The Keurusselkä Meteorite Impact Structure, Central Finland: Geophysical Data

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Abstract

A new meteorite impact structure "Keurusselkä" was discovered in Central Finland in 2003 by S. Hietala and J. Moilanen (Hietala and Moilanen, 2004a, 2004b). The discovery was based on shatter cone findings in a circular area of some 10 km in diameter between the village of Kolho and the western shore of the lake Keurusselkä. Traces of remnants of topographic rings are visible in digital elevation data: the diameters of these rings vary from 10 km to ca. 30 km. The lake Keurusselkä has several open lake areas east from the shatter cone findings. The deepest bathymetry (32-35 m) is in the central part of the lake but it does not have any direct connection to the structure, nor to the geophysical anomalies described below. The sparse Bouguer gravity data delineate a low of 7 mGal. However, in the area there are other negative gravity anomalies nearby. Airborne magnetic data show a striking ring anomaly of ca. 10 km of diameter slightly east from the Bouguer anomaly. Airborne radiometric and electromagnetic data do not reveal any specific anomalies in the area.

1. INTRODUCTION

The current database of terrestrial impacts reveal some 175 structures with various ages and diameters (e.g., Pesonen et al., 1999). The latest "Nordic" discovery is the Keurusselkä impact structure in 2003 (Hietala and Moilanen, 2004a, 2004b). Since impact structures are characterized by distinct geophysical anomalies (e.g., gravity low, weak magnetic relief, dipping seismic reflectors, etc) we decided to look whether this structure has observable geophysical signatures (Pesonen et al., 2004).

2. LOCATION AND CONFIRMATION OF AN IMPACT ORIGIN

The structure (centred at 24° 36' E and 62° 08' N) is located in Central Finland, 220 km north from Helsinki and 60 km west from Jyväskylä. The structure lies on a broad land area that divides the lake Keurusselkä into two narrow waterways (Fig. 1a). The structure covers at least a 9.5 km wide round area but it may have been originally much larger. The target rocks are Paleoproterozoic granites and mica schists with minor volcanic inliers. In situ and bouldered shatter cones were found at more than 40 places (Fig. 1b). They were observed in porphyritic granites, metamorphic rocks such as gneisses and granodiorites, and in meta-volcanic rocks. However, shatter cone locations are restricted inside a 12 km wide area. In many places they are well developed and it is easy to make difference between them and tectonic deformation surfaces. Orientations of measured shatter cone features point roughly to the centre of the structure.

Analysis of thin sections by optical microscope revealed shock features in one granitic breccia boulder. These include planar fractures (PFs) and planar deformation features (PDFs). Closely spaced PDFs in quartz grains occur in 1 to 3 sets and they are distinctive. High magnification reveals that PDFs are partially decorated, e.g. arrays of fluid inclusions in lamellae are visible. Quartz veins in the breccia specimen are recrystallized and it also appears that the sample is altered, which could be a result of post impact hydrothermal activity (Hietala and Moilanen, 2004a).

