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LiDAR-based geomorphological mapping and Quaternary stratigraphy in the Sodankylä region, northern Finland

Introduction

Geomorphological mapping based on an aerial LiDAR-derived digital elevation model, field observations, ground penetrating radar measurements and test pit surveys was carried out in a glaciogenic environment in Sodankylä, central Finnish Lapland (Sarala et al. 2015). The mapping area covered about 370 km^2, with the LiDAR data having a pixel size of 2m x 2m and vertical resolution 0.3 m. The geomorphology of the area consists of large till-covered hills, ground moraine plains, glaciofluvial sand and gravel deposits composed of esker systems and related delta and outwash formations of the Weichselian cold stages, followed by proglacial glaciolacustric and post-glacial lacustric and fluvial sand/silt deposits. Furthermore, large areas in topographical depressions are covered by Holocene mires.

Methods

The new mapping process included preliminary interpretation based on the use of LiDAR data and revision of earlier Quaternary maps and reports. The geomorphological interpretation process was supported by the pre-existing soil and peat drilling data, geochemical mapping data, stratigraphical observations (mainly from the test pits), bedrock outcrop observations and topographical map databases. Based on the preliminary interpretation, several field observation targets and stratigraphical study points were selected. For the stratigraphical work, both ground penetrating radar (GPR) and excavator test pits were employed.

Samples for age determinations were collected from the till-covered, stratified sand layers of the two test pits. Sample preparation and optical stimulated luminescence (OSL) measurements were carried out at the Helsinki University, the Laboratory of Chronology, Finland.

Results

The study proved that the benefit of LiDAR data compared with traditional interpretation methods was in more detailed identification of surface deposits particularly in densely forested areas. This is an advantage, for example, in the case of till-covered stratified sand and gravel deposits, and in shallow till areas where the LiDAR interpretation provides more precise edging of the morphologies. As an example, based on the LiDAR mapping it was possible to distinguish several till-covered delta and sandur deposits which based on OSL dating date back to the Early Weichselian stadial (74-89 ka).

