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Upscaling deep buried geochemical exploration techniques into European business -

UpDeep project

Final seminar
Online: https://ilonait.adobeconnect.com/gtk/
26th March, 2020, 12:00-16:00 EET

GTK brgm GEUS TU WIEN TECHNISCHE UNIVERSITÄT WIEN Vienna|Austria VTT LTU BUSINESS AB geocool SPINVERSE

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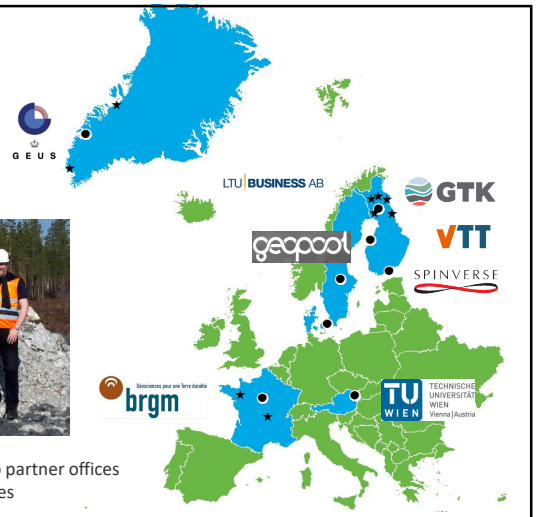
Up Deep

UpDeep team



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● UpDeep partner offices
★ Field sites

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Upscaling deep buried geochemical exploration techniques into European business -

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Up Deep

Moderator

Maarit Middleton
Senior Scientist
Environmental solutions, GTK
Rovaniemi, Finland

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Instructions to listeners

- Speaker cameras are turned off to avoid overloading the network
- Your microphones are switched off
- At the end of every presentation 5 minutes has been reserved for asking questions from the speaker
- **Ask questions or comment by typing to the Chat window**
- The moderator (Maarit Middleton, Vesa Nykänen) will follow the Chat and choose a couple of questions for the speaker to answer
- In the end of the seminar a longer slot of questions and comments is reserved
- Send the remaining questions and comments directly to the speaker and the UpDeep team by email

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Program

- 12:00 Welcoming words / **Saku Vuori**, GTK
- 12:05-12:15 Introduction to UpDeep project / **Vesa Nykänen**, GTK
- 12:20-12:35 Surface geochemical consulting / **Jens Rönnqvist**, Scandinavian Geopool
- 12:40-12:55 UpDeep Standard reference material bank / **Pertti Sarala**, GTK
- 13:00-13:15 Streamlined surface geochemical sampling protocol / **Jérémie Melleton**, BRGM
- 13:20-13:50 Statistical data analysis of surface geochemical data including case studies from Finland, Greenland and France / **Peter Filzmoser**, Vienna University of Technology

Program

- 14:30-14:50 GEM - web tool for geochemical data collection, management and analysis / **Maarit Middleton**, GTK
- 14:55-15:15 Surface geochemistry in exploration / **Nick Cook**, Mawson Resources
- 15:20-15:30 UpDeep project from the perspective of the EIT Raw Materials / **Olli Salmi**, Baltic Sea Co-Location Centre
- 15:40-16:00 Questions and closing words, **Vesa Nykänen**, GTK

Program

- 14:00-14:30 Break

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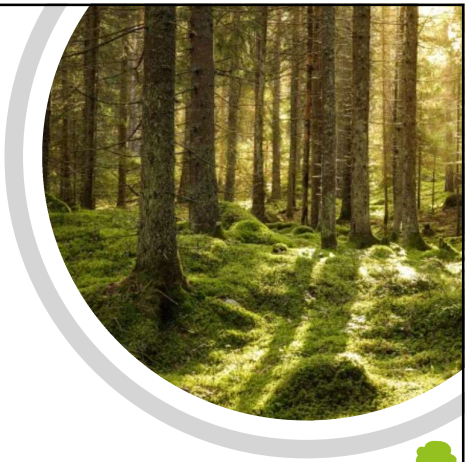
Welcoming words

Saku Vuori
Director, Science and Innovations
GTK
Espoo, Finland



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Questions?

Saku Vuori
Director, Science and Innovations
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Espoo, Finland
saku.vuori@gtk.fi

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Need and motivation for UpDeep

- Demand for **geochemical exploration techniques**
  - on poorly exposed terrains
  - sites with thick sediment covers
  - detecting deeply seated mineralisation
- Applicable to **environmentally sensitive regions**
- Reasonable processing times for **land access permitting**
- surface geochemical sampling techniques and analytical applications have been developed and applied in mineral exploration world-wide:
  - **partial leaches of soil horizons**
  - **biogeochemical exploration**

UpDeep final online seminar

Introduction to UpDeep project

Vesa Nykänen
Research Professor, Geoinformatics
Information solutions, GTK
Rovaniemi, Finland

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Background of the UpDeep project

- In Europe, many exploration companies are applying but acceptance varies
- UpDeep feasibility study: breakthrough would require solid scientific evidence and evidence that they would help in discovering a real deposit
- surface geochemical consulting business is global but no dedicated European service provider for data collection and interpretation is available

UpDeep project partners and expertise

Exploration, geoscience and geochemistry

Feasibility analysis, marketing, business

Mineral exploration services

Statistical, compositional data analysis

Data management and software

Goals of the UpDeep project

- **Create surface geochemical exploration consulting service business to Europe aiming at deep exploration**
- Promote the geochemical deep exploration concept using selective and weak leaches of soil horizons and plant tissue
- Facilitate the use of surface geochemistry in exploration companies
- Provide geochemical methods for green field exploration
- Facilitate ore discoveries at depth

Outcomes

- Surface geochemical consulting service
- Streamlined sampling and sample preparation protocols
- Protocol for standard reference material bank
- UpDeep Web Tool for exploration data management and analysis
- UpDeep Online Statistics Tool

UpDeep project facts

UpDeep	
Type of project	Upscaling
Thematic area	Exploration and raw materials resources assessment
Lead organisation's name:	Geological Survey of Finland
Coordinator's name:	Vesa Nykänen
Contact email:	vesa.nykanen@gtk.fi
Project duration:	1st April, 2017 – 31st March, 2020
Project budget:	2 milj. €

Dissemination and exploitation

- 2 research articles published, 4 submitted
- 14 presentations in conferences
- Training and marketing materials for courses and workshops
  - Short course at FEM 2019, Levi, Finland
  - Booth and short course at PDAC2020, Toronto, Canada

- Ph.D. candidate Dominika Miksova

  Vienna University of Technology

  "Combining absolute and relative information in compositional surface geochemical data analysis for mineral exploration"

Knowledge transfer and international co-operation

- Education of young applied geochemists and data analysts within the UpDeep team

David Heberlein, Heberlein Geoconsulting

Clemens Reimann, NGU

Colin Dunn, Colin Dunn consulting

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Questions?

