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Formation (and dating) of small impact craters on Earth as an analogue for Mars (Ilumetsa Craters Estonia)

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Crater-strewn-fields are present on planetary bodies with an atmosphere such as Earth and Mars, but the process of their formation is still not fully understood. For example, a recent discovery of small pieces of impact-produced-charcoal within the ejecta blanket of 100 m in diameter Kaali crater (Losiak et al. 2016) may suggest existence of very local (∼10 cm thick layer in the distance of ∼10 m from the rim), short lived (∼hours) thermal anomalies (∼300°C) in the ejecta blanket of even small craters. Ilumetsa in SE Estonia is an atypical example of crater-strewn-field consisting of only two relatively large, rimmed 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 (Plado 2012 MAPS). Structures were previously dated by the 14C analysis of gyttja from the bottom of IL (Liiva et al. 1979 Eesti Loodus) to be 7170-6660 cal. BP. About 600 years older age (7570-7320 cal. BC: Raukas et al. 2001, MAPS) was proposed based on dated layer of peat in which glassy spherules, interpreted as dissipated melt or condensed vapor (however their chemical composition was not reported). Ilumetsa is listed as a proven meteorite impact 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.

The aim of this study was to search for possible impact related charcoals in order to determine the size and extend of thermal anomalies around small impact craters, as well as to determine how this atypical strew field was formed. Additionally, we hoped to determine/confirm the age of those structures.

We have found charcoal in a similar geological setting as in Kaali Main crater in both Ilumetsa structures. The calibrated (95,4% probability) time ranges of four dated samples from IL and one sample of IS span the time interval from 7670-6950 cal. BP (consistent with previous dating). One sample from IS is younger (4830-4580 cal. BP) – it was found less deep than other charcoals found within the same trench, and it may be interpreted as a remnant of a “recent” forest fire, later buried within the sediment derived from the erosion of the raised rim. The second sample is older (8540-8400 cal. BP). It was found on a greater depth than most of the samples and may represent an older plant material that was buried within the sediments before the impact happened. More 14C dating will be performed. Chemical analyses of sediments exposed in profiles did not reveal any specific enrichment with respect the host rocks in elements (Ni, Cr) that could be related to extraterrestrial material. INAA measurements will be performed. Field search for metal-containing meteorites was inconclusive (until now nothing was found), but preliminary studies on the atmospheric entry modeling of the Ilumetsa meteoroid shows that using standard value of strength (4.4e6 - 4.4e7 N/kg) for a stony meteoroid, cannot lead to reproduction of the Ilumetsa craters formation due to cascade fragmentation specific for such weak bodies.

In conclusion: the Ilumetsa structures were formed around 7000 cal. BP, but a clear proof of their impact origin is still missing. More analysis is being currently performed. Understanding formation of small terrestrial impact craters will lead to better understanding formation of similar structures on other planetary bodies, and their influence on their environment.