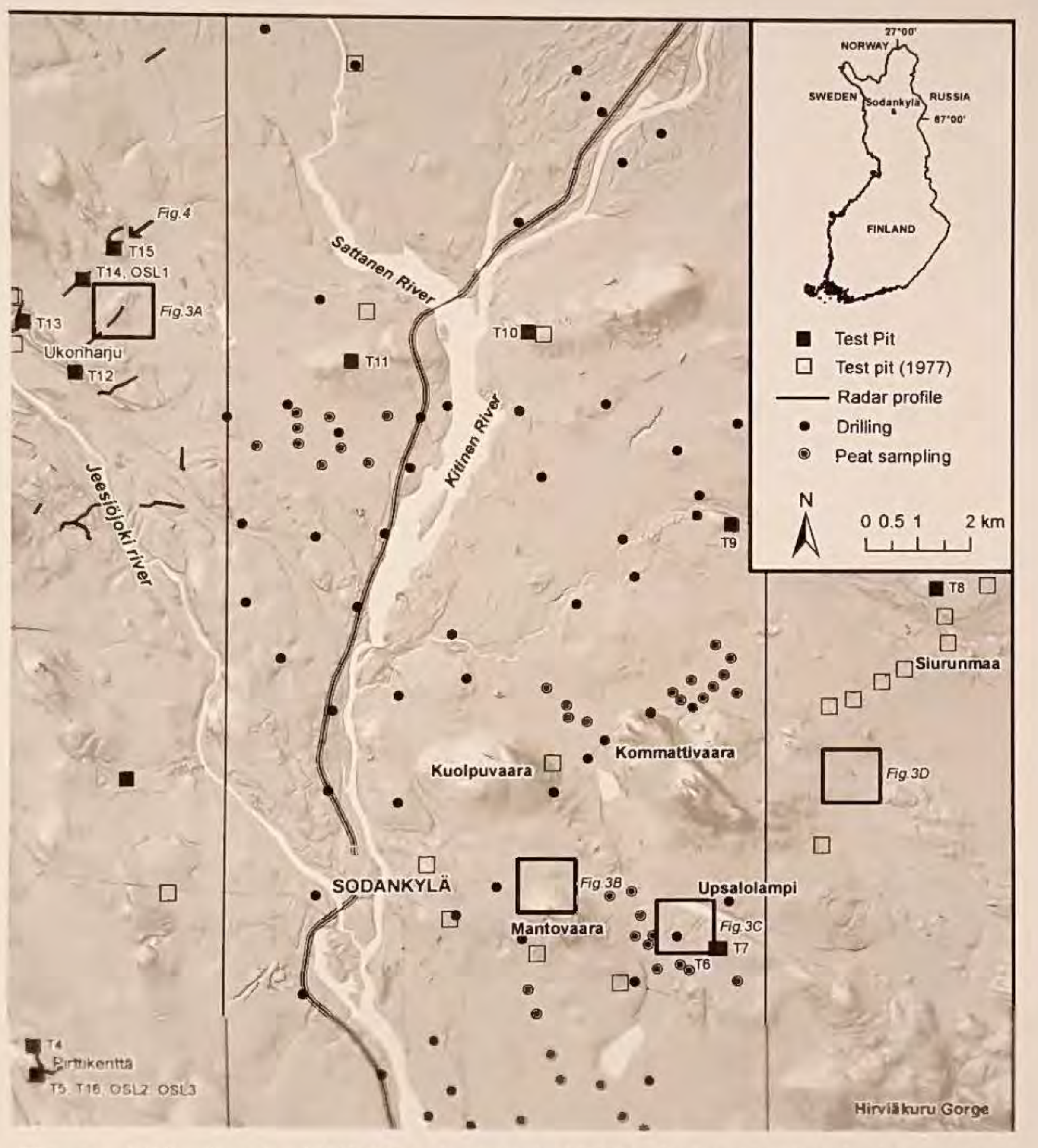

Fig. 1. Hill-shaded LiDAR-derived DEM of the Sodankylä region in central Finnish Lapland and the location of the study area. The sites of new and old test pits, soil drilling and peat survey points and GPR profiles are shown on the map.

