**KEURUSSELKÄ - DISTRIBUTION OF SHATTER CONES.** S. Hietala[1] and J. Moilanen[2], [1]Kiveläntie 2 B 13, FI-42700 Keuruu, Finland, satu.hietala@gmail.com, [2]Vuolijoentie 2086, FI-91760 Säräisniemi, Finland, jarmo.moilanen@vaala.net.

**Introduction:** Keurusselkä impact structure was discovered by authors in 2003 [1], [2]. Well-formed shatter cones in situ and boulders confirmed impact origin. A breccia with multiple sets of planar deformation features (PDFs) in quartz grains support this conclusion. Structure is located in Central Finland (centered at 62°08´N, 24°37´E).

Exposed bedrocks of the region are Paleoproterozoic granites and mica schists with volcanic inliers of Central Finland Granitoid Complex. The age of the granite basement is 1880 Ma.

Precise age of the structure is unknown. It probably is between 1880 - 600 Ma. 1880 Ma is the youngest age known for shocked target rocks and 600 Ma ago present day erosion level was mainly achieved.

Shatter cones are only impact related material found in situ. Most breccias have been boulders only, which makes them difficult to connect to Keurusselkä structure for sure. No impact melts or suevites have been found. However, many glacier-transported boulders of impact melts (kärnäite) from Lappajärvi crater (located 120 km NNW) have been found.

Lack of clear crater rim, crater depression and impact rock strata suggest that Keurusselkä is a remains of old and deeply eroded impact stucture.

**Shatter cones:** We have continued mapping shatter cone distribution of the Keurusselkä impact structure. Our mapping in 2003 - 2004 show that shatter cones are spread over 12 km wide area.

We have recorded 65 outcrops with in situ shatter cones or shatter cone like features in GIS database today. All in situ shatter cones or shatter cone like features have been found inside an area approximately 14 km in diameter. There are also some topographic features matching to this 14 km wide circular structure.

In the central part of the structure strongly fractured outcrops are full well developed shatter cones. This area is about 7 km in diameter and may be roots of the central uplift of the structure. Outside the central part of the structure most shatter cones are not well developed and outcrops shows only few shatter cones but also some good shatter cones can be found.

Close to the edge of the 14 km wide area there are outcrops where no or only some shatter cones or shatter cone like features can be seen. Not all of these features are convincing shatter cones. Some look like slicken-slides with high amplitude surface features. Some of them may be slicken-slides. We have observed a trend how shatter cones evolve when distance from the impact point increases. We have come to conclusion that most distant shatter cone like features we have found so far are still related to the impact structure but this must be studied more carefully in future.

We have also measured directions of shatter cones. This is not a simple task since only measurements that seem to make any sense are made along the topside striation of a shatter cone. What is the true topside of the cone is not always so obvious.

**A breccia dike:** In Autumn 2006 we discovered an in situ breccia dike almost at the center of the structure. This is the first in situ breccia we have found and it may be impact related. It seems to be younger than shatter cones since the dike interrupt one in situ shatter cone and there are no shatter cone features in the dike.

True nature of the dike is not known yet, but it may be lithic breccia or pseudotachylite. It may be suitable material to date impact. Even if it is not impact related it may give us a minimum age limit for impact event.

There are also few new breccia findings, which may contain shocked features. Mineralogical and chemical studies on breccias and shatter cones are going.

**Geophysics:** First results of geophysical studies at Keurusselkä were reported 2006 [3]. Finnish Geodetic Institute (FGI) carried out gravity measurements at year 2005. Four profiles (E-W, N-S, NE-SW, NW-SE) across the structure were measured. Local gravity anomaly is -9 mGal but it does not fully match with the shatter cone distribution. Gravity anomaly is not symmetrical but like a belt in NE-SW direction. It is not clear how gravity minimum is related to impact site. Topographic features on the area consist deep fractures and faulted blocks. Regional geology is also characterized by brittle faults and strongly NE-SW and S-W fracture zones, which could be due to Middle Proterozoic orogenic period. NE-SW fracture zone is in same direction than negative anomaly belt. It is also seen in aeromagnetic map. There are also other negative gravity anomalies nearby which could be due to strongly weathered porphyritic pyroxene-bearing granitoids.

Geological Survey of Finland (GSF) measured existing magnetic data in 2002 [4]. The flight altitude was 32m, flight directions N-S and line separation 200m. At the impact site amplitudes range between 50600nT and 51400nT, in center of the shatter cone area intensity value is 50950nT. Higher amplitudes are connected to metavolcanic basement. Regional aeromagnetic data from an airborne survey show no obvious magnetic anomalies related to the structure. Airborne

magnetic data show some ring structures east from shatter cone area and negative gravity anomaly and also there are positive anomalies that occupy inside the shatter cone region. It is known that the magnetic features in complex crater are complicated. Also deep erosion level of the structure may have weakened original magnetic features.

A detailed seismic survey has not been undertaken but there are three seismic profiles (SVEKA, FENNIA, FIRE) closely pass the structure and in which FENNIA and FIRE could be useful. Published data from FIRE 2 line does not give detailed image of the surface region enough to see any details of the structure [5]. Approximately 5 km long section of FIRE 2 line is inside the shatter cone area. There is one observed outcrop with shatter cone like features on the line. The line is about 6 km from the center of the structure at its closes point and it does not give good profile of the structure.

