



Photos by P. Sarala

Surficial geological and till geochemical exploration

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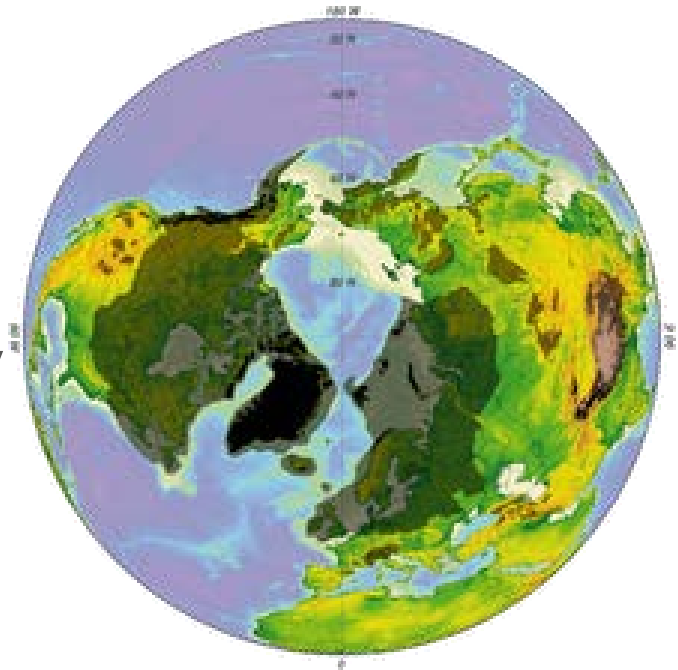
Geological Survey of Finland / Oulu Mining School

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Background

- Large areas in the Northern Hemisphere were glaciated several times during the Quaternary period
 - Glaciers eroded the bedrock surface, transported material and formed the soils and morphologies which are typical for example in Canada, NW Russia and Nordic countries
 - Surficial deposits are composed mainly of till and glaciofluvial/fluvial sand and gravel deposits



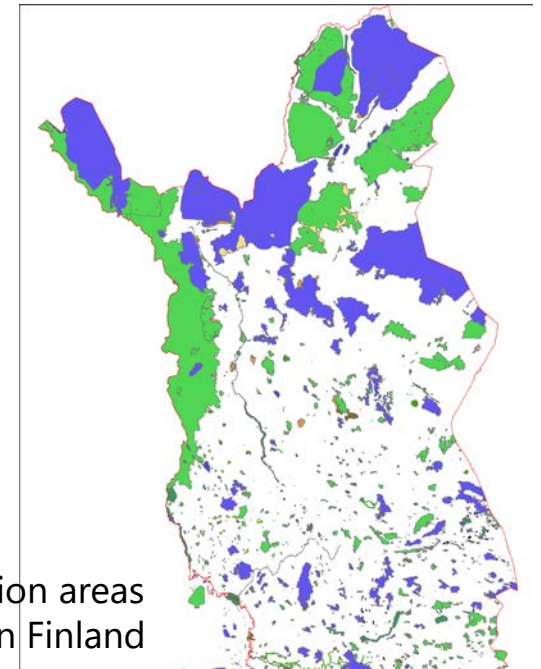
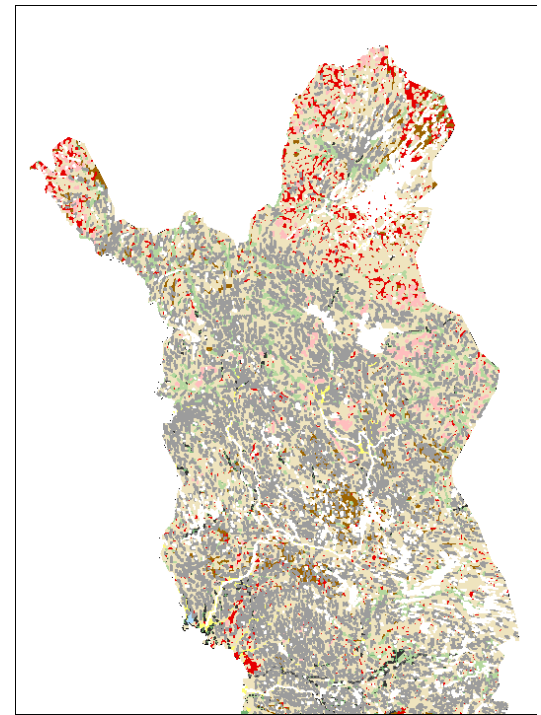
Background



- A role of surficial geology in mineral exploration and the mining project
 - Most of the indicators for mineral exploration have been found and are still found from the transported cover
 - Important particularly in glaciated terrains
 - Exploration work is relative easy and cost-effective using soils
 - Strong historical background in mineral exploration in Finland
 - Quaternary geological mapping has integrated to exploration
 - Finns have been frontiers of surface geological and till geochemical research and mapping methods
 - Finnish governments have always supported mineral exploration
 - Mining Act defines the rules for the permits in different exploration phases
 - Many possibilities to do surface geological research and soil sampling without time-consuming permit process

Background

- 97 % of land area is covered by Quaternary deposits
 - Exploration is challenging in the northern and/or Arctic regions due to complex glacial deposits, large peat bog and tundra areas as well as pre-glacial weathered bedrock in places
- Targets in surface geological and geochemical exploration have been in subsurface ore deposits
 - Focus is moving into detection of ore deposits in deeply weathered bedrock or blind in the bedrock
- Logistical problems and short summer season, large conservation areas and some political issues restrict conventional research and sampling