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UpDeep team

- Business
  - Jens Rönnqvist, jens.ronnqvist@geopool.com
- Project management
  - Vesa Nykänen, vesa.nykanen@gtk.fi
- Science
  - Maarit Middleton, maarit.middleton@gtk.fi

http://projects.gtk.fi/updeep

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Surface geochemical consulting

Jens Rönnqvist
Business development manager, geologist
Ab Scandinavian GeoPool Ltd
Kokkola, Finland

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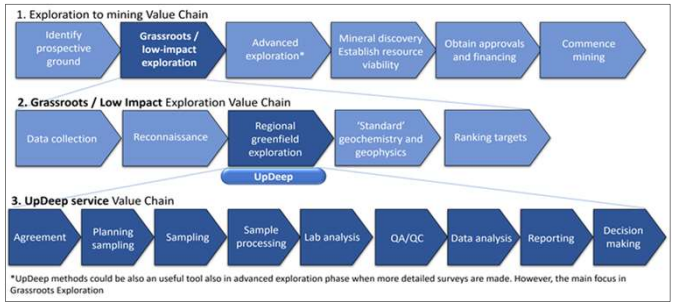
Value chain



Low impact

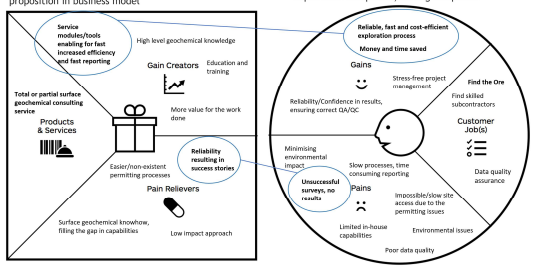
- No heavy machinery is required
- Social license
  - It is much easier to start a project with very low impact methods
- Traceability of projects in good standing
  - Something that will become more important in future
  - Can increase the value of the mineral resource
- Permitting is easier than for most other methods

Value proposition

- Low impact
- Reliability
- Cost efficiency
- Quick process

Value map describes the features of a specific value proposition in business model

Customer profile describing the main segments: junior exploration companies, mining companies



Value Proposition: Our low environmental impact geochemical exploration service will help mineral exploration industry to identify and prioritize potential targets for further exploration (e.g. drilling) by reducing time and cost while improving reliability in target detection.

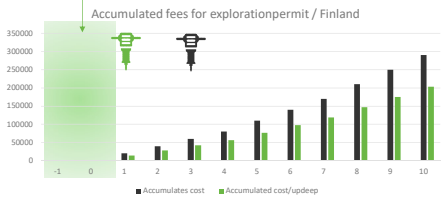
Reliability

- Well developed QAQC protocoll
- Surface geochemical standard reference sample bank.
- A new layer of information that is not available in most projects. There is a large scope to improve interpretation when combining to other data sources.
- Increasing the confidence in prioritization and identifi drilling targets.
- Enhancing success in exploration and decreases exper drill sites can be carefully selected.
- Documentation
- Sophisticated statistical analysis
- Online statistical tool

Cost efficiency / quick process

- Sampling method is fairly quick.
- Surveys can be done before exploration permit (in some jurisdictions)
- Optimized sampling grid reduces costs
- Overall costs are lower than many geophysical surveys
- Digital data flow from sampling design to field data collection and data analysis. → Minimum time spent on data management

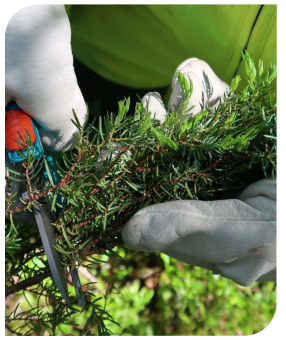
Example:
The exploration permit was reduced with 30% due to use of UpDeep methods



GeoPool perspective

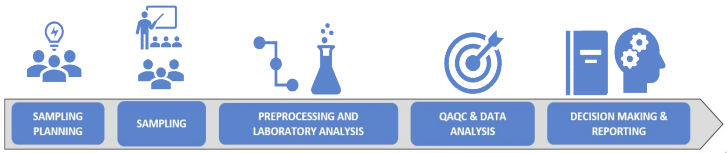
- Work flow
  - Planning
  - Sampling
  - QAQC
  - Interpretation
- Network:
  - Other experts, geochemist, statistician, laboratories, exploration companies, research institutes

Webtool
Reports
Case studies



Service

- Full package or individual parts



SAMPLING PLANNING	SAMPLING	PREPROCESSING AND LABORATORY ANALYSIS	QAQC & DATA ANALYSIS	DECISION MAKING & REPORTING
What to sample? When to sample? Analytical method? When?	Training! Protocolls Parameters to collect? Randomized sample numbers. Sampe equipment	A number of items to discuss with lab and agree upon. Data formats Expectations on quality	A number of items to discuss with lab and agree upon. Data formats Expectations on quality	

Things to think of if you would like to conduct a surface geochemical survey

- Start planning in beginning of year
- Be aware of the QAQC protocoll, it has an impact on the budget
- Communicate with the laboratory
- Sampling in early summer for plant tissue
- Train the field crew
- Weather can have impact on soil sampling (heavy rain)
- Expect results in the end of summer
- Use the knowledge available from the UpDeep project
- Contact: jens.ronnqvist@geopool.fi

UpDeep final online seminar

Questions?