**Petrophysics:** Petrophysical data were taken at 2004 and 2006. Density and susceptibility was measured on 35 samples of shatter cone rocks. The collected rocks were typical basement rocks from the area that consist shatter cones: granites, metavulcanites, diorites and micagneisses. Densities were between 2500g/m$^3$ - 2680g/m$^3$ in granitoids and micagneisses were denser, 2750-2920g/m$^3$. Susceptibilities were rather low in all measured shatter cone rocks; they varied between 90-1560 x10$^{-6}$ SI. Fractured shatter cone samples did not show major changes in density or susceptibilities. Rocks petrophysical properties should be compared with the distance from the impact site centre.

**Conclusions:** Mapping of Keurusselkä shatter cones revealed that impact related features spread at least over 14 km wide area. This makes Keurusselkä the second largest impact crater after Lappajärvi known in Finland. The size of Keurusselkä structure suggests that the original, now deeply eroded crater was a complex impact crater with a central uplift.

**References:** [1] Hietala S. and Moilanen J. (2004) *LPS XXXV,* Abstract #1619. [2] Hietala S. and Moilanen J. (2004), Tähdet ja avaruus 1/2004, 24 - 29 (in Finnish). [3] Ruotsalainen et. al. (2006) Lithosphere 2006, 163 - 167, GSF. [4] Aeromagnetic map. 2002. Keurusselkä 2232-10. 1:20 000. GSF. [5] Kukkonen et. al. (2006), Special paper 43, GSF.

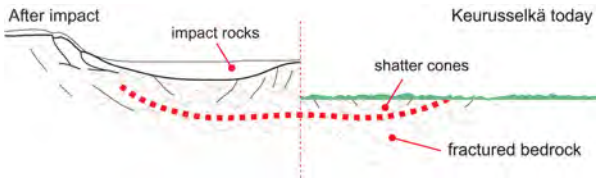


**Fig. 1:** Keurusselkä structure before and now. Present day erosion level is below the original crater floor.

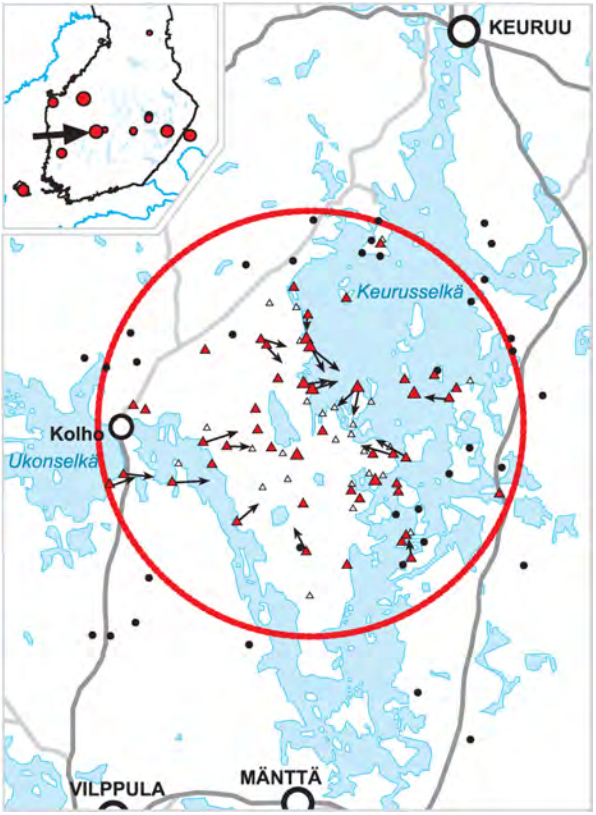


**Fig. 2:** Keurusselkä impact structure. Red circle is 14 km wide. Red triangles = in situ shatter cones. White triangles = shatter cone boulders. Black dots = outcrops, no shatter cones. Arrows = direction of shatter cones.

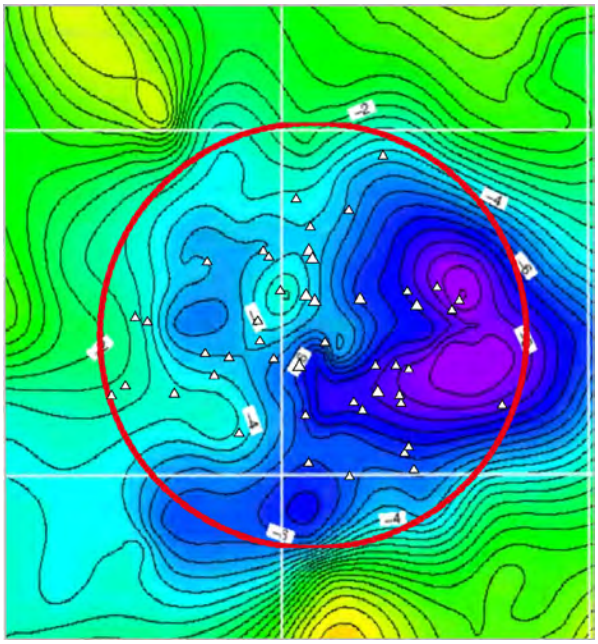

**Fig. 3:** Gravity map of Keurusselkä. Red circle is the same as in map above. White triangles are in situ shatter cones. Gravity map © FGI.