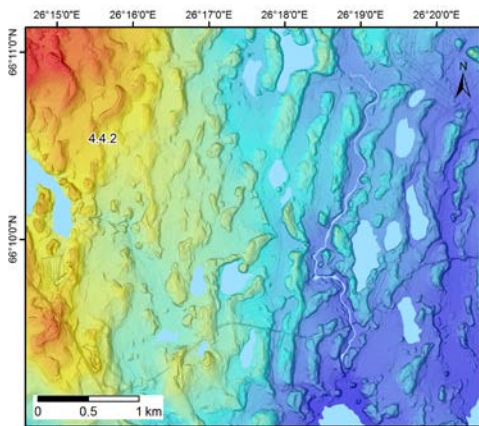
Stages of surficial mineral exploration

- Glacial dynamics and morphological interpretation
 - Estimation of glacial transportation, directions and distances
- Collection and analysis of all pre-existing data
- Surficial boulder hunting/layman samples
- Stratigraphical work with test pits or soil drilling
 - Target-scale study of different glacial deposits and till stratigraphy
- Till geochemical sampling in different scales
- Heavy/Indicator mineral studies
- Deep drilling and large sampling
- Supporting geochemical research and sampling
 - Weak/selective leach methods
 - Water and stream sediment methods
 - Biogeochemistry
 - Snow sampling
- Data analysis, interpretation of the results and reporting

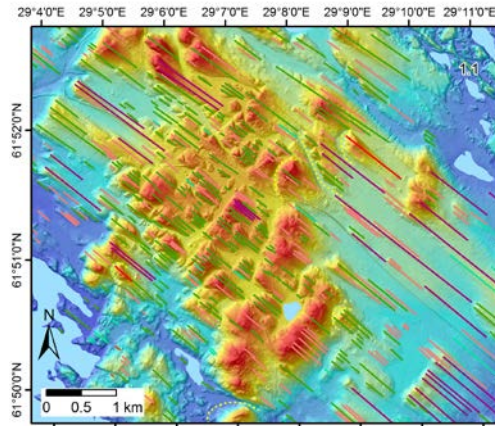


Geomorphological interpretation

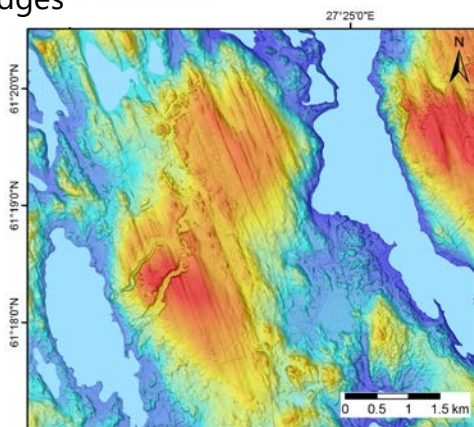
- Aerial photographs, **LiDAR**, satellite images, maps



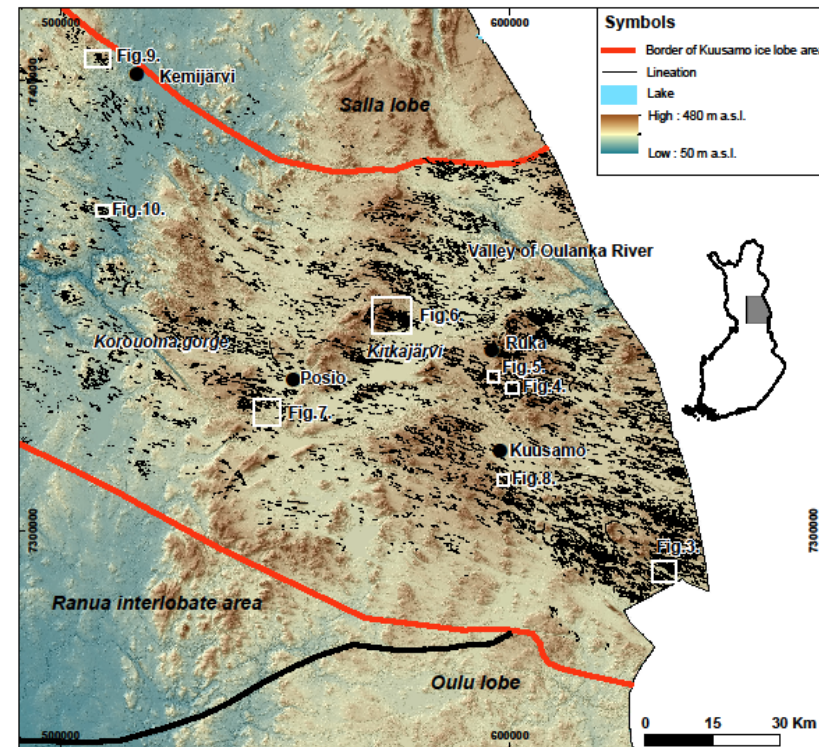
Ribbed moraine ridges



Drumlin field



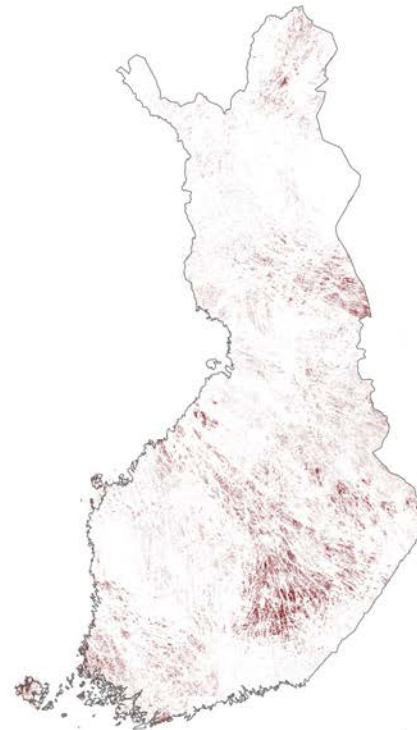
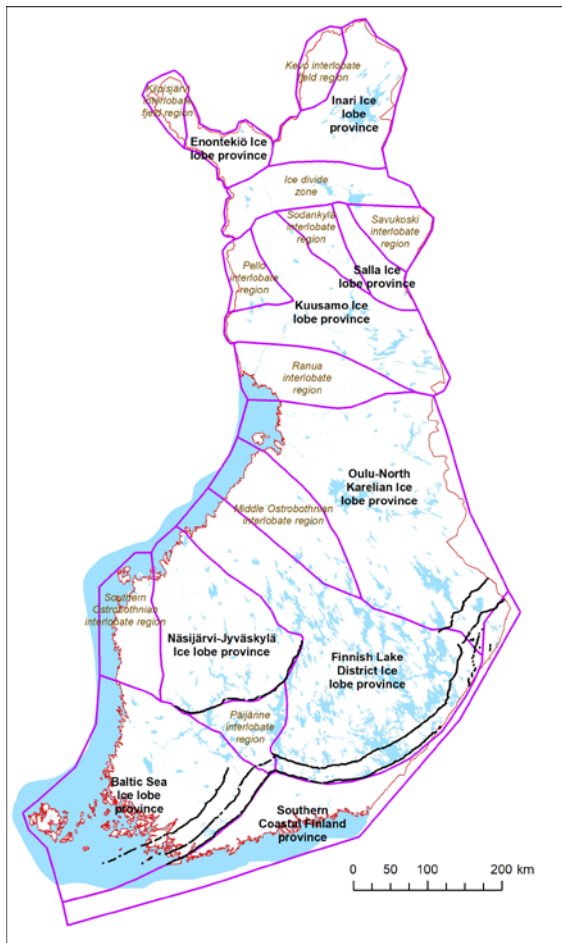
Fluted surface