Jens Rönnqvist
Business development manager, geologist
Ab Scandinavian GeoPool Ltd
Kokkola, Finland
jens.ronnqvist@geopool.fi

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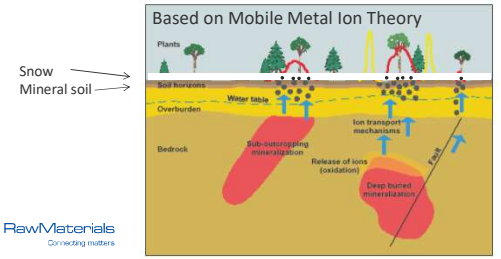
Surface geochemical exploration methods

- Surface geochemical methods:
  - Direct geochemical signal from subcropping or buried mineralization in the bedrock through the transported cover
  - Environment-friendly, low impact sampling methods
  - Easy and quick sampling
  - Wide range of commercial analytical methods for different sample materials with relative low cost



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UpDeep Standard reference material bank

for the top soil and plant geochemistry in mineral exploration

Pertti Sarala
Research Professor, Geochemical exploration
Mineral Economy Solutions, GTK
Rovaniemi, Finland

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Background

- Soil weak leach and biogeochemical SRMs specific to European environments are not available
- CRMs are very expensive and the availability of the elements is very limited => Need for creating European SRM sample bank for surface geochemistry
- SRMs are a cost efficient way of monitoring laboratory accuracy especially in small projects
- The UpDeep reference sample materials include both mineral soil and biogeochemical materials for the purpose of mineral exploration in the glaciated terrain
- An idea is to demonstrate:
  - Practical sampling procedures
  - Immediate sample pre-processing
  - Analytical test procedure for producing surface geochemical SRMs

Soil sampling

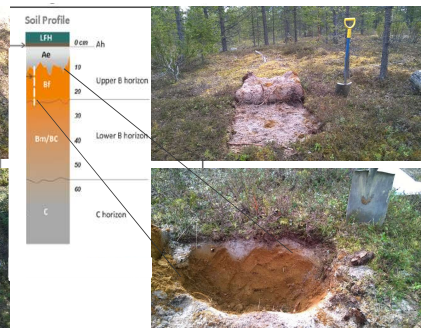
- Sampling was carried out in northern Finland, at the Mäkärä target site (12th-13th June, 2017) in northern Sodankylä
  - Active mineral exploration targets for Au-REE (quartz-hematite vein + deeply weathered bedrock)
  - Sampling on top of known mineralization (glacial till cover 1-3 m)
- Total amount of subsamples was:
  - 64 Ah-horizon samples (total weight of the natural moist samples was c. 8 kg)
  - 164 B-horizon samples + other half to storage (total weight of the natural moist samples was c. 15.5 kg)

Plant Sampling for the UpDeep SRM bank

- Sampling on two Au prospects in northern Finland (Tiira, Mäkärä)
  - Norway spruce foliage and bark, Scots pine bark, common juniper foliage

Soil sampling

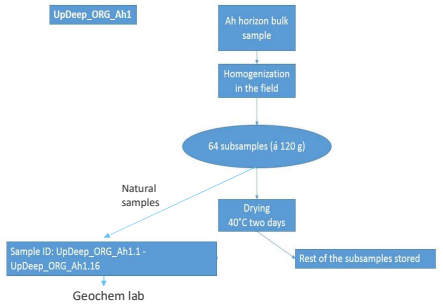
Ah horizon sampling



B horizon sampling

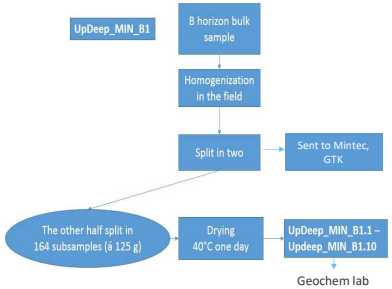
Sample processing – soils – Ah horizon

- Sample homogenization and packing into ziplock plastic bags in the field



Sample processing – soils – B-horizon

- Sample homogenization and packing into ziplock plastic bags in the field



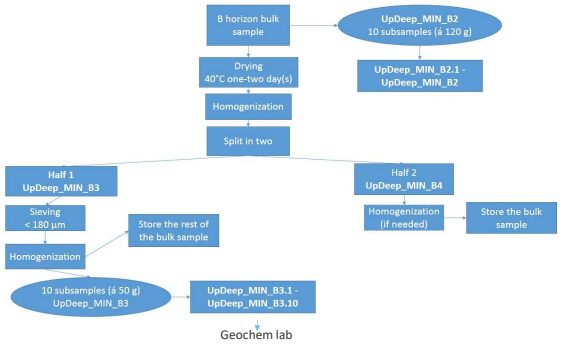
UpDeep SRM bank materials – soil samples for weak leach

dried, unsieved organic Ah horizon (UpDeep_ORG_Ah1) and mineral soil materials (UpDeep_MIN_B1)

dried, sieved mineral soil materials (UpDeep_MIN_B3)

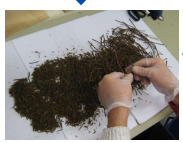
Sample processing – soils – B-horizon

- Sample pre-processing in the laboratory (Mintek)



UpDeep biogeochemical SRM bank

Plant samples were dried in a large industrial oven in 40°C for 48 hours



Common juniper and Norway spruce samples were sorted by hand into twig and needle materials

Milling at Mintec

Ashing at Labtium

Homogenization at Mintec

Subsamples to geochem labs

UpDeep biogeochemical SRM bank

a

UPDEEP_SPRU_TWIG_DRY in a HDPE bottle and a plastic bag

b

UPDEEP_PINE_BARK_ASH in individual packaging of 0.5 g samples

SRM Reports

- The reports/certificates of available sample materials are available in the UpDeep webpages
- Certificates include a short description of materials, their preprocessing and dissolution techniques together with analysis results and their basic statistical evaluation
- Certificates are delivered to customer together with sample materials
- To develope the UpDeep analytical database, the customers are encouraged to sent their analytical results concerning the SRM materials to the supplier

Chemical analyses for the subsamples in the UpDeep SRM bank

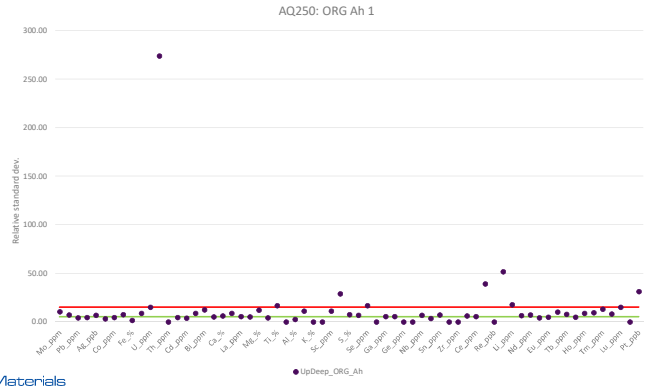
Soil samples:

