IMPACT EVENTS IN ESTONIA AND THEIR POSSIBLE ENVIRONMENTAL CONSEQUENCES. Anto Raukas, Institute of Geology at Tallinn Technical University, 7 Estonia Avenue Tallinn 10143, Estonia Phone +372 –6454 659 Fax +372-6312074 Mail: Raukas@gi.ee

The first scientifically registered meteorite fall in Estonia was on July 4, 1821, when a stony meteorite as large as a man`s head fell to the earth near the village of Kaiavere (Fig.). Since then, several meteorites and meteorite falls (in 1855, 1863, 1872, *etc*.) have been recorded.

Up to now, Kaali and Ilumetsa groups of craters and four single forms – Kärdla, Tsõõrikmäe, Simuna and Neugrund with a total of 15 depressions have been distinguished in Estonia. A giant meteorite crater of Kärdla on the Island of Hiiumaa, 4 km in diameter and 400 m in depth, was formed in the middle of the Ordovician, approximately 455 Ma ago and is buried under Ordovician sediments.

Distribution of impact craters and meteorite falls in Estonia. I – Craters: E1 – Kaali; E2 – Kärdla; E3 – Ilumetsa; E4 – Tsõõrikmäe; E5 – Simuna; E6 - Neugrund. II – Meteorite falls: 1 – Kaande (Oesel); 2 – Tännasilma; 3 – Pilistvere; 4 – Kaiavere; 5 – Iigaste.

The Neugrund crater, about 5 km in diameter, is located between the islands of Osmussaar and Suur-Pakri and is about 474 Ma old. The environmental consequences of Kärdla and Neugrund impacts have not yet been precisely studied, but can only be guessed drawing comparisons with analogous structures in other regions.

Nine hollows of Holocene age have been registered at Kaali and five at Ilumetsa. The biggest craters are the Kaali main crater (diameter 110 m, depth 22 m, crater wall 4-7 m) and Ilumetsa Põrguhaud (diameter 75-80 m, depth 12.5 m, crater wall several metres). Lennart Meri, President of Estonia and a well-known writer, analysed in 1976 the Kaali catastrophe and concluded, that the striking impression this catastrophic event produced was long preserved in the minds of islanders. Since the appearance of a crater lake and a new landform with uplifted and destroyed dolomite blocks was somewhat mystical and unexpected, people started to use the site as a place of sacrifice. It may well be that tales about the dreadful event passed from generation to generation and it has found reflection even in the Nordic mythology and folklore (“Kalevala”, “Edda”).

To solve the problem, we should know the age and energy of the impact. According to different authors, the energy needed for the formation of the Kaali main crater must have been up to 10^{19} ergs. The initial velocity of the meteorite with an initial mass of 400 – 10 000 tonnes (most probably about 1000 tonnes upon entering the atmosphere) was 15 to 45 km/sec. At the time of impact its weight was probably 20-80 tonnes and velocity 10-20 km/sec. The meteorite broke into pieces in the air and fell to the earth from NE or SE under an angle of $35\text{-}40^0$.

Based on the archaeological evidence from the burning of ancient strongholds at Asva and Ri-

dala, and dendrochronological data, archaeologists reached the conclusion that the Kaali meteorite could not have fallen before the turn of the 7^{th}-8^{th} centuries BC, *i.e.* about 2600 years ago. In 1961, the idea was supported by the geologist Aaloe. His conclusion was based on the radiocarbon dates obtained on charcoal from the craters (2530±130, 2660±200 and 2920±240 years). Based on the results of pollen analyses and radiocarbon dating of peat from the lake bottom, Saarse placed the age of the craters at 3500 to 3900 years. However, it was not certain that the sediments studied originated from the bottom of the section. There is also a general disturbance of sediments in the lake of the main crater caused by the rammed-down timber (for a former pavilion in the middle of the lake) and slumping of sediments. The length of the time interval between the crater formation event and the age of the lowermost radiocarbon-dated sample from the crater lake deposit is also uncertain. In consideration of the above, we reached the conclusion that the craters should be much older than believed earlier.

During our study, detailed geological and geophysical mapping and complex studies of meteorite debris and micrometeorites in the Kaali crater field were carried out, and microimpactites were searched for in surrounding lakes and bogs. In all the four mires studied, microimpactites - mainly glassy spherules formed on the melting and vaporisation of meteoritic matter and target rocks during the impact of crater-producing meteorites – were identified only in one layer dated by palynological and radiocarbon methods at about 7500 years BP. Based on these dates, it may be concluded that the Kaali craters were formed in the Early Atlantic. At that time, the Northern Baltic area was already inhabited and it is conceivable that the large crater-producing meteorite impact, releasing an amount of energy comparable to that of the Hiroshima bomb, produced a striking and long-lasting impression on people.

Using the same method, we obtained an age of ca. 6600 years BP for Ilumetsa impact in SE Estonia. There are traces of different types of settlements in the vicinity of the Ilumetsa craters, which means that this part of Estonia was inhabited before and after the time of impact. The biggest crater at Ilumetsa is called Põrguhaud (The Hell's Grave). It is difficult to say whether the name is derived from the meteorite fall or from the morphology of the hollow ("leading to the hell"). As a conclusion, it may be said that even medium-size meteorite bodies could induce remarkable environmental consequences (forest fires, *etc*.) and became fixed in the memories of ancient people.