are up to scale). A large flat area south from Ilumetsa Large is a bog.

2. Samples and methods

We have collected charcoal-containing samples from three trenches (two IS and one IL) located in the outer rim of both Ilumetsa structures, within their proximal ejecta blankets (Fig. 1). In *Ilumetsa Large* all charcoal samples came from a single 10-20 cm thick layer within the massive sand. This layer was slightly inclined outward the crater and located at the depth of 55-65 cm. Charcoal was unevenly distributed along the trench, being mostly present

at the distance between 1.7-2.8 m (measuring from the rim of the trench furthest away from the crater center). Most pieces of charcoal were very small, 1-2 mm in length, but few larger pieces (up to 1 cm) were identified. In the shorter trench of *Ilumetsa Small* only 6 charcoal samples were collected - but all of them were at least 5 mm in length (Ilume_S_2_3). All came from approximately the same depth, but did not form a continuous layer (smaller pieces than sampled were not found at this level). In the longer trench, significantly more charcoal was present, but its distribution within the strata was more complex. Similarly to the Kaali Main and IL crater, charcoal pieces were not distributed along the entire trench. In IL they were at the distance of 4.9-7 m (with a couple of pieces at 8 m distance – but on significantly lower depth than other pieces from the "main sequence"). Most of the charcoal was found within a lens-like (~20 cm in diameter) grey zone located at the depth of 65-85 cm. The color of this clayey-siltstone is most probably due to a large amount of charcoal and organic material. A large, 2.5 cm in length, piece of charcoal was found in the middle of this zone (Ilume_S_1_11g). A similar, but smaller grey zone was identified in one more place (50 cm from the first one). A couple of pieces were also found just above the level of ground water (90-110 cm). Some charcoal was also visible at the much shallower depths of 50 cm – below the soil level (Ilume_S_1_48). Most charcoal was dispersed as pieces of <5mm in length at a depth of 60-70 cm.

^{14}C dating was performed at the VERA (Vienna Environmental Research Accelerator) laboratory at the University of Vienna (Austria). The samples were chemically pretreated with the standard ABA (acid – base – acid) procedure used at VERA [5]).

3. Results and discussion

Ages determined for the charcoals from both craters are consistent with the previous ages obtained for the gyttja within the IL crater [2]. The most probable age of the craters is derived by combining youngest samples from both craters that are older than the gyttja within IL [2]. Those samples, even though they were taken from locations ~600 m from each other, are the same (95% probability). This approach helps to minimize an old wood problem in estimating age of those structures.

Old wood problem could explain slightly older ages of the samples from IL and IS (L_1_13, L_1_21, L_1_33, S_1_32, S_1_36). Three samples marked in a green box on Fig. 2 are ~1000 years older than the expected age of the craters. All of those samples come from grey circular zone with abundant large pieces of charcoal. We interpret them as remains of a pre-impact forest fire that was intermixed within ejecta. Two samples characterized by younger age were found on shallower depths (~50-60 cm) and probably post-date the impact and were introduced into subsurface by erosion of the crater rim.

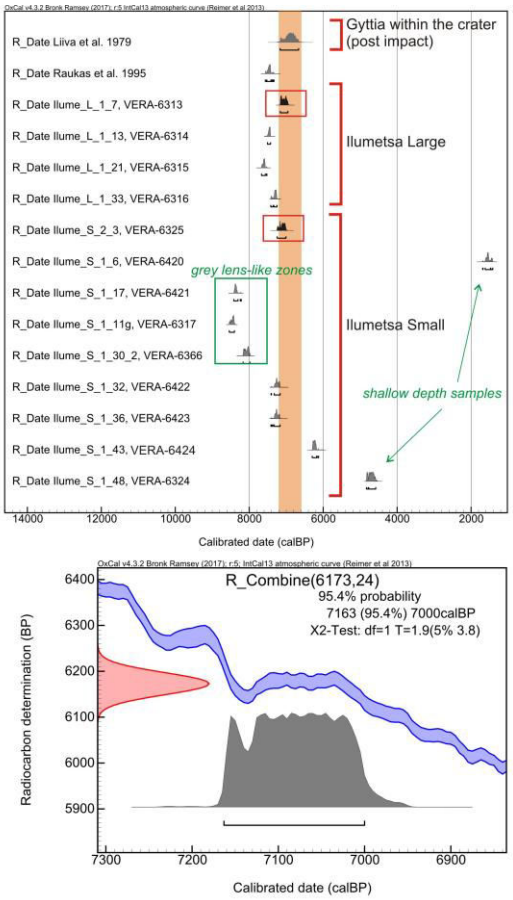

Figure 2: A) Detailed results of the ^{14}C dating of charcoal pieces found within both Ilumetsa craters. Vertical reddish stripe represents age of the sediments from inside the IL. B) Most probable age of the craters is derived from a combination of samples marked with red square on fig. 2A.

Acknowledgements

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