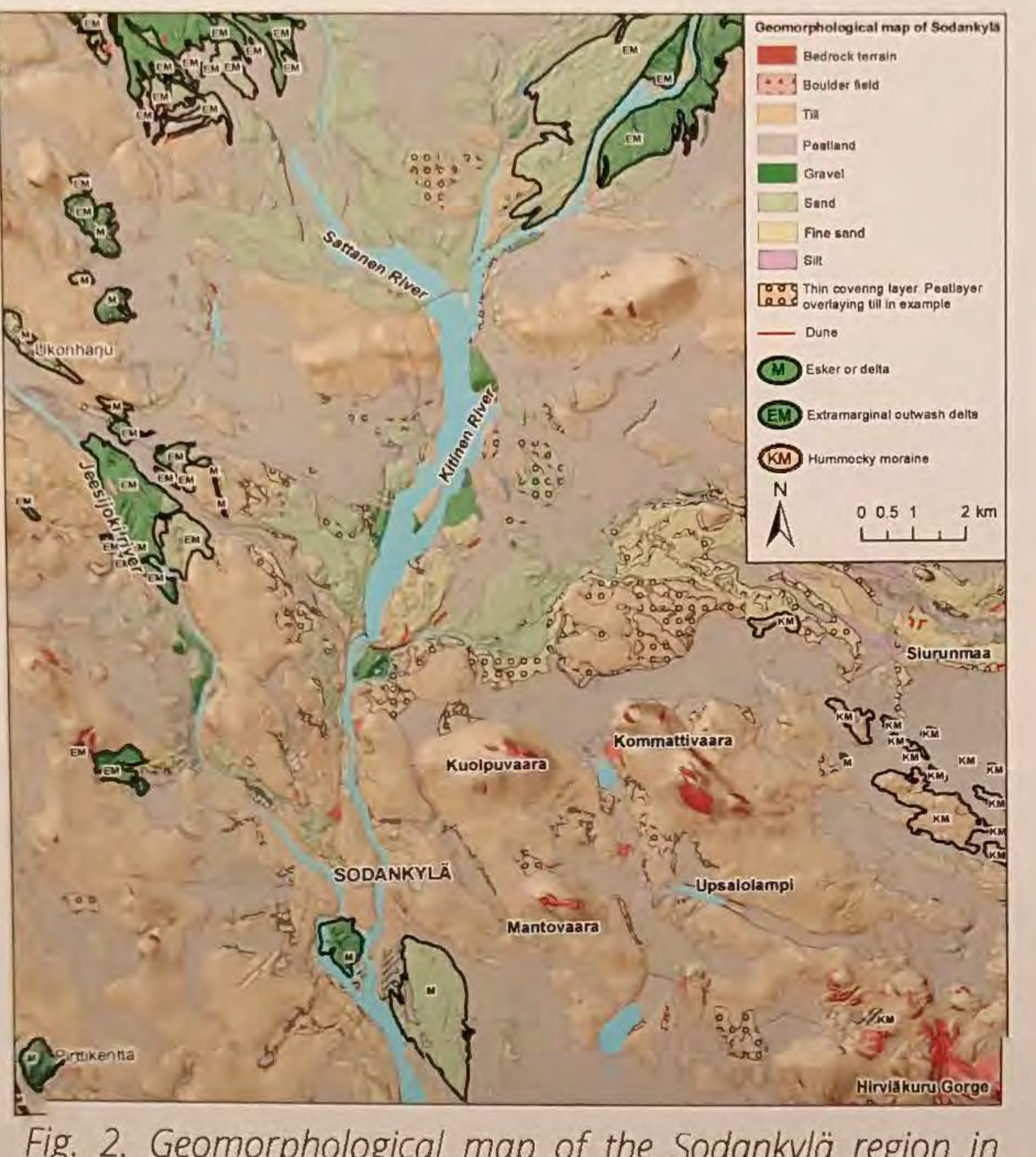

Fig. 2. Geomorphological map of the Sodankylä region in central Finnish Lapland. The hill-shaded LiDAR-derived DEM is in the background.

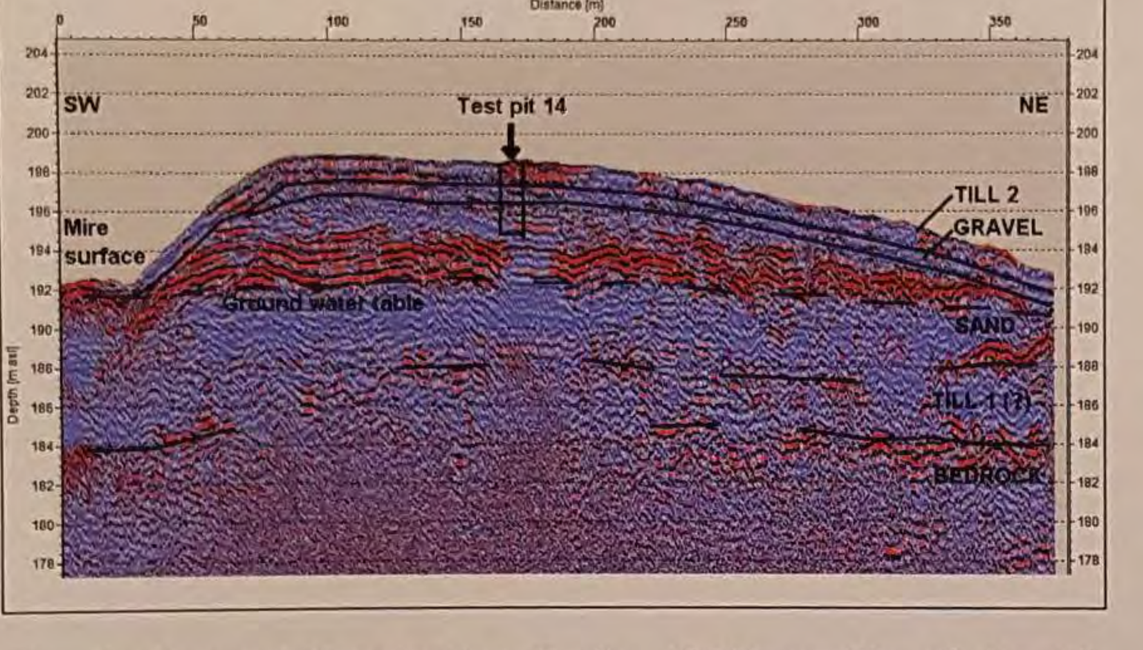

Fig. 4. Ground Penetrating Radar (GPR) profile of the till-covered delta formation on the northern side of Ukonharju.

