New sites of proposed postglacial fault scarps in central Finland

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Over the past ten years, digital elevation modeling (DEM) based on LiDAR (Light Detection and Ranging) technology has proved to be a significant advance in geomorphic studies (e.g. Johnson *et al.* 2015, Palmu and Nenonen 2015). Digital LiDAR DEMs are high-resolution elevation models with 2 m by 2 m grid cells and ~ 0.3 m vertical resolution. The airborne LiDAR is particularly useful in densely forested areas, because the LiDAR technology allows vegetation cover to be filtered out and subtle topographic features can be mapped beneath the forest canopy. Among other things, the LIDAR technology has provided great benefits for the study of postglacial faulting (PGF).

To date, besides showing known postglacial fault scarps and paleo-landslides from northern Fennoscandia in greater detail, the LiDAR DEMs have revealed many new sites of proposed PGF scarps and landslides (e.g. Sutinen *et al.* 2014, Bauer *et al.* 2016; Fig. 1). Interestingly, some of these new findings come from central and south-central Fennoscandia (Smith *et al.* 2014, Berglund and Dahlström 2015, Mikko *et al.* 2015, Palmu *et al.* 2015a,b, Olesen 2016, Ruskeeniemi *et al.* 2017). Sutinen *et al.* (2014) have suggested that based on LiDAR DEMs, a hundred or so 1–2 m offset faults remain to be found solely in northern Finland. Moreover, many smaller, centimetre-scale offsets clearly exist but are too small to be seen even in LiDAR DEMs. In situations with no Quaternary overburden there are, even with LiDAR techniques, few means to identify (and to date) movements along the abundant bedrock scarps (Berglund and Dahlström 2015).

With the aid of LiDAR techniques, the present author has detected several PGF candidates in central Finland. Two of the PGF candidates belong, in the author's view, to the class A (almost certainly neotectonics; see Olesen *et al.* 2000). These candidates are Kuhasenmäki in Joutsa, Central Finland, and Rapa-Ryysä in Polvijärvi, North Karelia (Fig. 1). These PGFs are 2–3 km long surface ruptures striking approximately in the NE–SW direction (Figs 2 and 3). They both appear on a drumlinized till plain in supra-aquatic area. Their scarp height is less than 0.5 m and they are quite hard to detect in LiDAR DEMs. They represent reactivated thrust (or reverse) faults dipping in the SE direction. They are associated with bedrock lithological contacts and/or ancient fault lines (see http://gtkdata.gtk.fi/Maankamara/index.html). In Polvijärvi, the strike and dip of foliation in the local bedrock coincide with those of the Rapa-Ryysä

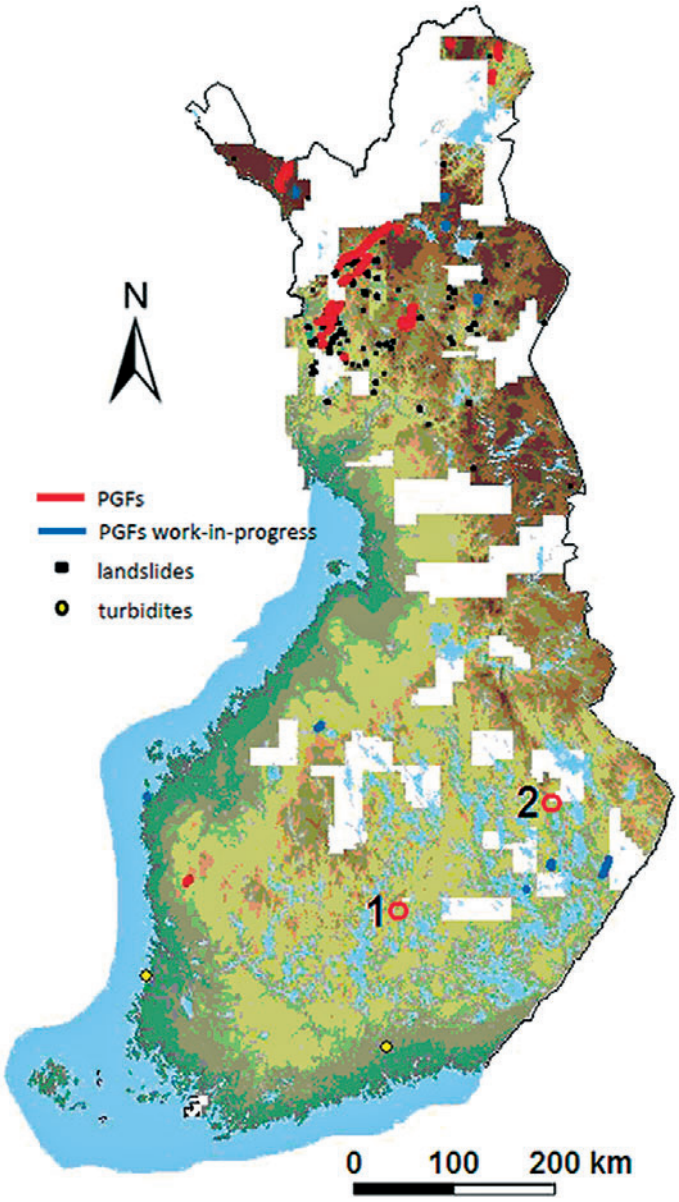

Figure 1. Topographic map showing PGFs and PGF candidates, paleo-landslides and other morphological features of Quaternary deposits possibly related to late- and postglacial seismic activity in Finland (white areas not screened using LiDAR-based elevation models; Ruskeeniemi et al. 2017). New sites of proposed PGFs are added in the map: (1) Kuhasenmäki, Joutsa (6866228, 454930 ETRS-TM35FIN), (2) Rapa-Ryysä, Polvijärvi (6976036, 611464 ETRS-TM35FIN).