- Modified aqua regia digestion (1:1:1 (HNO_3:HCl:H_2O) Aqua regia digestion Ultratrace, Ah samples, laboratory: Bureau Veritas Laboratories)
- Weak acid leach (1:1 (HNO_3:HCl) Aqua regia digestion for Ah and B horizon samples, laboratory: ALS)
- Sodium pyrophosphate (for Ah and B horizon samples, laboratory: ALS, Acme Laboratories)
- Ionic leach^{TM} (a static sodium cyanide leach using the chelating agents ammonium chloride, citric acid and EDTA with the leach solution buffered at an alkaline pH of 8.5, B-horizon samples, laboratory: ALS)

Plant samples:

- HNO_3 and/or Aqua regia for the plant samples, laboratories: Actlabs, ALS Minerals/ALS Global and Bureau Veritas Minerals Acmelabs

Analytical data for soils in SRM bank



Purpose of the UpDeep SRM bank

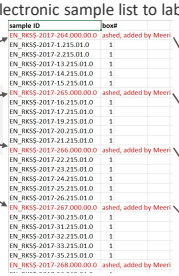
- External monitoring of laboratory accuracy, also laboratory precision and trends

SRM bank
- Homogenized bulk of the SRM

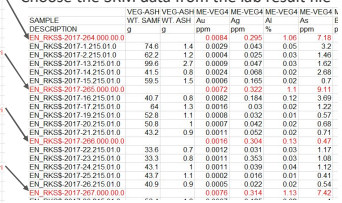
- Concentrations of the preanalysed aliquots in a spreadsheet file
- Certificate: statistics of the preanalysed aliquots (SRM Master table)

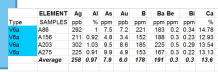
Send SRM aliquots to lab

Electronic sample list to lab



Choose the SRM data from the lab result file





UpDeep SRM bank offerings

1. Samples shipped to customers
   - The current bank is small, but easily updated
   - New sample types added by request
2. Expertise to prepare and sample for client specific SRM/PRM sample sets
3. Expertise to produce SRM/PRM samples at GTK's Mintec laboratory
   - Drying, homogenization, milling, subsampling
   - Ashing and analysis reguests to external laboratories and storage

Contacts:

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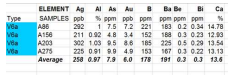
maarit.middleton@gtk.fi

Purpose of the UpDeep SRM bank

SRM data from the lab result file

Concentrations of the preanalysed aliquots from the SRM bank



X-chart

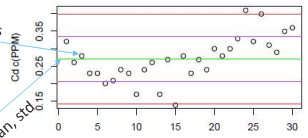


Table of
- SRM_Mean(PPM)
- SRM_SD(PPM)
- SRM_RSD%
- ProjMean(PPM)
- ProjSD(PPM)
- ProjRSD%
- Bias%
- Precions % 10 and 20%

UpDeep final online seminar

Questions?

Pertti Sarala
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Streamlined surface geochemical sampling protocol

Jérémie Melleton
Economic geologist
Frence Geological Survey, BRGM
Orléans, France

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What to sample and where, how?

- All information about:
  - Targets (geology, geography, geophysics, former prospects, etc…)
  - Anthropogenic activities (land uses, industrial activities, old aerial photographies, national database….)
  - Ownerships

Geological map *Corine Land cover* *Ownership* *Aerial photographies*

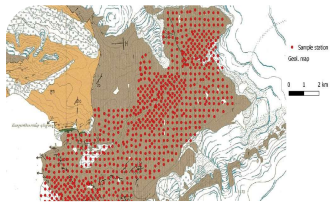
Example of available data to plan sampling campaign in the Vendée Sb district, France)

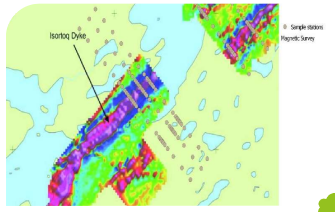
Objectives

- Optimized sampling and sample preparation procedures
- Checklist for samplers

What to sample and where, how?

- Random sampling – same distance
  - More regional
  - Broader signal
  - Low resolution
- Targeted sampling, higher density at target
  - Cost and time reducing
  - High resolution
  - Requires some prior knowledge

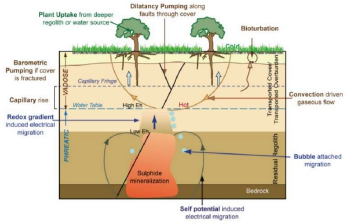




What to sample and how?

Vegetation

- Select one or more specie(s) available at all stations
- Same plant part, e.g.: leafes, twigs of comparable thickness, bark
- Sample multiple plants within sample station
- One sample = 50 – 200 g weight depending on analytical method
  - Dry pulp or ash
- Large root system preferable



Modified from Aspandiar et al. 2008

Bark and twigs sampling, Finland

Twigs sampling, France

Equipment

Influenced by target commodity

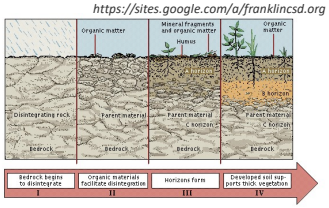
- Shovel – plastic or steel (no paint), hand auger
- Gloves
- Cotton bags
- Plastic bags
- Scissors/shears – preferably ceramic
- Portable weight
- Ruler
- Tarpaulin
- pH-meter including resistivity and acid
- GPS/tablet with fieldapp

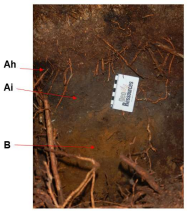
What to sample and how?