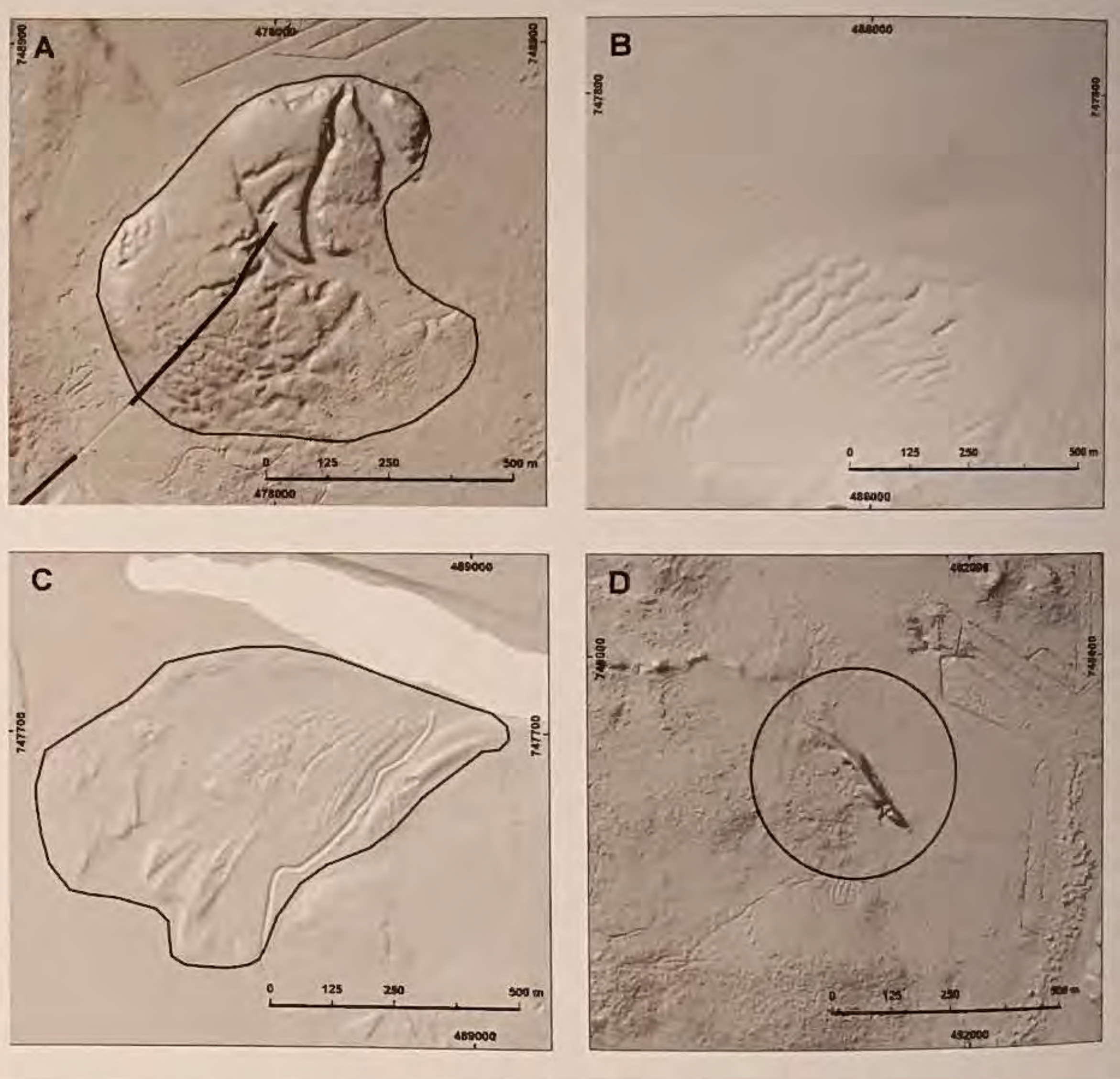

Fig. 3 A) Till-covered, stratified sand deposit interpreted as a delta formation after soil drilling observations, GPR profile marked as double line (multidirectional shading); B) lateral drainage channels on the northern slope of Mantovaara hill (hill shading); C) outwash delta on the southern side of Upsalonlampi (hill shading); D) small esker ridge in the forested mire (multidirectional shading).