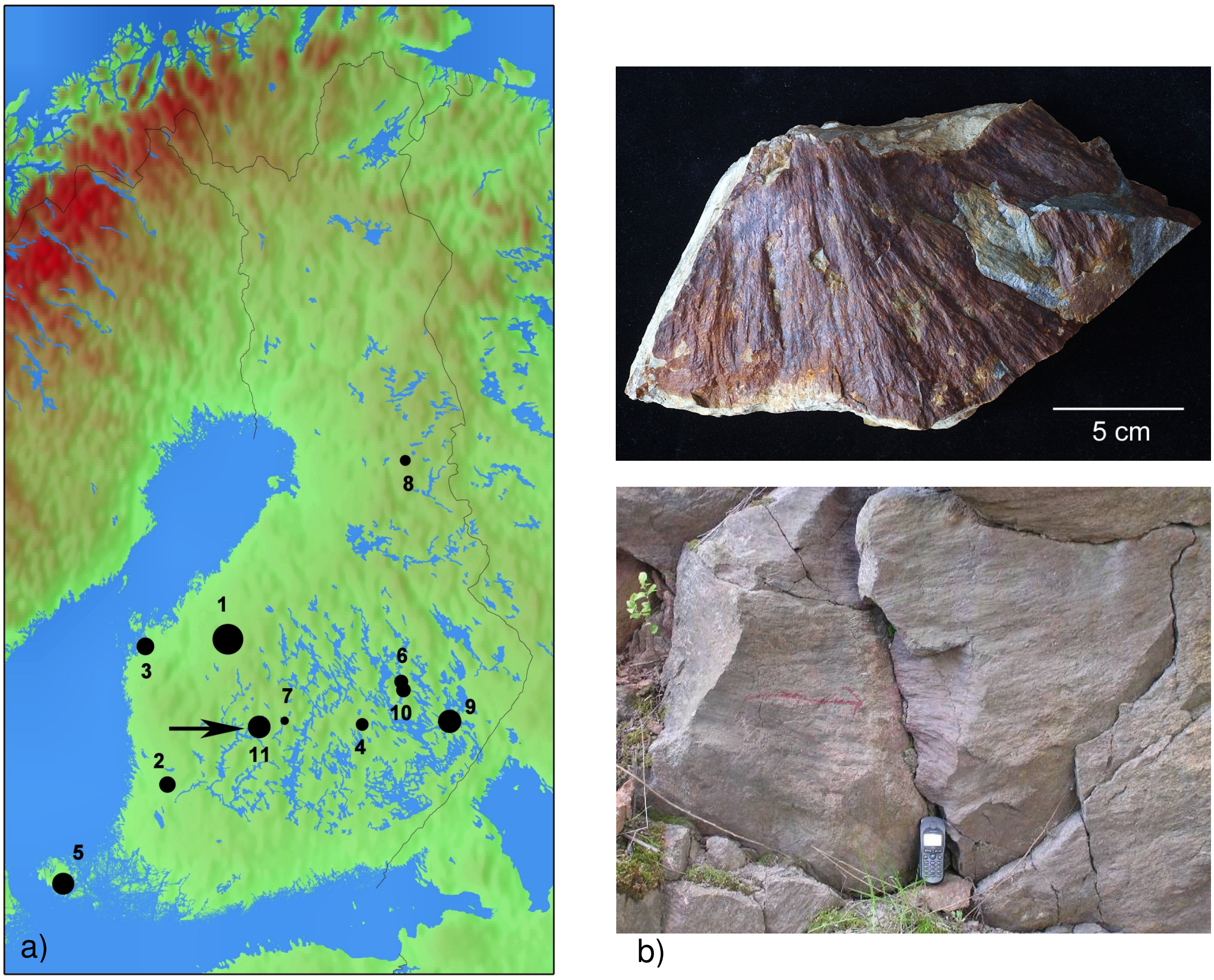


Figure 1. (a) The eleven confirmed impact structures in Finland. Keurusselkä is No.11. Other structures are: 1 Lappajärvi, 2. Sääksjärvi, 3. Söderfjärden, 4. Iso-Naakkima, 5. Lumparn, 6. Suvasvesi N, 7. Karikkoselkä, 8. Saarijärvi, 9. Paasselkä, 10. Suvasvesi S.
(b) Examples of shatter cones from Keurusselkä area. Shatter cones in a small-grained volcanic boulder, found from the central crater (top), and *in-situ* rock shatter cones near the village of Kolho (below). (Photos J. Moilanen and T. Kohout)

