Geological Survey of Finland: Steps from seamless mapping towards a National Geological 3D-framework

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Picture 1. Geological mapping in Kopparnäs, Finland. Picture by: Riikka Kietäväinen

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Introduction

- The Geological Survey of Finland (GTK) has systematically mapped the geology and Earth resources of Finland over the last 100 years.
- From the 1980’s all of the field observations have been stored in a GTK database.
- The map sheet based approach was replaced in 2005 by a seamless bedrock map database, which was recently developed further towards a system of nationwide thematic layers compatible with the (IUGS-CGI-GeoSciML) standards.
- GTK has a long tradition of geophysical modeling and more than 20 years of experience with ore deposit scale 3D-modeling.
- GTK in 2017 started preparation for a National Geological 3D-framework of Finland.

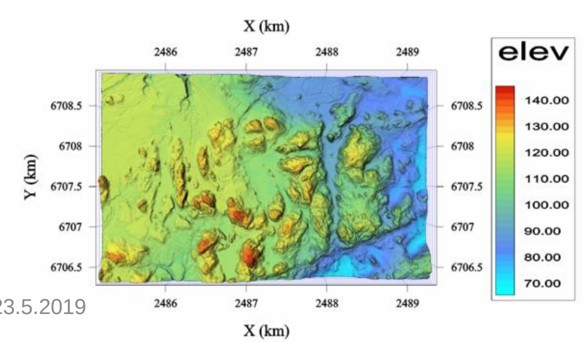
NGFF (National Geological Framework of Finland) - 3D modelling

Definitions/NGFF 2019-

- NGFF (National Geological Framework of Finland)
- NGFF Data Models and Model Feature Catalogs

3D modelling

- 3D modelling methods: explicite and implicite, numerical and stochastic simulations and inversions, resulting the use of several different softawre/codes
  2019
- Application of NGFF with the 3D software data structures and the actual 3D modelling 2020-