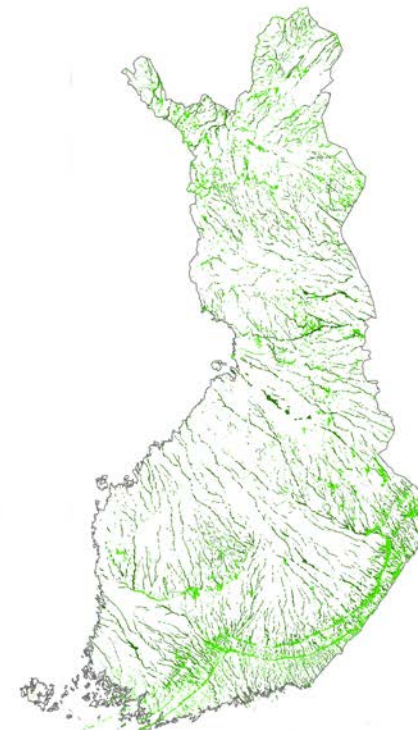
Example of lineations mapping in the Kuusamo Ice Lobe area in eastern Finland

Glacial morphology

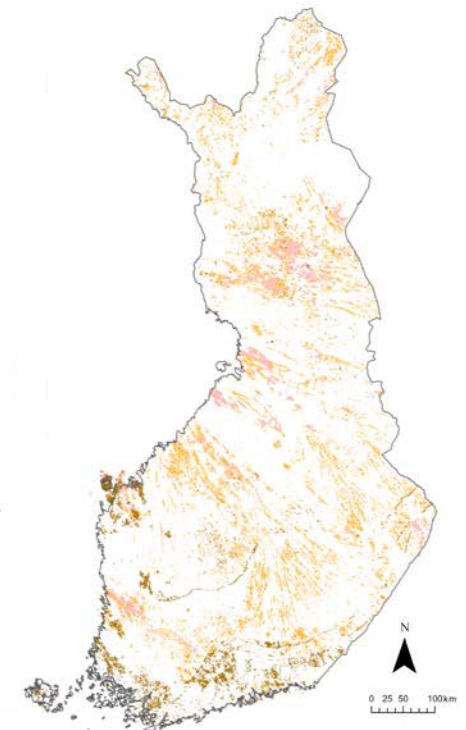
- A new LiDAR-based, nationwide database of glacial features in Finland is now available at GTK's spatial data products service:
https://hakku.gtk.fi/en/locations/search?location_id=186