Fig. 5. Interpretation of the stratigraphy A) in the test pit JPRA-2014-1 with two till units and glaciofluvial sands on the top; B) of the bottom part of till-covered, Early Weichselian deltaic sand deposit in test pit JPRA-2014-13, including till unit 1 on the bottom followed by the planar-bedded sands (SAND 1), ripple-bedded sands (SAND 2) and cross-bedded sands (SAND 3) on top (note load-cast structures in the middle of the photo), OSL sample 1 was taken from the ripple-bedded sand; and C) bottom part of the glaciotectonised (faulted), Early-Weichselian sandur deposit with the graded-bedded sand-gravel layers at Pirttikenttä, where the sampling points of OSL2 (upper) and OSL3 are also shown.

Photos Pertti Sarala.

Reference

Sarala, P., Räisänen, J., Johansson, P. & Eskola, K.O. Aerial LiDAR analysis in geomorphological mapping and geochronological determination of surficial deposits in the Sodankylä region, northern Finland. GFF. (Published online 29.10.2015). DOI: 1080/11035897.2015.1100213.

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Sutinen, R., 2005. Timing of early Holocene landslides in Kittilä, Finnish Lapland. Geological Survey of Finland, Special Paper 40, 53-58.

Sutinen, R., Hyvönen, E. and Kukkonen, I., 2014. LiDAR detection of paleolandslides in the vicinity of the Suasselkä post-glacial fault, Finnish Lapland. International Journal of Applied Earth Observation and Geoinformation 27, 91–99.

ORAL

LiDAR-based interpretation of deglacial dynamics in SW Finland

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The aim of the research was to develop a proper working procedure for LiDAR data interpretation over large deglaciated areas and to promote the understanding of ice stream dynamics and related ice-marginal behavior of the Scandinavian Ice Sheet, especially in SW Finland. The detailed dynamic behavior of the ice streams is still poorly understood, but now the ALS-based high-resolution LiDAR (Light Detection And Ranging) data will facilitate the mapping of glacial landsystems (a holistic approach of terrain evaluation). It enables more accurate and uniform landform analysis over wide areas than with traditional geomorphological techniques and other methods of remote sensing. Like all remote sensing methods, LiDAR interpretations are also dependent on ground control, but the needed field work is much more focused and minimal.

The study area exhibits the withdrawal of the Scandinavian ice sheet from the II and III Salpausselkä ice-marginal complexes in SW Finland, recording the end of the relatively cold Younger Dryas period. A detailed picture of deglaciation and related ice-marginal depositional patterns, ice flow indicators, and hydrological changes depicted by esker patterns has been established for the deglacial Loimaa and Vanajavesi sublobes on the eastern part of the Baltic Sea ice stream. New landform features or assemblages supplemented with field observations have been mapped for the area.

The overall results support the usefulness of glacial landsystem approach even for deglacial environments with varying maturity of landsystem development. Moreover, the results explain the complex behaviour and ice flow patterns at the NE end of the III Salpausselkä affected by the deglacial activity of the Vanajavesi sublobe or ice flow corridor that best describes the landsystem development within the area. Fast deglacial changes in ice flow and landform patterns were affected by subtle changes in bed topography, proglacial water depths as well as changes in hydrological regime of the ice. We also suggest the presence of large subglacial lake and related outburst route within Urjala-Toijala area.

POSTER

LiDAR-based geomorphological mapping and Quaternary stratigraphy in the Sodankylä region, northern Finland

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The high resolution of LiDAR-derived Digital Elevation Models (DEMs) has improved the mapping process by clarifying interpretation of densely forested areas and allowing the identification of fine-scale land surface features not originally distinguished in the aerial photos and in the field. Such geomorphologies include low-relief features on top of moraine hills. The Geological Survey of Finland (GTK) carried out geomorphological mapping in 2013-2014 in the Sodankylä region of northern Finland. The mapping process was supported by the Quaternary stratigraphical and geochronological works.