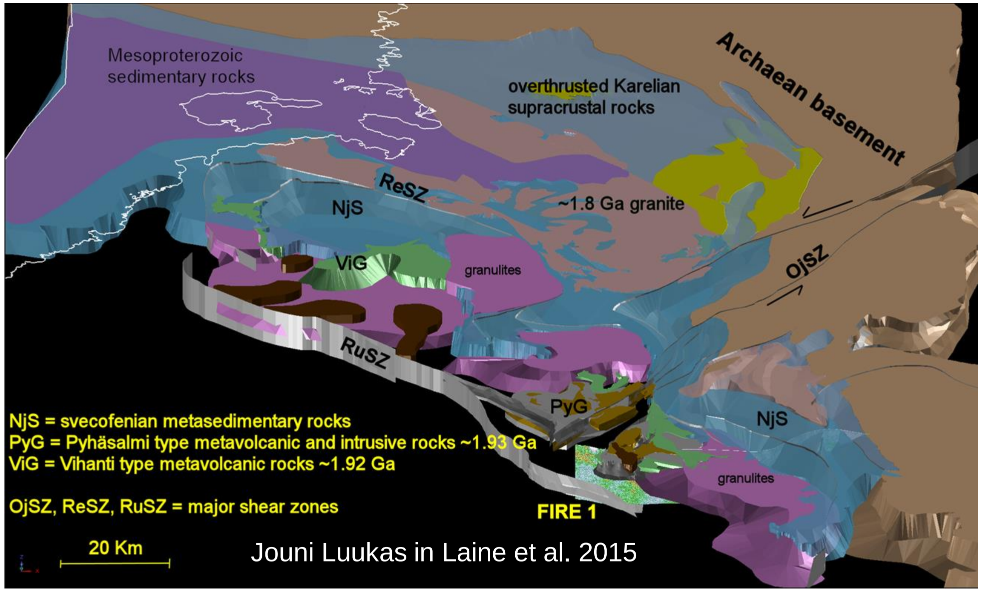
3D database

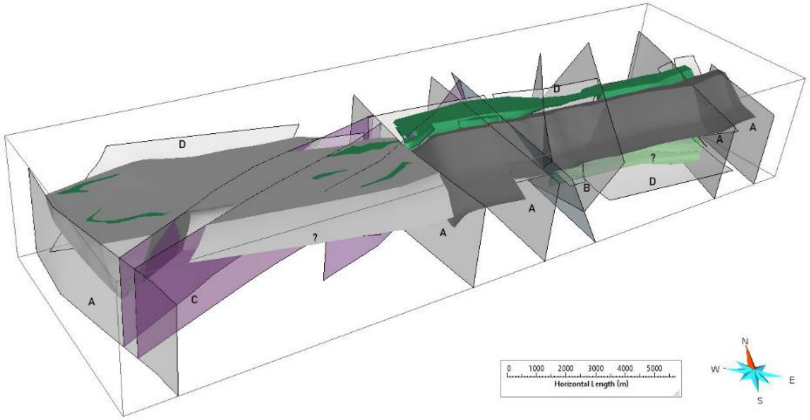
- 3D models: From crustal 3D geological models to 3D models of few centimeters,
  3D models built using XRFtomography, photogrammetric and geophysical tools or by geophysical inversion
  3D database testing
  2019
- Spatial (2D and 3D) – Finstrati unit database 2020-

Eeva-Liisa Laine, Heidi Laxström, Jussi Ahonen 23.5.2019

Bedrock Geology

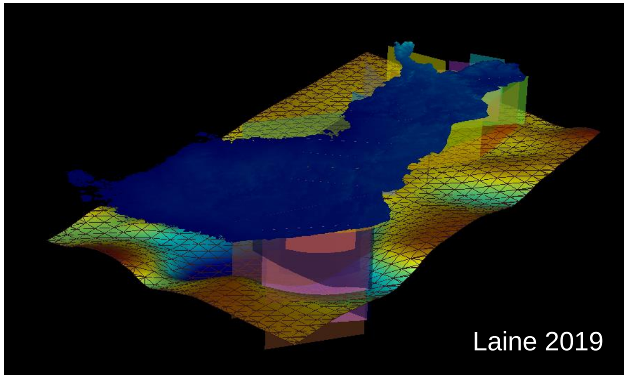
- Crustal scale bedrock 3D modeling (ver. 1.0 / 2019; depth of Moho, tectonic province boundaries and crustal scale structures)
- Belt scale 3D modeling (geological models / mineral system models) of bedrock; the generic GTK approach (2019; definitions, work flows, testing); two case-study projects ongoing
- Ore deposit-scale modeling (mostly contracted work)
- GECCO project (funded by the Academy of Finland) combines expertise in high performance computing and geomodelling. The aim is to analyze the sources of the uncertainties and the tools to manage and visualize these using stochastic geophysical inversion.
- Testing of different scale (nationwide-belt scale-ore deposit scale) models within the NGFF data model

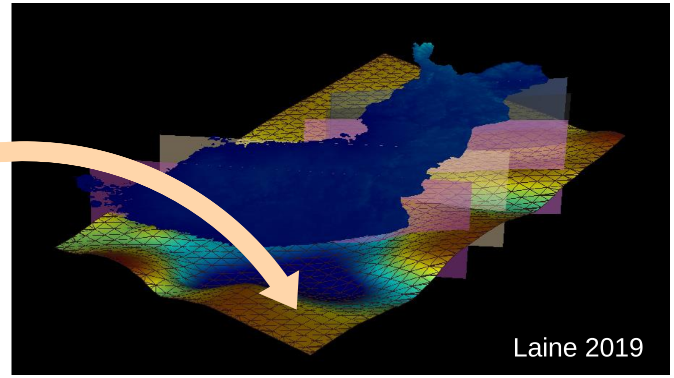




An updated Outokumpu 3D geological model by Laine 2019

The present process towards the crustal model





January-March

- Geological cross sections across geologically important contacts
- Compilation of geophysical data and interpretations