Lineations



Glaciofluvial deposits

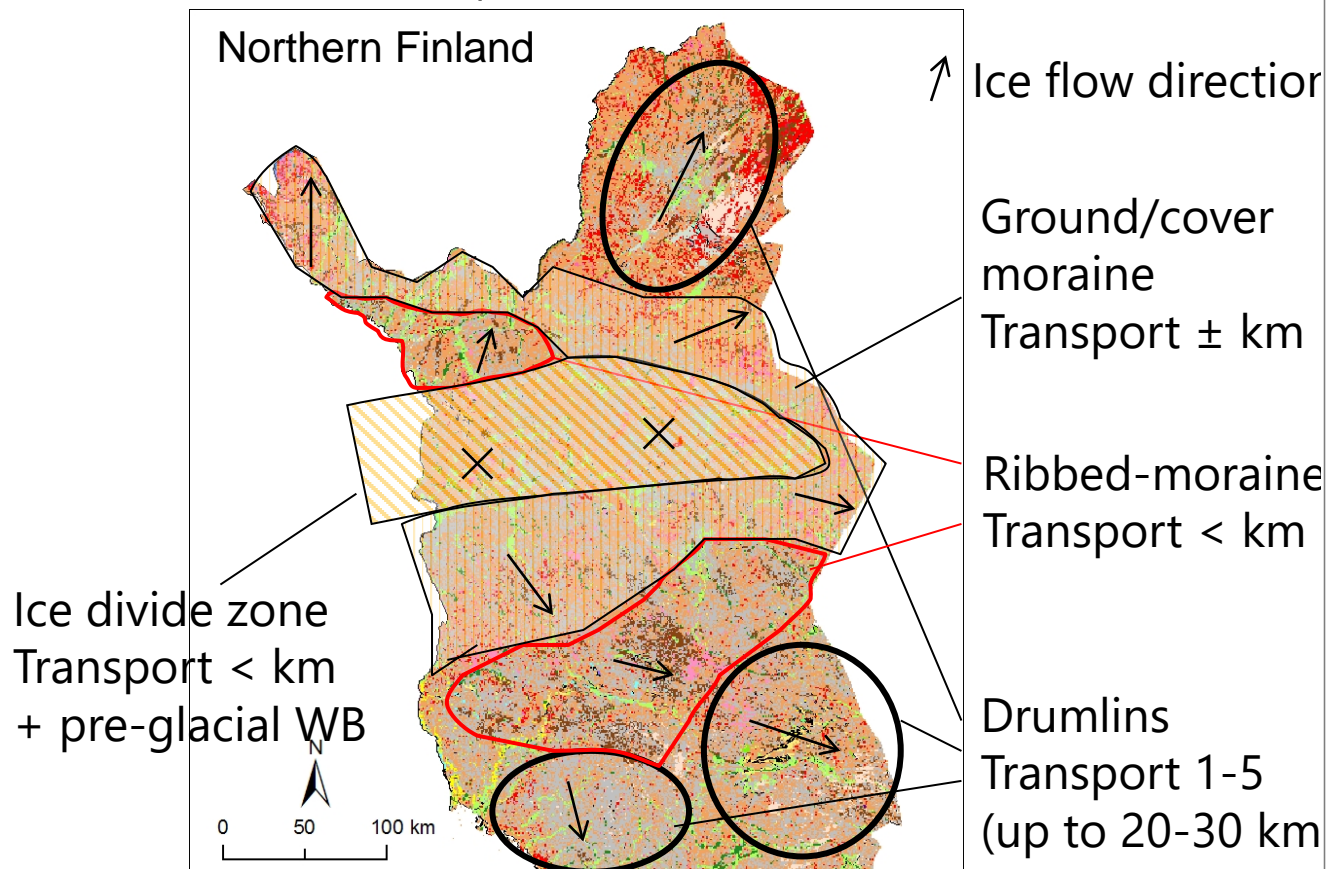


Moraine formations

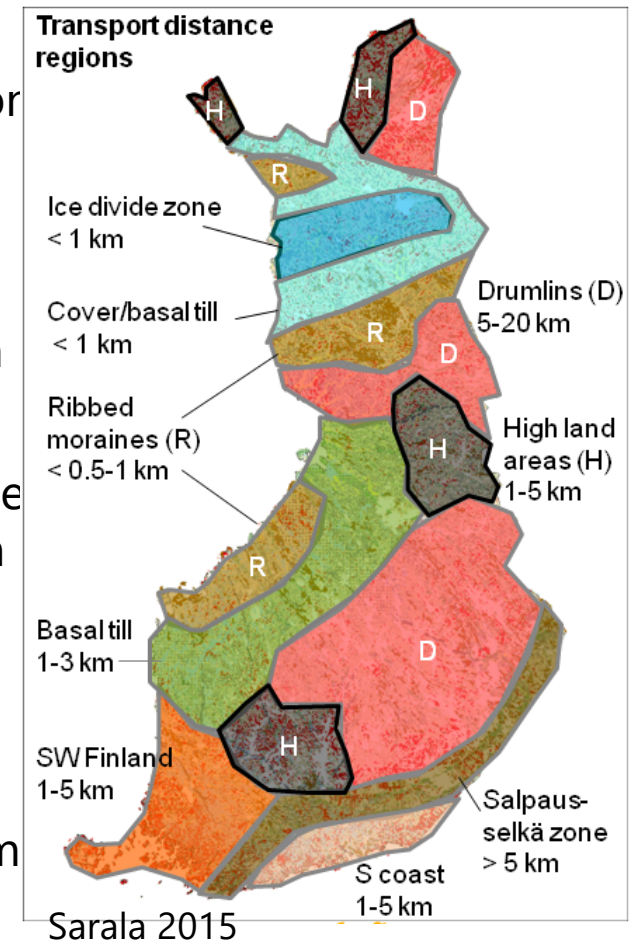


Transport distances based on glacial morphologies

- Moraine deposit types can be roughly used as an indicator of glacial transport and secondary dispersion (for till geochemistry, indicator minerals, boulders etc.)



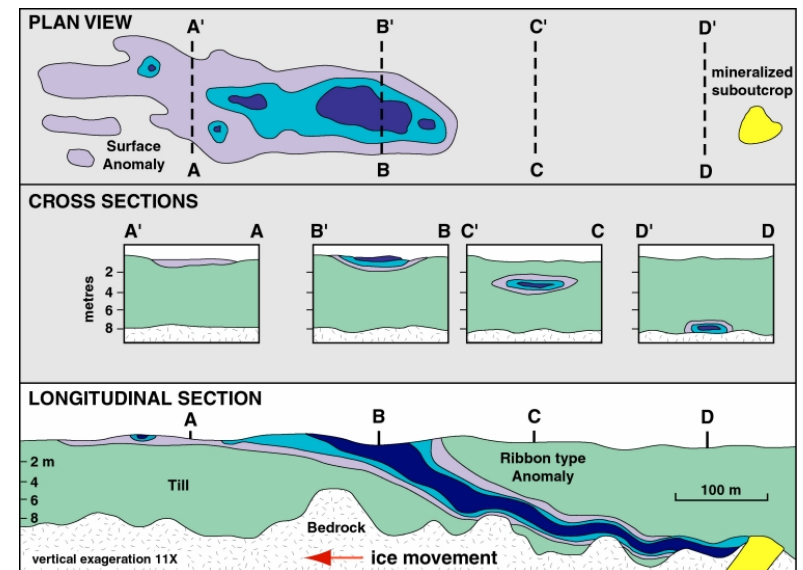
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Till geochemistry