3. GEOPHYSICS, TOPOGRAPHY AND BATHYMETRY

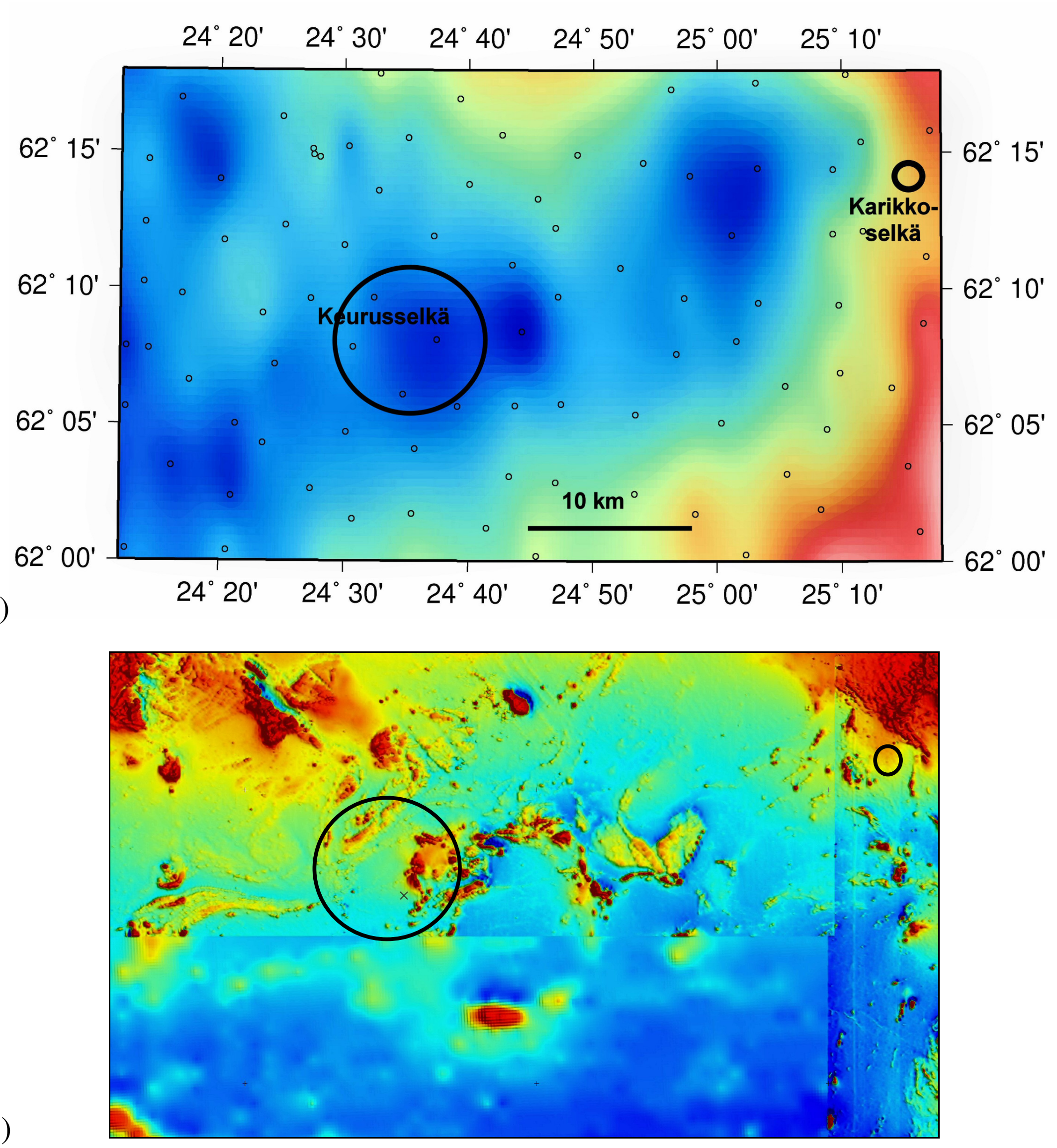
The structure is not occupied by a lake as most of known impact craters in Finland. No distinct topographical depression, crater rim or central uplift is to be seen. However, some weak traces of remnants of topographic ring-like structures are visible in digital elevation data: the diameters of these rings vary from 10 km to ca. 30 km. The lake Keurusselkä is 27 km long with several open lake areas east from the shatter cone area. The deepest bathymetry (32-35 m) is in the central to northeastern part of the lake but it does not have any direct link to the structure, nor to the geophysical anomalies (see below).

Gravity. Impact craters are generally associated with a circular gravity low (Plado et al., 1999). The gravity lows are due to lower densities caused by impact fracturing. The gravity low is often associated by a gravity high caused by central uplift of denser rocks There are no detailed gravity surveys done in Keuruu area and therefore we had to rely on the National Gravity Grid of the Geodetic Institute, where the density of data is one per every 5 kilometers. Theoretically an uneroded impact structure of the Keurusselkä size (D ca. 10 km) should have a gravity low of 10-15 mGal (Pilkington and Grieve, 1991) as is the case, for example, with the young Lappajärvi impact structure (D 23 km, Abels et al., 2001). The sparse Bouguer data (Fig. 2a) delineates a negative, ca. 7 mGal gravity anomaly. However, in the area there are also other negative anomalies, for example one located some 20 km NE from Keurusselkä. The new geological map (by Mikko Nironen, GSF), for example, shows that on the western shore of the lake there are felsic rocks with lower densities which can contribute to the gravity minimum. However, these formations are not circular and do not restrict to Keurusselkä structure, but occur numerously in Central Finland.