Geomorphological mapping was based on an aerial LiDAR analysis supported by field observations, ground penetrating radar measurements and test pit surveys in a glaciogenic environment. The mapping area covered about 370 km^2, with the LiDAR data having a pixel size of 2 m x 2 m and vertical resolution 0.3 m. The geomorphology of the area consists of large till-covered hills, ground moraine plains, glaciofluvial sand and gravel deposits composed of esker systems and related delta and outwash formations of the Weichselian cold stages, followed by pro-glacial glaciolacustric and post-glacial lacustric and fluvial sand/silt deposits. Large areas in low land areas are covered by Holocene mires.

The study proved that the benefit of LiDAR data compared with traditional interpretation methods was in more detailed identification of surface deposits particularly in densely forested areas. This is an advantage, for example, in the case of till-covered stratified sand and gravel deposits, and in shallow till areas where the LiDAR interpretation provides more precise edging of the morphologies. As an example, based on the LiDAR mapping it was possible to distinguish several till-covered delta and sandur deposits which based on OSL dating date back to the Early Weichselian stadial (74-89 ka).

POSTER

Characterization of Riikonkumpu fault scarp in Kittilä

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The resent availability of high-resolution LiDAR-based digital elevation models provides an outstanding possibility to discover and map postglacial fault scarps that crosscut glacial sediments and landforms (Palmu et al. 2015). In addition to establishing their geographical distribution, direction, and height in DEM surfaces, there is also apparent need to document their stratigraphic geometries in more detail in order to understand and estimate their possible implications for seismic hazards.

The Riikonkumpu postglacial fault (PGF) scarp in Kittilä, northern Finland, was investigated with airborne LiDAR DEM, GPR, and lithostratigraphical studies of a 80 m long and 5 m deep trench excavated during the fall 2015 fieldwork. The maximum height of the PGF is 1.5-2 m and its SW-NE trending geometry can be traced about 15 km. The Riikonkumpu PGF is parallel to the Isovaara PGF (Sutinen et al., 2014) located ca. 10 km SW of the Riikonkumpu site.

The trench through glacial sediments was orientated perpendicular to the LiDAR-detected fault line and excavated to reach the surface of intensively weathered metaphyllitic bedrock. Quaternary sediments and bedrock features on the vertical sections the trench were logged and photographed to create 3D imaginary of the sedimentological details. This information was used to study and interpret the lithostratigraphical and structural features of the fault rupture in Quaternary deposits and the bedrock underneath. This paper describes results of these investigations.

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Palmu, J.-P. Ojala, A.E.K., Ruskeeniemi, T., Sutinen, R. and Mattila, J., 2015. LiDAR DEM detection and classification of postglacial faults and seismically-induced landforms in Finland: a paleoseismic database. GFF, DOI: 10.1080/11035897.2015.1068370

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POSTER

Appearance of PGFs in Finland – case Lauhavuori

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Northern Fennoscandia has experienced late- and postglacial fault (PGF) activity and high-magnitude seismicity attributable to lithospheric plate stresses and glacio-isostatic rebound. During the last decades, PGFs have been found and described in northern Fennoscandia, the first fault scarps being discovered in western Finnish Lapland in the 1960s. LiDAR-based digital elevation models (DEMs) have recently provided a new and accurate remote sensing mapping methodology for systematic screening and detection of geological and geomorphological features. It allows the rapid and low-cost mapping of late- or postglacial faults and, for instance, mapping of landslides from areas where they have not previously been recognized (Palmu et al., 2015).

In Fennoscandia, most PGFs have been found in Finnish Lapland and Norrbotten in Sweden. Recently, new potential PGF systems were discovered in Lauhavuori, western Finland (Palmu et al., 2015), and in Bollnäs, central Sweden (Mikko et al., 2015), both representing the southermost locations of PGFs in Fennoscandia.

This paper describes the preliminary findings of the proposed Lauhavuori PGF. The general geological and geomorphological description of the PGF features in this locality is given. The geomorpological features extracted from the LiDAR DEM include