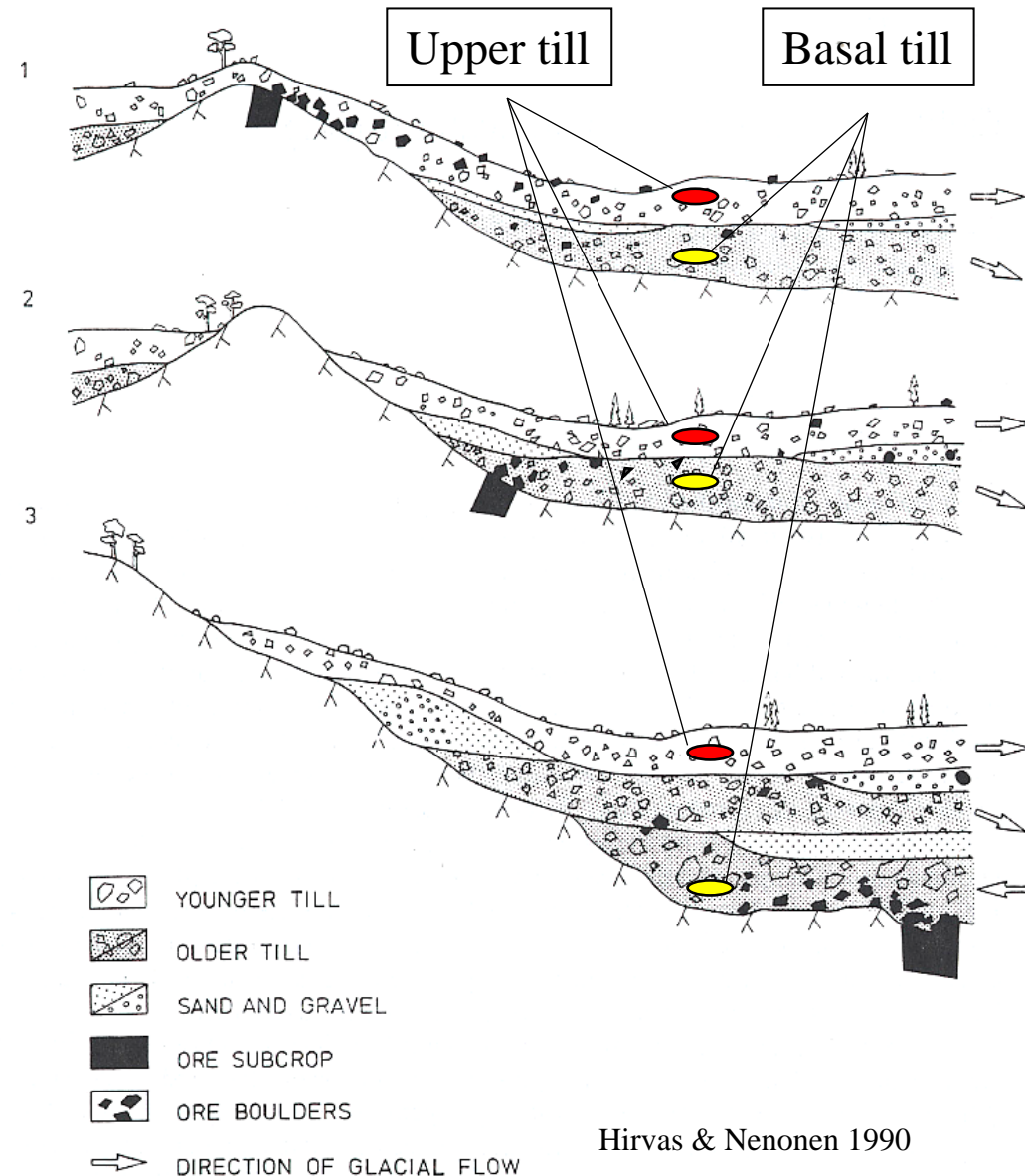


- Soil and till samples have been used a long time in exploration in the glaciated terrains
 - Till is a representative medium for exploration (secondary dispersion)
 - Till stratigraphy and the deposition mechanisms of the moraine formations must be known
 - Appearance of weathered bedrock should be consider
 - Sampling is usually easy and effective
 - Till geochemistry (< 0.06 mm) with Aqua Regia is the most used method