Magnetics. The combined low-altitude and high-altitude airborne magnetic data (Fig. 2b) reveal a striking ring anomaly of ca. 10 km of diameter. This anomaly consists of positive anomaly patches surrounding the weak negative central anomaly. The magnetic ring is slightly east from the Bouguer anomaly and also east of the structure defined by shatter cones. We note here that magnetic ring anomalies with a weak central relief are typical to impact structures but in the same time, there are also similar type magnetic anomalies nearby of which not all are related to impacts. It is possible that the magnetic ring is assocated with a granitic intrusion or magnetite or sulphide occurrences rather than to an impact structure.

Other geophysical data. Airborne radiometric and electromagnetic data do not reveal any specific anomalies in the area (see also Chapter Discussion and Conclusions).

Age. The age of the Keurusselkä structure is undefined. Since shatter cones seems to be present in all Palaeoproterozoic (1.88 Ga) rock types of the region, the maximum age of the structure must be younger than ~1.88 Ga. However, related to the Svecofennian acretion and formations of island arcs in the Central Finland, somewhat younger (1.83-1.7 Ga) rocks and associated ductile to semiductile faults and fractures are are also present. Morphological and field relationships show that the structure represent deeply eroded remains of large complex impact structure which present day erosion level is below the original crater floor. At this point it is impossible to say for sure is the ca. 10 km structure an eroded bottom of the crater or just an eroded root of the central uplift. In latter case, some traces of original impact structure would be found in much wider area. It seems also possible that the structure has gone through tectonic modification as evideneced by hydrothermal feauteres, mylonizations etc.



a)
b)

Figure. 2. (a) Bouguer gravity and (b) airborne magnetic map of the Keurusselkä area (for details, see Pesonen et al., 2004 and references therein). Small dots in (a) are places with gravity measurements. The circle denotes the area where shatter cones have been found. Karikkoselkä impact structure (D ~ 2.5 km) is shown in upper right corner. (Aeromagnetic map, courtesy Hanna Leväniemi, Geologial Survey of Finland.)

4. CONCLUSIONS AND DISCUSSION

Although the Keurusselkä structure has distinct geophysical anomalies associated, they appear, somewhat east from the area covered by shatter cones. To better constrain the location of the structure more gravity data will be collected. We will also look the seismic FIRE-transect data to see if the eastern margin of the impact structure will show up in seismic reflection data.

Petrophysical properties of the rocks will be measured to check if they show evidences of fracturing due to shock. Tentative petrophysical results show evidences of density decrease probably due to fractal jointings in the rocks within the central area. We will also study the available deep drill core samples from mining wells in order to isolate possible shock features. More impact rocks will be searched in the area to further confirm the recent discoveries of monomict and polymict lithic breccias by one of us (SH) in the central part of the area. Finally, using paleomagnetic techniques we try to date the Keurusselkä impact event.

REFERENCES

Abels, A., Plado J., Pesonen, L.J., Lehtinen, M., 2002. The Impact Cratering Record of Fennoscandia. Pp 1-58 *in* Plado, J., Pesonen, L.J. (Eds.), *Impacts in Precambrian Shields*, Springer Verlag, Berlin. 336 pp.

Hietala, S., Moilanen, J., 2004a. XXVI LPSI, Houston, Texas. CD-ROM.

Hietala, S., Moilanen, J., 2004b. Keurusselkä on muinainen osuma. *Tähdet ja avaruus* **1/2004**, 24-29. (in Finnish)

Pesonen, L.J., Elo, S., Lehtinen, M., Jokinen, T., Puranen, R., Kivekäs, L., 1999. Lake Karikkoselkä impact structure, central Finland: New geophysical and petrographic results. Pp 131-139 *in* Dressler, B.O., Sharpton, V.L. (Eds.), *Large Meteorite Impacts and Planetary Evolution II. Geological Society of America, Special Paper* **339**. 464 pp.

Pesonen, L.J., Poutanen, M., Ruotsalainen, H., 2004. Lisähavaintoja Keurusselän kraatterista. *Tähdet ja Avaruus* **3/2004**, 29-30. (in Finnish)

Plado, J., Pesonen, L.J., and Puura, V., 1999. Effect of erosion on gravity and magnetic signatures of complex impact structures: Geophysical modeling and applications. Pp. 229-239 *in* Dressler, B.O., Sharpton, V.L. (Eds.), *Large Meteorite Impacts and Planetary Evolution II. Geological Society of America, Special Paper* **339**. 464 pp.

Pilkington, M., Grieve, R.A.F., 1992. The geophysical signature of terrestrial impact craters. *Reviews of Geophysics* **30**, 161-181.