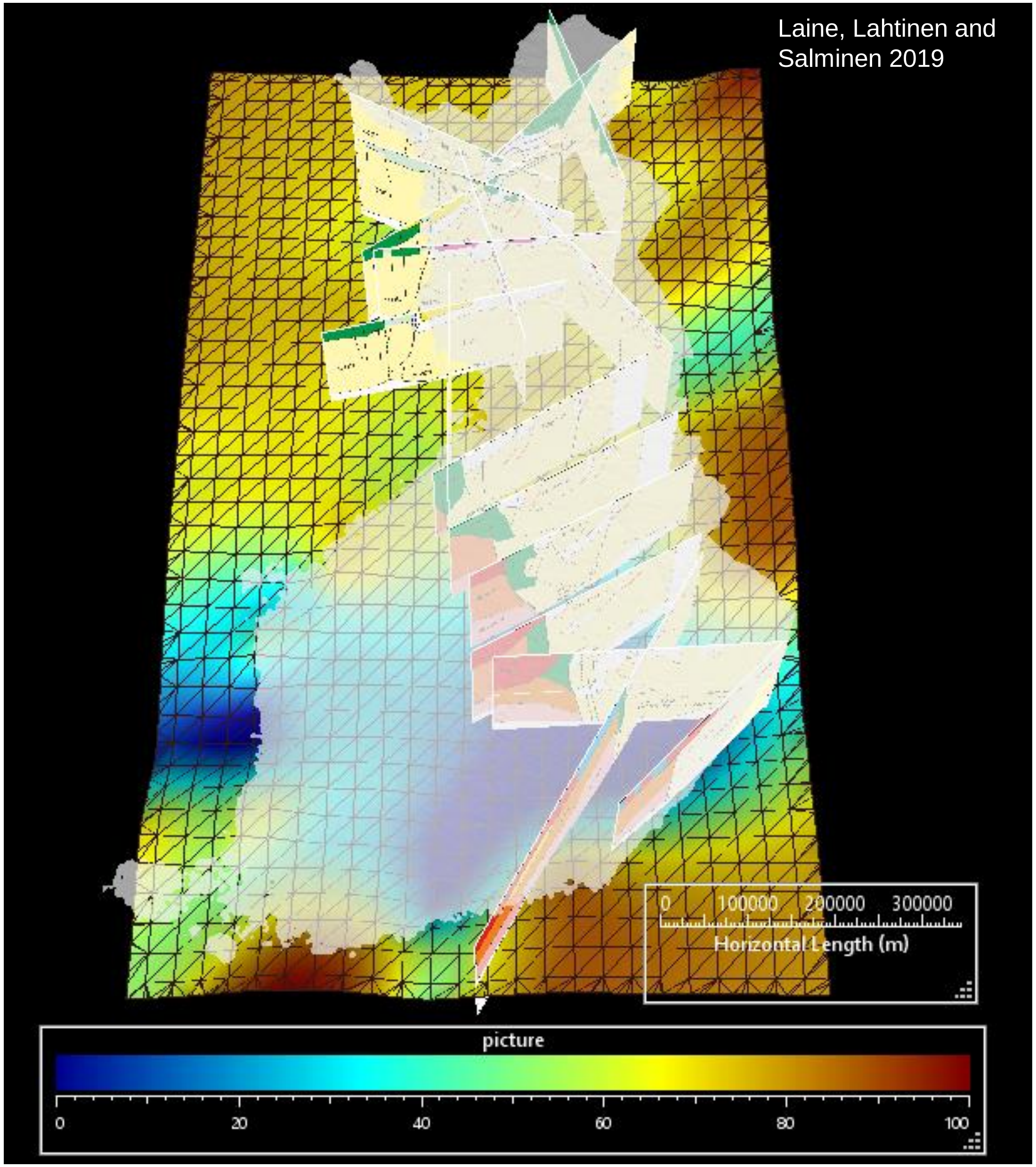
April-December

- Workshops: geological cross sections, geophysical data used for validation
- 3D visual inspection of the 3D data and geological interpretations/inversions

2020

- Identifying structures from different cross sections and connecting them to surfaces
- Building a 3D geological modelmodel

Included in the project lead by research professor Raimo Lahtinen (geology) and the specific WP ”3D crustal model” is lead by senior scientist Suvi Heinonen (geophysics), this 3D modelling work is done by several geologists and geophysicists at GTK.