Till stratigraphy and sampling strategy

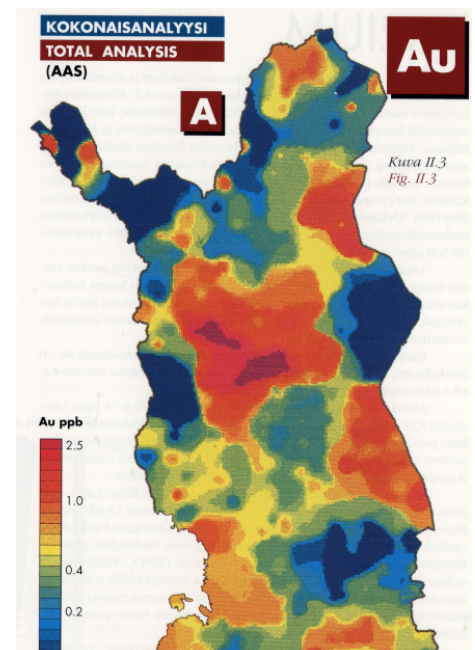
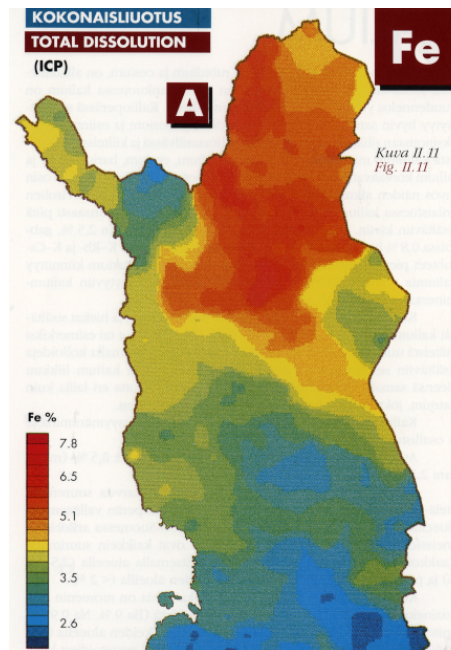
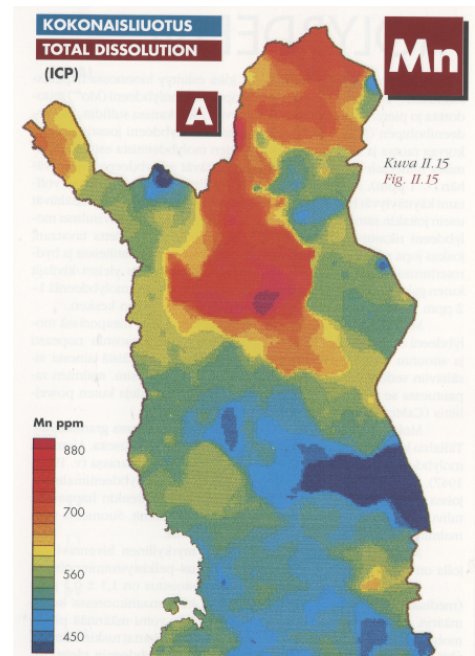
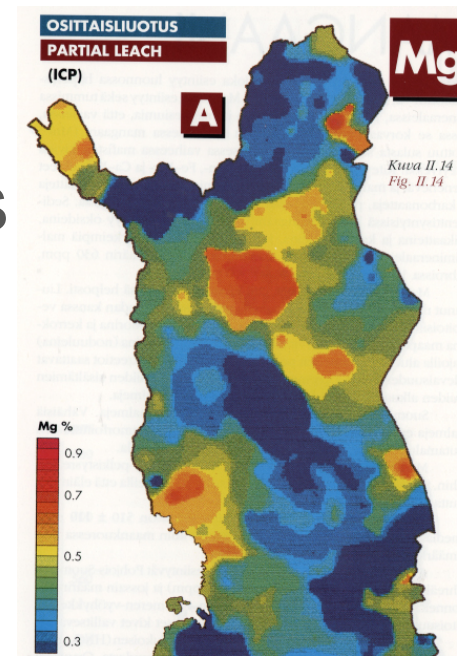
- Single/uniform movement
 - One or two glaciers erode bottom sediments and bedrock, and deposit the eroded material as till beds having almost the same pebble orientation
- Complex stratigraphy
 - During several advance phases material was eroded and transported with variable distances and directions
 - Tracing requires good knowledge of the local till stratigraphy
 - Complicated glacial history is a challenge in planning till sampling, in data processing and in interpretation



Hirvas & Nenonen 1990

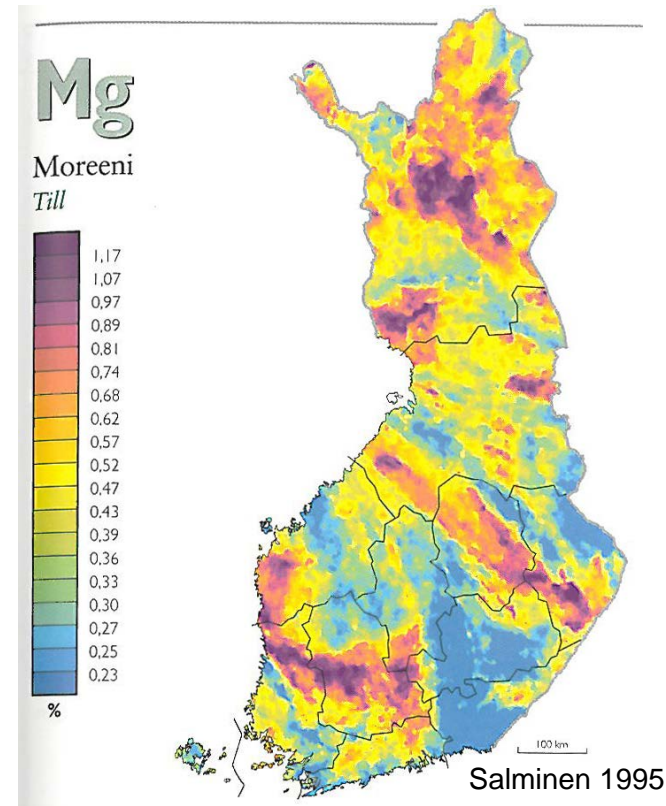
Geochemical databases

- Nation-wide till geochemistry with sampling density 1/16 km² ja 1/4 km² (e.g. Koljonen 1992: Till geochemical Atlas)
- Different types of regional and also target-scale datasets + sample materials for re-analyses
- Nowadays also Outokumpu and Rautaruukki databases in GTK
- Furthermore, large datasets relating to environmental follow-up work
- More info:
<https://gtkdata.gtk.fi/mdae/index.html>

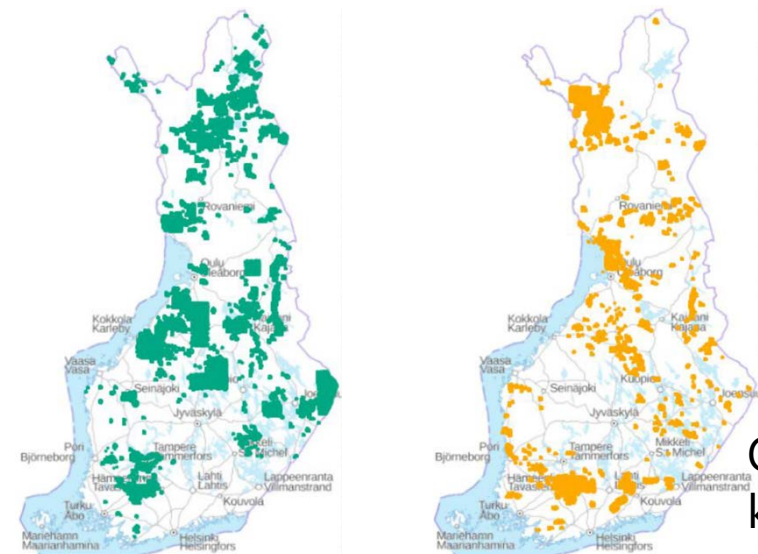


Different till datasets

- Regional grid sampling covering whole Finland (82 000 sampling points)
 - 1 sample point / 4 km²
 - About 68 000 collected from till depth about 2 m, rest from the previous datasets by composing different ways
 - Analysed using ICP-AES and GFAAS method (Aqua regia)
- Target scale till geochemical datasets
 - More than 50 000 sampling points