Kuva 1. Postglasiaalisiirrokset ja -siirrosehdokkaat (PGF), maanvyörymät ja muut häiriöt kvartäärisedimenteissä, jotka mahdollisesti liittyvät myöhäis- ja postglasiaaliajan seismiseen aktiivisuuteen Suomessa (valkoisilta alueilta ei ole ollut käytettävissä LiDAR-korkeusmalleja; Ruskeeniemi et al. 2017). Kuvaan on merkitty myös uudet todennäköiset PGF-siirrokset: (1) Kuhasenmäki, Joutsa (6866228, 454930 ETRS-TM35FIN), (2) Rapa-Ryysä, Polvijärvi (6976036, 611464 ETRS-TM35FIN).

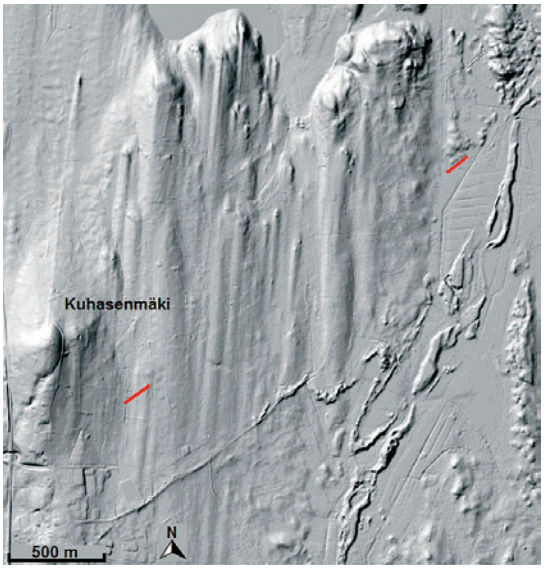

Figure 2. Kuhasenmäki postglacial fault near Leivonmäki village centre in the municipality of Joutsa, Central Finland. LiDAR DEM model adopted from https://kartta.paikkatietoikkuna.fi/?lang=fi.

Kuva 2. Kuhasenmäen postglasiaalisiirros Leivonmäen kirkonkylän kupeessa Joutsassa Keski-Suomessa. LiDAR-korkeusmalli: Paikkatietoikkuna https://kartta.paikkatietoikkuna.fi/?lang=fi.

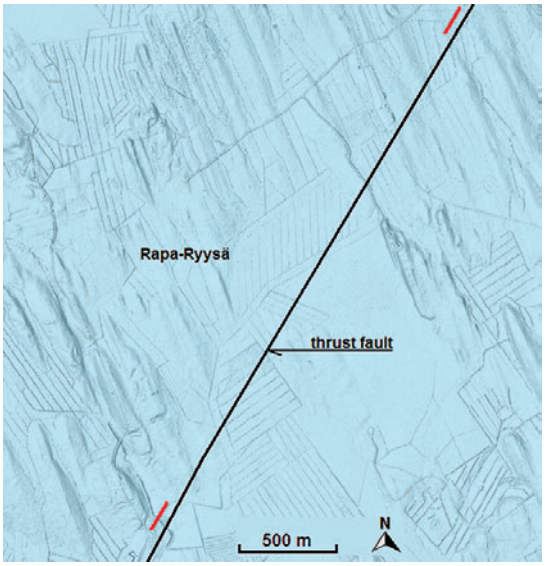

Figure 3. Rapa-Ryysä postglacial fault in Polvijärvi, North Karelia, following an ancient thrust fault line interpreted from geophysical data sets. The rock type is biotite paraschist. LiDAR DEM model and bedrock information adapted from http://gtkdata.gtk.fi/Maankamara/index.html.

Kuva 3. Rapa-Ryysän postglasiaalisiirros ja vanha geofysikaalisesta aineistosta tulkittu työntösiirroslinja Polvijärvellä Pohjois-Karjalassa. Kallioperä on biotiittiparaliusketta. LiDAR-korkeusmalli ja kallioperätiedot: Maankamara http://gtkdata.gtk.fi/Maankamara/index.html.

PGF (Gaál et al. 1975 and their Map 5). On the basis of their dimensions (surface rupture length, scarp height) it is plausible that these PGF faults were reactivated in single M 4.5–5.5 earthquake events (e.g. Wells and Coppersmith 1994).

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Tiivistelmä:

Uusia postglasiaalisiirroksia löydetty keskisestä Suomesta

Laserkeilaukseen perustuvaa maaston korkeusmallia (engl. LiDAR DEM) voidaan hyödyntää monenlaisissa geomorfologisissa tutkimuksissa. Eräänä tutkimuskohteena ovat kallioperän nuoret siirrokset, jotka kertovat myöhäis- ja postglasiaaliajan seismisestä aktiivisuudesta. Uusia siirroksia on laserkeilauksen avulla löydetty Pohjois-Fennoskandian lisäksi myös aikaisempaa etelämpää. Tässä artikkelissa kuvataan kaksi keskisestä Suomesta löydettyä nuorta siirrosta, Kuhasenmäki Joutsasta ja Rapa-Ryysä Polvijärveltä. Ne ovat 2–3 km pitkiä ja alle 0,5 m korkeita siirroksia, jotka erottuvat korkeusmalleissa heikkoina lounais-koillissuuntaisina linjoina. Ne edustavat kaakkoon kaatuvia uudelleen aktivoituneita työntösiirroksia, jotka liittyvät kallioperän kivilajikontakteihin ja/tai vanhoihin liikuntosaumoihin. Mittasuhteiden perusteella niiden voidaan arvioida syntyneen yksittäisissä, suuruusluokan M 4,5–5,5 maanjäristyksissä.

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