Main structures into GOCAD / Geomodeller based on geological and geophysical data (seismic sections)

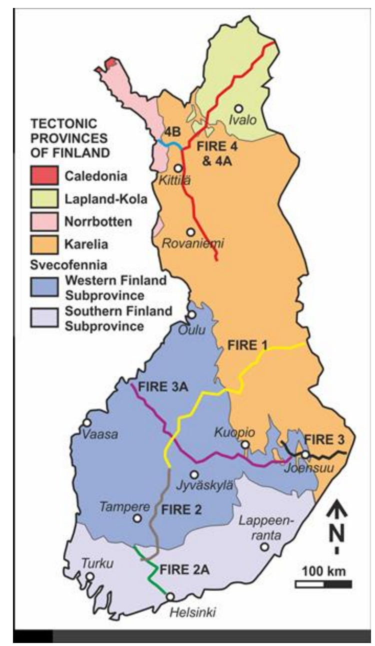
↓

Digitation of these structures using geological cross sections and geophysical fw (inv) modelling: GOCAD and Geomodeller (Groundhog?) test versions

↓

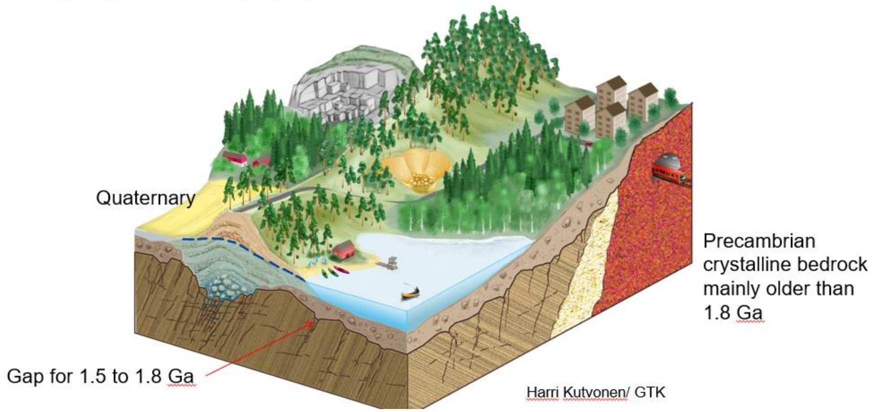
Final Finland Crustal model 2020: surfaces, solids, voxels,

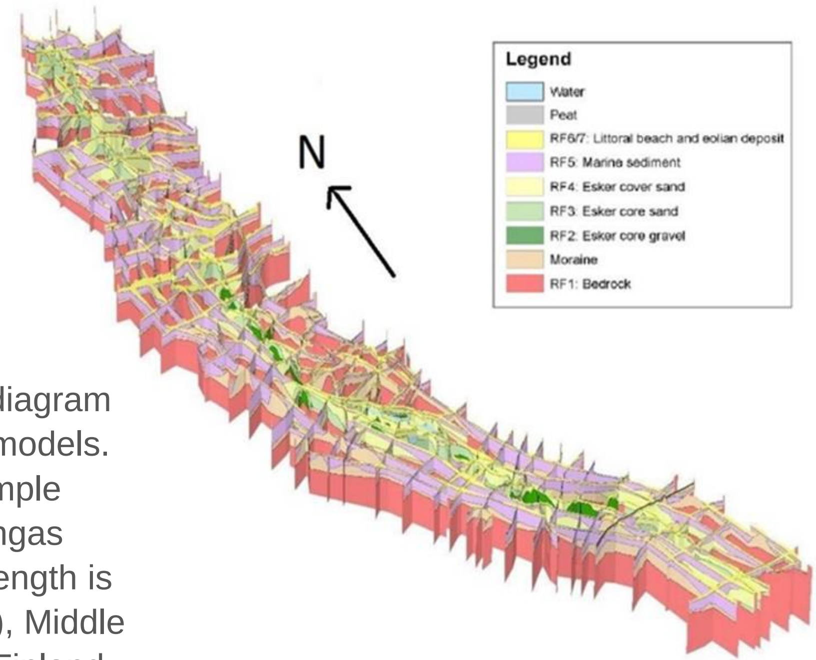
(Updating)