Soil

- Consistency is important!
- Sample same soil horizon: Ah, B or constant depth in areas with poorly developed or no soil horizons
- If possible, keep distance to anthropogenic contamination (e.g. roads, buildings, agriculture)
- pH measurement of soil + acid (test of carbonate)
- One sample = 200 – 300 grams

https://sites.google.com/a/franklincsd.org





Typical soil profile, France

Field preparation

VEGETATION

- Wash or not to wash?
- Dry samples as soon as possible
- 70 °C for 24 hours, but attention for volatile elements
- If not, leave samples in cloth bag, in well ventilated and in sun if able

Vegetation sample on field preparation, Greenland

Field preparation

SOIL

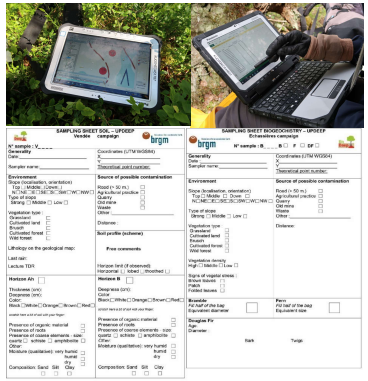
- Dry samples as soon as possible
- Measure pH in the soil at the sample station or back in the camp
- Add weak acid/vinegar to the solution and remeasure pH – testing the buffer capacity
- If able, test resistivity for redox clarification
- Soil moisture measurement

On field soil pH analyse, Finland

On field data acquisition

- **Field observations** (environment, possible sources of contamination) and **measurements** can be stored digitally or manually
  - Export the planned list of samples (sample IDs) from the UpDeep Web Tool (.csv)
  - Save data onto variable fields of the 'UpDeep standard log sheet' format (.csv) with any geodata collection software
- Check that the format of your data is the same to 'UpDeep standard log sheet'

→ upload to the UpDeep Web Tool



QA-QC

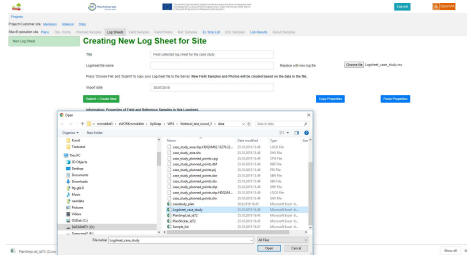
Field duplicate

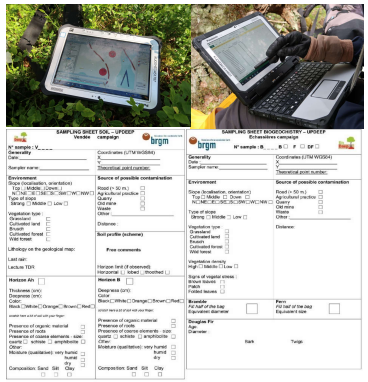
- Testing the combined effect of
  - Real geochemical variation
  - Sampling error
  - Sample preparation error
- 5-10 % of sample stations should be duplicates
- In case of lab duplicate, double the amount of the field duplicate.

Sample + duplicate, Greenland

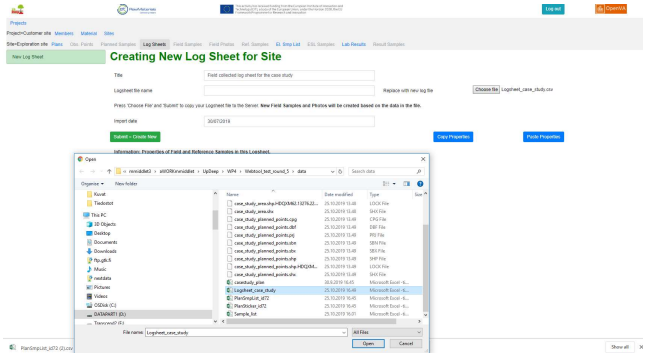
On field data acquisition

- **Field observations** (environment, possible sources of contamination) and **measurements** can be stored digitally or manually





On field data acquisition



→ upload to the UpDeep Web Tool

RawMaterials Connecting matters

brgm

Up Deep

RawMaterials Connecting matters

UpDeep final online seminar

Statistical data analysis of surface geochemical data including case studies from Finland, Greenland and France

Peter Filzmoser, Professor
Institute of Statistics and Mathematical Methods in Economics
Vienna University of Technology, TUWien
Vienna, Austria

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Up Deep

RawMaterials Connecting matters

UpDeep final online seminar

Questions?

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This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

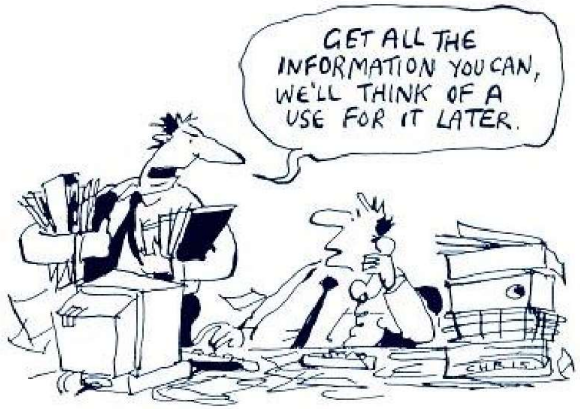
Up Deep

Outline

- Data collection
- Data quality
- Representing information
- Preprocessing
- Analyzing data
- Conclusions

RawMaterials Connecting matters

Up Deep



Sampling design

Practical considerations

- Budget restrictions also limit the number of samples.
- Samples need to be placed on the expected target AND on the background.
- For surface geochemical sampling, it is not clear which sample media to consider! Ideally, the different sample media are present at all sample locations.

Sampling design

Geological considerations

- Pre-knowledge on expected target mineralizations available?
- Pre-study in the area? Geochemical data? Geophysics data?
- Orientation of the geological structure –→ line or grid sampling?

Sampling design

Statistical considerations

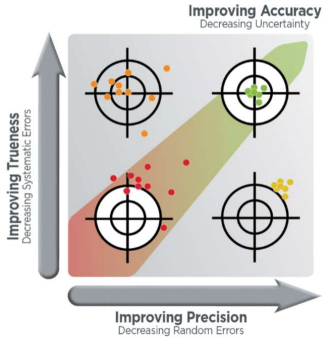
- Ideally, at least 3 samples placed on top of the mineralizations.
- At least 30 samples available – the more, the better.
- Line sampling might be cheaper than grid sampling.
- Line sampling: linear transects need to cross target; if possible use several linear transects (e.g. parallel).
- Geostatistical methods (variogram estimation, kriging) can be useful to place (additional) samples.

Data quality

QAQC: Quality Assurance and Quality Control

Data uncertainty: Accuracy versus Precision

- Accuracy (trueness): systematic errors lead to a bias of the measurements
- Precision (repeatability): how good is the repeatability of the results



Data quality

Main task: look at the data! (appropriately!)