GTK



Heavy mineral research

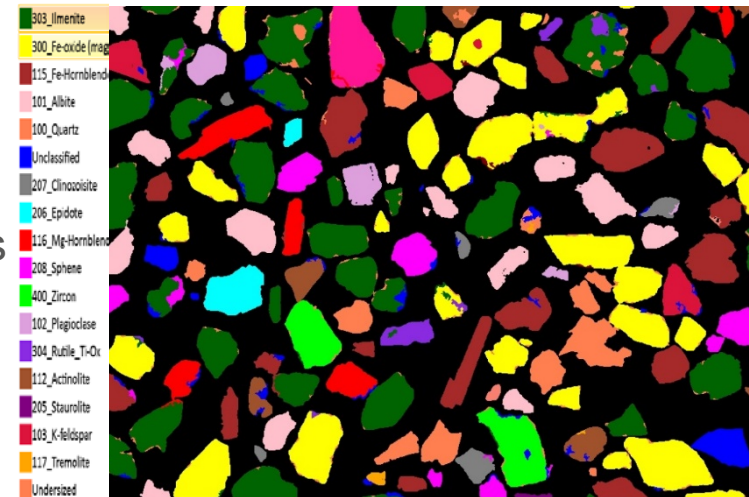
- Heavy mineral study is a traditional method in exploration
 - Mineral concentration based on gravity
 - Effective method for example Au, PGE, W and diamonds exploration, but also for base metals
 - concentration methods: e.g. Panning, Spiral concentrator, Knelson, Shaking table, Heavy liquids, Hydroseparator
- Advanced indicator mineral analysis
 - FE-SEM+EDS and MLA => Semi-automated and/or automatic identification
 - Classification and quantity of all mineral grains
Grain size and shape; mineral phases and inclusions



Photo J. Valkama



Photo J. Valkama



Advanced, low-impact geochemical methods

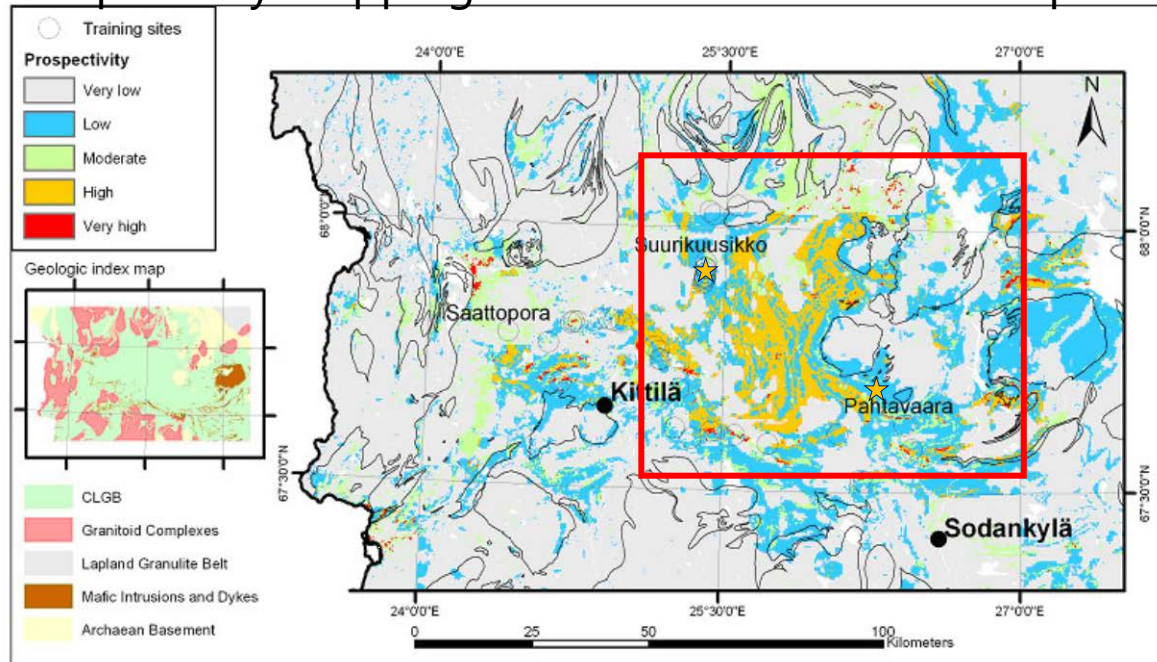
- Many light-weight and effective methods available for everyman's right sampling
 - Sampling for selective/weak leach analyses (Ammonium acetate, Bioleach, MMI, Ionic leach, Entzyme leach, Soil Gas Hydrogen etc.)
 - Biogeochemistry (plants and peat)
 - Snow geochemistry
 - Stream sediment and water geochemistry
 - On-site methods, like pXRF, pXRD, pLIBS, pRAMAN...