Quaternary Geology

(Very) brief stratigraphy of Finland



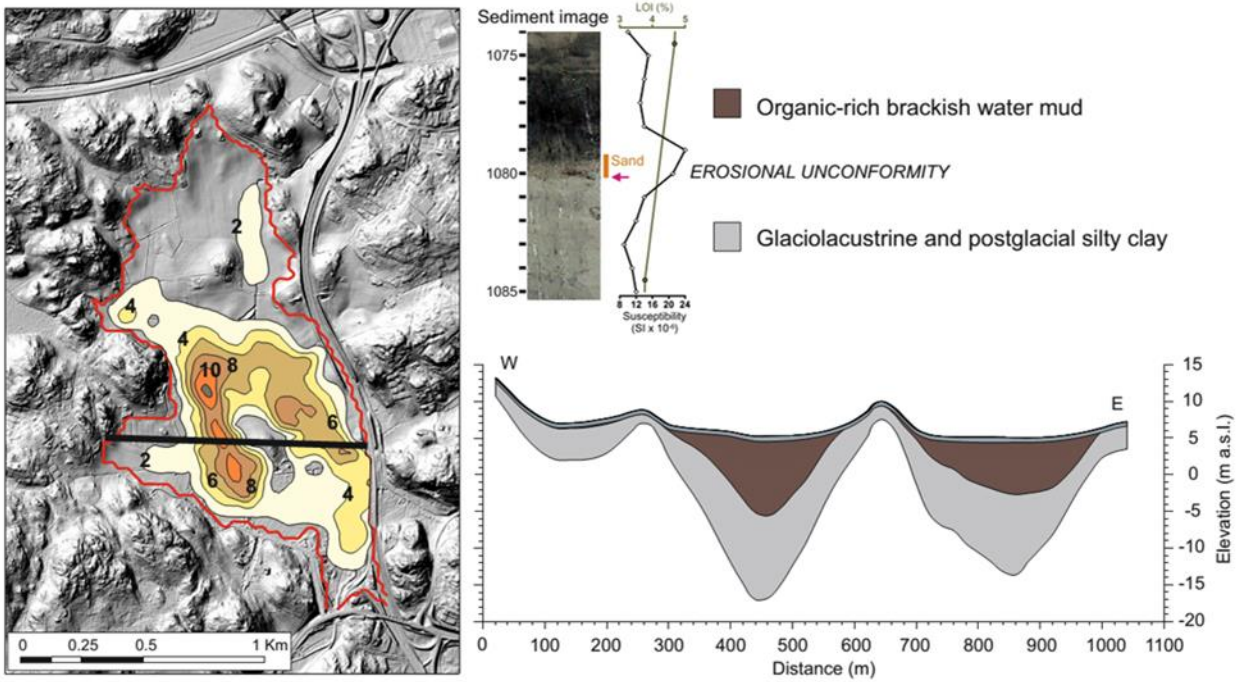


Typical fence-diagram used in esker models. This is an example from Karhinkangas esker (model length is approx. 12 km), Middle Ostrobothnia, Finland (Putkinen et al. 2014).

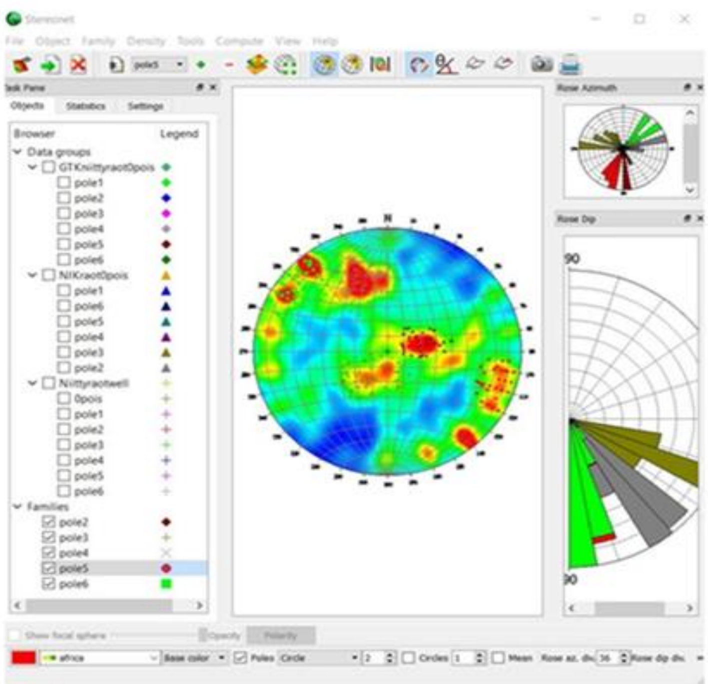
In the following years the main focus will be (1) use of the new unit-based surficial geology data model to 3D modeling and (2) improved coherence of the local (e.g., groundwater) and more regional models.