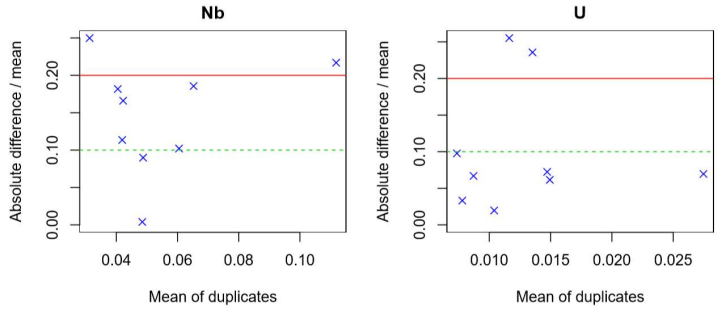
- QAQC 0: **Data overview**: tables with statistical information; plot revealing data distribution
- QAQC 1: **Process quality**: Does the analysis sequence show (temporal) patterns?
- QAQC 2: **Accuracy**: concentration of reference samples versus analysis sequence
- QAQC 3: **Laboratory contamination**: compare routine and blank samples
- QAQC 4: **Field precision**: compare routine samples with field duplicates
- QAQC 5: **Analytical precision**: compare routine samples with laboratory duplicates

Data quality

- For a QAQC analysis, use
  - Routine samples: samples that are collected to investigate occurance of mineralization
  - Field duplicates: collected at same sampling sites to monitor uncertainty
  - Laboratory duplicate: monitor laboratory precision
  - Blank samples: monitor laboratory contamination
  - Reference materials: monitor laboratory accuracy, precision and trends

Data quality

GEUS data: Example for QAQC 5 (Laboratory precision)



Data preprocessing

Detection limit (DL) problems: values below a lower or above an upper DL

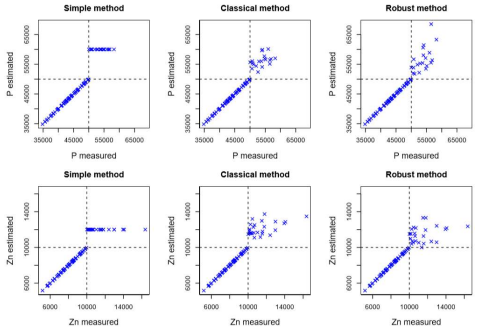
UpDeep: Development of a method for estimating values >DL

Traditional procedure: Set value >DL equal to *constant*×DL, e.g. 1.2×DL.

UpDeep: Incorporate whole "composition" in a regression framework to estimate values >DL.

Data preprocessing

- UpDeep: develop method to estimate values above an upper detection limit (DL) Regression of censored variable of CoDa transformed remaining elements. Comparison of non-robust least-squares and robust regression.



Data preprocessing

Geochemical data are **compositional data**!

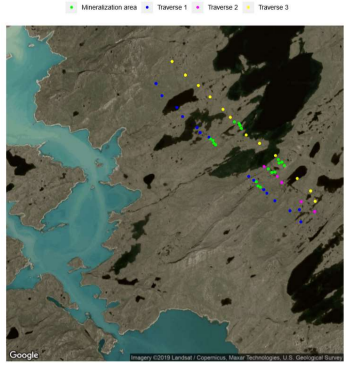
This means that the relevant information is contained in relative rather than in absolute values.

Absolute information: element concentrations

Relative information: the building blocks for a CoDa (Compositional Data Analysis) are log-ratios of the concentrations of pairs of elements (of the same sample material.

Correlation analysis

- **UpDeep**: south of Greenland; 3 parallel transects, length 12 km Soil samples, and samples from *Salix Glauca* and *Empetrum Nigrum*

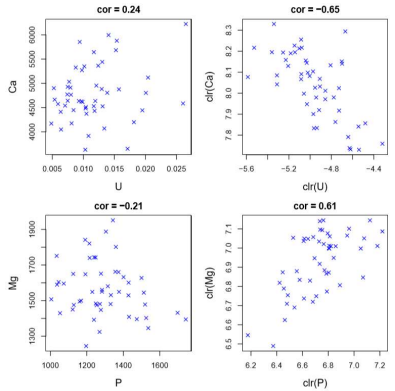


Mineralized area with known deposits of Fe, Ti, V (proxy Sc)

Correlation analysis

GEUS data: Regular samples of *Empetrum nigrum*

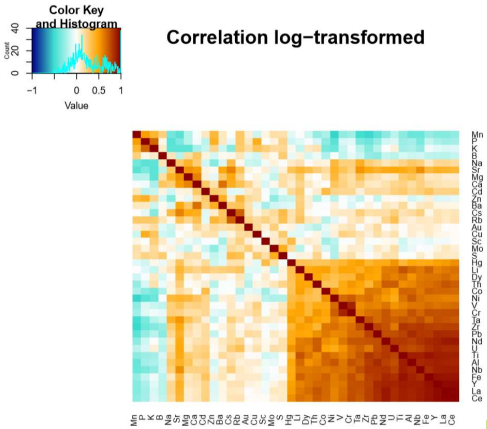
Compare correlations for original data and clr-transformed data:



Correlation analysis

GEUS data: Regular samples of *Empetrum nigrum*

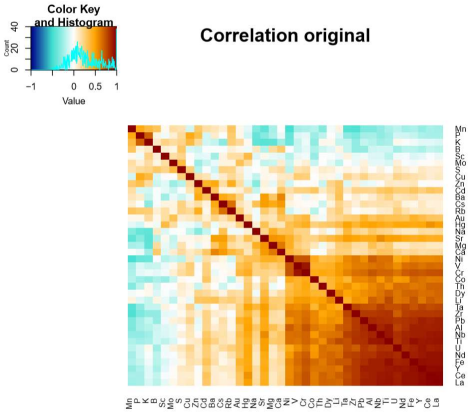
Compare all correlations in correlation heatmap: **log-transformed data**