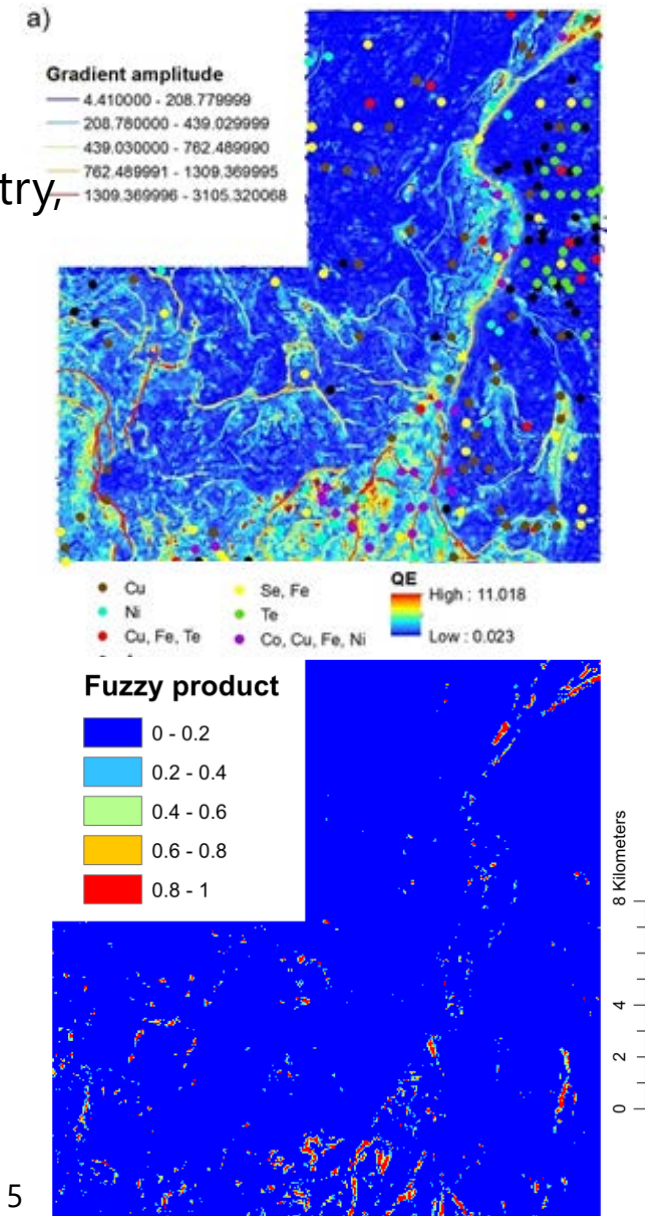
Modelling, Prospectivity mapping and SOM

The use of different datasets together, such as till geochemistry, geophysical data and lithology

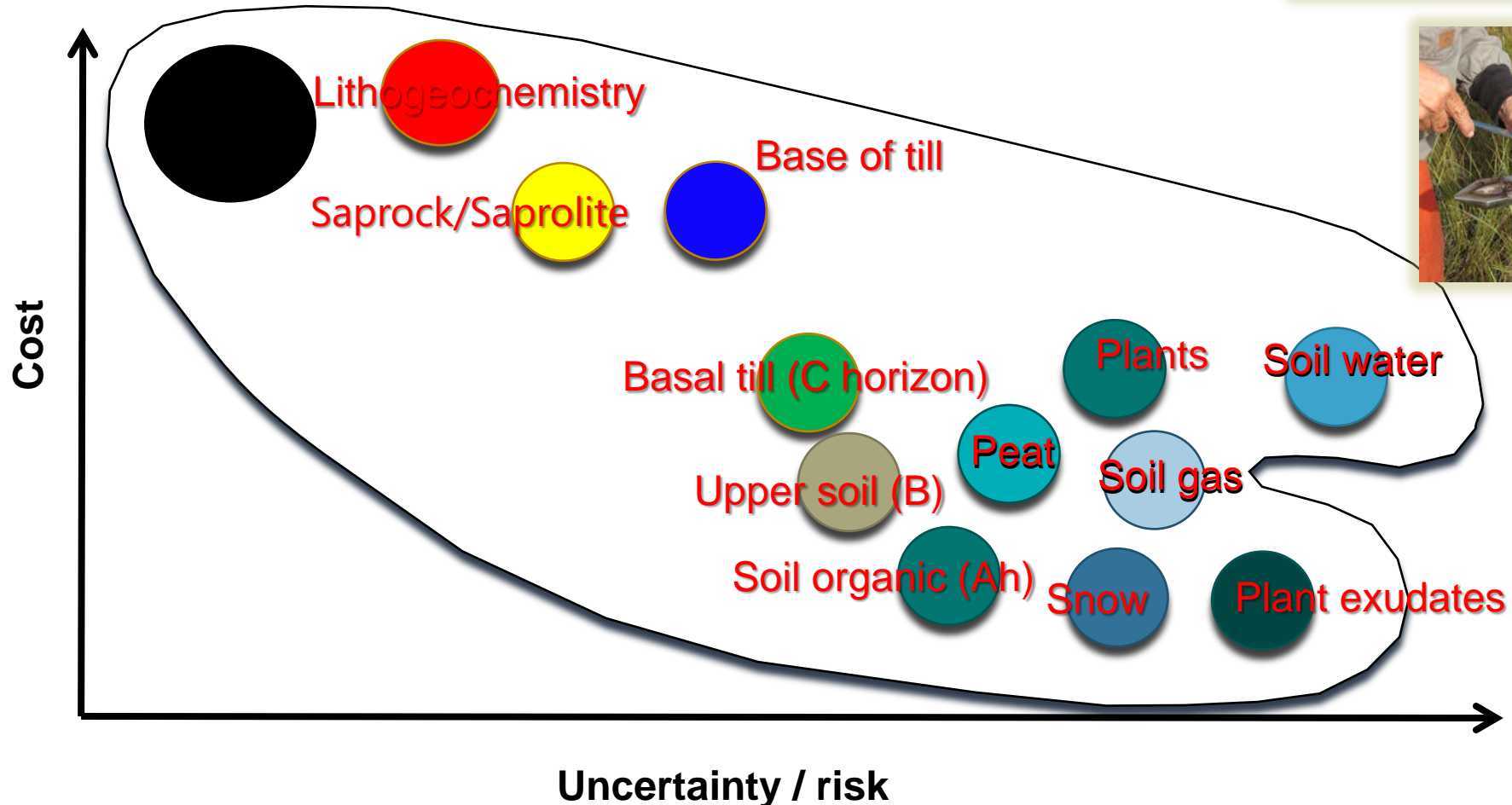
Prospectivity mapping for Au in central Finnish Lapland



Nykänen & Salmirinne 2006



Cost vs. risk





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Photo P. Sarala