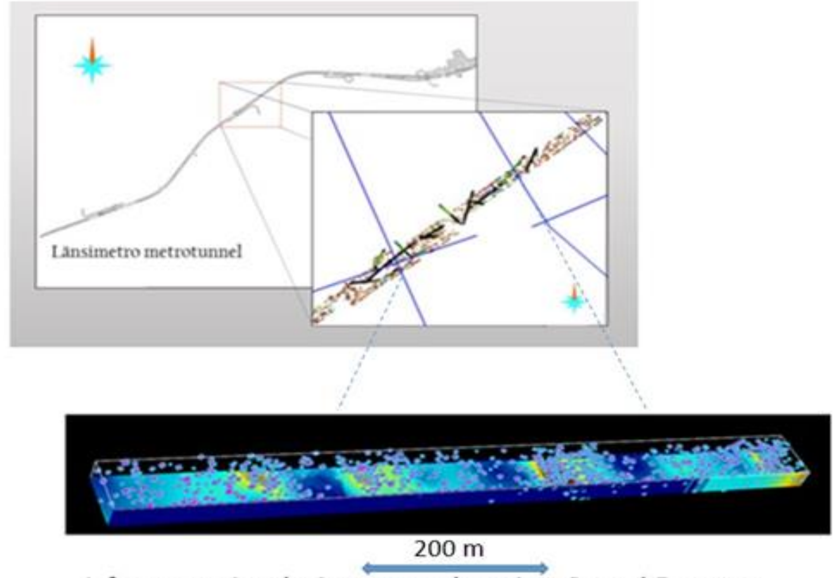
Engineering Geology

- Engineering-geological modelling builds upon 2D and 3D models of superficial deposits, sedimentological logs, their geotechnical properties and drill holes (e.g. Ojala, 2007; Ojala et al., 2017)



In the southern coast of Finland, the fine-grained sediments are roughly subdivided into two parts: the underlying glaciolacustrine and postglacial silty clay and the overlying organic-rich brackish water mud with a poor bearing capacity and higher abundance of sulphide minerals that form sulphuric acid upon oxidation. The distribution and thickness of these two units are modeled in the Suurpelto area, Espoo (Ojala et al., 2007; Ojala et al., 2017).





A fracture simulation example using Gocad Fractcar plugin and ISATIS software

Laine and Valtonen 2018 in Kohonen et al. 2019

Statistical analysis of Niittykumpu fracture orientations, 3D visualization of the Niittykumpu metrotunnel fracture data with weakness zones (blue), and fracture simulation of one fracture set showing fracture density (blue for sparse and yellow for dense fracturing) in the background. The used software were Emerson GOCAD with Fractcar plugin made by RING consortium and ISATIS (Geovariances).

Future challenges

- Saving 3D geological models from very different sources and built for varying purposes into the same 3D database
- The harmonization of regional data models (structural geology) and applied data models (bedrock weakness zones, fractures and jointing) also taking into account the use of 3D models in different applications outside GTK
- Using the new geophysical, photogrammetric, lidar scanning and XRF tomography data for 3D geological models – demand of large data storage
- (Precambrian bedrock lacks mostly clear lithological contacts and stratigraphy – there may a need of of completely different approaches in 3D modelling – they should perhaps be voxet based rather than built using surfaces: a totally different software structure from those available for younger geological formations)
- Uncertainties related to 3D geological models

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Thank you!

Picture Heidi Laxström