Correlation analysis

GEUS data: Regular samples of *Empetrum nigrum*

Compare all correlations in correlation heatmap: **original data**



Correlation analysis

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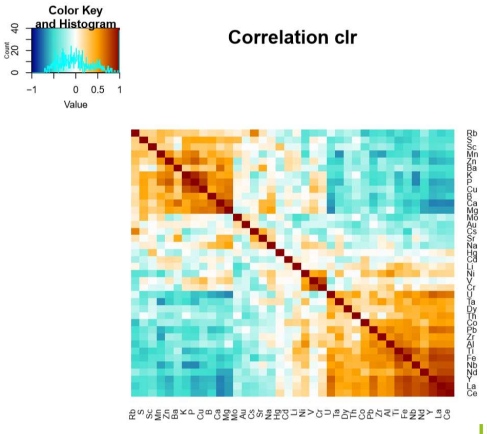
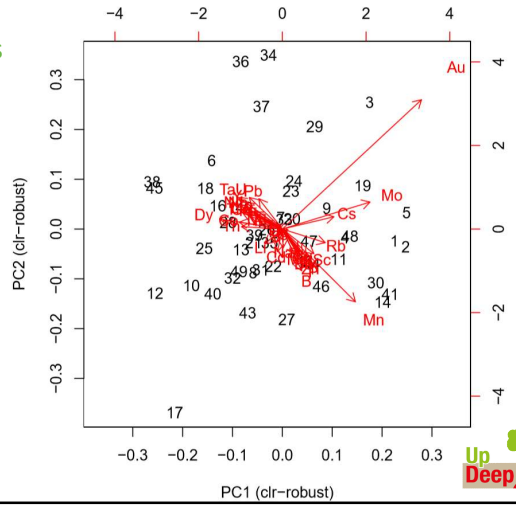
Compare all correlations in correlation heatmap: **clr-transformed data**



Principal component analys

- **GEUS data**: Robust PCA (clr) of *Empetrum nigrum*



Identification of mineralization

Development of a statistical method to identify mineralization:

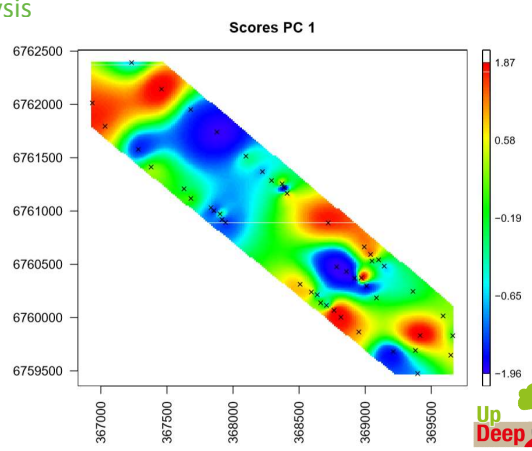
- Univariate case (measurements on a linear transect)
- Bivariate case (measurements on a grid in the plane)

Idea: Consider log-ratios of element pairs, e.g. log(As/V). Why? One of the elements could be“stable”, the other varying at mineralized zones. Log-ratios could help to reduce uncertainties of measurements.

Interest is in log-ratios with strong local changes. Develop a method that automatically detects log-ratios with high spatial curvature.

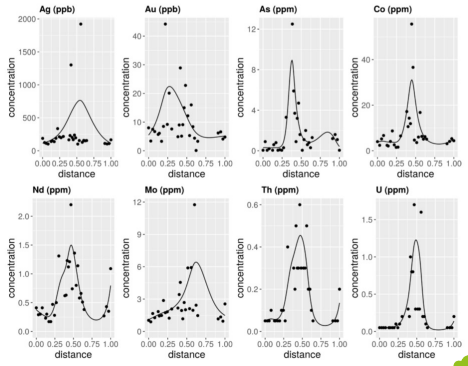
Principal component analysis

- **GEUS data**: Robust PCA (clr) of *Empetrum nigrum*



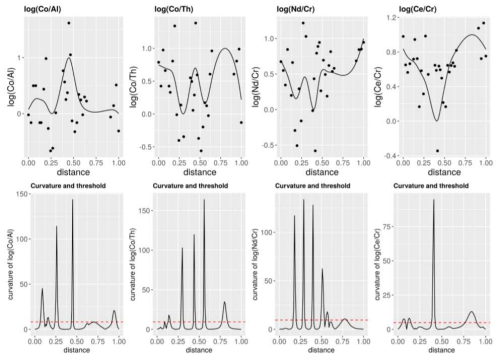
Identification of mineralization

Idea: consider pairwise element log-ratios, but from GAM fits (univariate!)



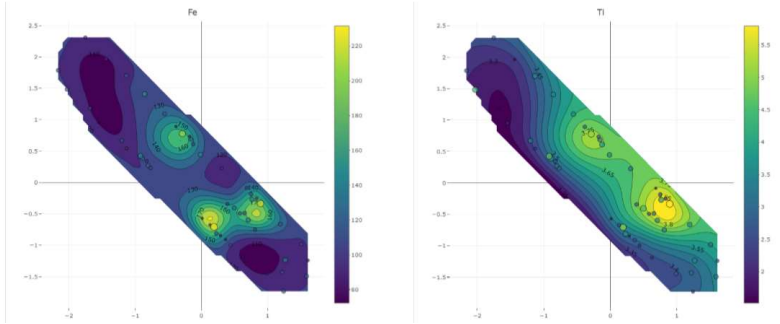
Identification of mineralization

Based on smooth log-ratios,
compute a measure of **curvature.**



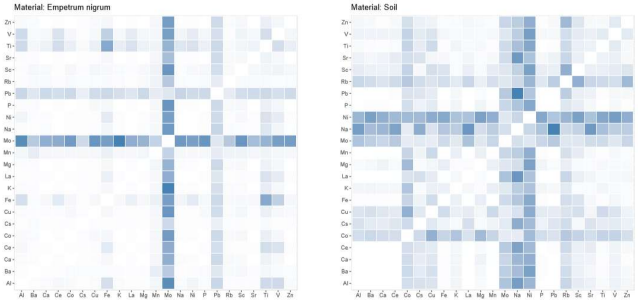
Identification of mineralization

GEUS data can be treated as 2D grid data: GAM fits for Fe (left) and Ti (right)



Identification of mineralization

Color intensity corresponds to interestingness of log-ratio pair (GEUS data).



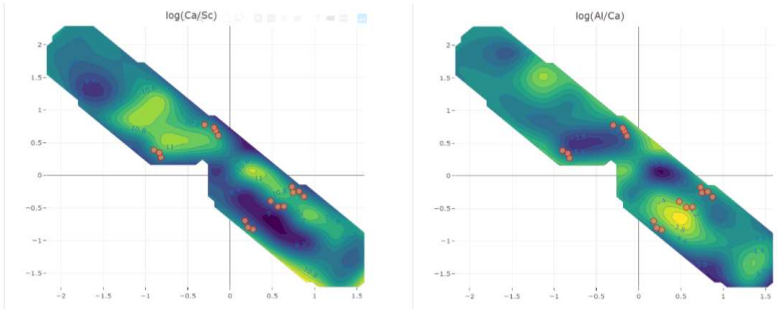
Identification of mineralization

Table of top-15 ranked log-ratios for each available material for GEUS data

Media	Salix glauca		Empetrum nigrum		Soil	
Ranking	log-ratio	c-value	log-ratio	c-value	log-ratio	c-value
1	V/Zn	31	Al/Co	36.75	P/Zn	29.29
2	Co/Zn	29.32	La/Ti	35.35	Cs/P	26.35
3	Al/Ca	29.04	Ce/Sr	33.73	Co/Mo	26.02
4	Cs/Rb	25.89	Ca/Ce	32.74	Fe/Pb	24.10
5	Fe/La	24.27	Ce/Co	32.66	Ca/Na	23.86
6	Ca/Sc	23.93	Ce/K	31.09	Ba/V	23.53
7	Co/V	23.15	Ca/La	29.96	Fe/Rb	22.41
8	Na/Zn	22.49	Al/La	29.9	Fe/Sc	21.77
9	La/Sr	21.96	Ca/Ti	29.78	Fe/Ti	21.55
10	Al/Sc	21.5	Co/La	27.89	Al/Pb	21.46
11	Na/V	21.16	Ce/Na	26.66	Ce/Mg	20.96
12	Ce/Fe	20.74	Al/Sc	26.32	Mg/Pb	20.90
13	Co/Na	19.88	Al/Ca	25.93	Pb/Sc	20.65
14	Ca/K	19.83	Ce/Zn	25.92	Mo/Na	20.60
15	Ba/Mn	19.5	La/Mg	25.42	Sr/Zn	20.46

Identification of mineralization

Two highly ranked log-ratios (material *Salix glauca*)



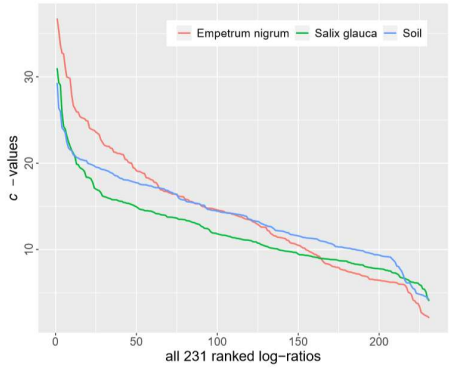
Conclusions

UpDeep project: What we have learned from a statistical point of view:

- Sampling design: rather difficult to guide from a pure statistical viewpoint
- Data collection: needs to be well structured and planned (GEM web tool)
- QAQC: the more we care, the more promising the statistical results
- Data preprocessing: statistics can help to improve data quality (censored data)
- Data analysis: geochemical data are **compositional data**!
- Identify mineralization: the methods based on paiwise log-ratios seem to be promising

Identification of mineralization

Curvature measure allows to compare sample materials:



Methodological papers

D. Mikšová, C. Rieser, and P. Filzmoser (2019). Identification of mineralization in geochemistry along a transect based on the spatial curvature of log-ratios. *arXiv* 1912.02867.

D. Mikšová, C. Rieser, P. Filzmoser, S.M. Thaarup, and J. Melleton (2020). A method to identify geochemical mineralization on linear transect. *Austrian Journal of Statistics*. To appear.

D. Mikšová, P. Filzmoser, and M. Middleton (2020). Imputation of values above an upper detection limit in compositional data. *Computers and Geosciences*. To appear.

D. Mikšová, C. Rieser, P. Filzmoser, M. Middleton, and R. Sutinen (2020). Identification of mineralization in geochemistry for grid sampling using general additive models. Submitted for publication.

RawMaterials
Connecting matters

UpDeep final online seminar

Questions?

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This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Up Deep

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UpDeep final online seminar

30 minute break

Seminar continues at 14:30 EET (Finland time)

While waiting go and see the UpDeep Online Statistics Tool for global surface geochemical data sharing
http://gtkdata.gtk.fi/updeep/

GTK brgm GEUS TU WIEN VTT LTU BUSINESS AB geopool SPINVERSE

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Program

- 14:30-14:50 GEM - web tool for geochemical data collection, management and analysis / **Maarit Middleton**, GTK
- 14:55-15:15 Surface geochemistry in exploration / **Nick Cook**, Mawson Resources
- 15:20-15:30 UpDeep project from the perspective of the EIT Raw Materials / **Olli Salmi**, Baltic Sea Co-Location Centre
- 15:40-15:50 Questions and closing words, **Vesa Nykänen**, GTK

Upscaling deep buried geochemical exploration techniques into European business -

UpDeep project

Moderator

Vesa Nykänen
Research Professor, Geoinformatics
Information solutions, GTK
Rovaniemi, Finland

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UpDeep final online seminar

GEM web tool for geochemical data collection, management and analysis

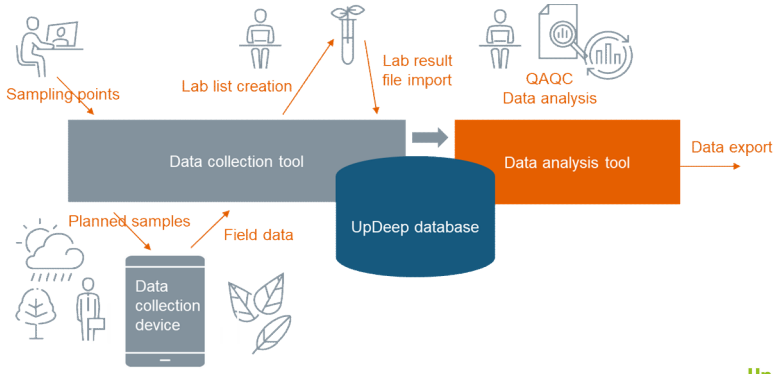
Maarit Middleton
Senior Scientist
Environmental solutions, GTK
Rovaniemi, Finland

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

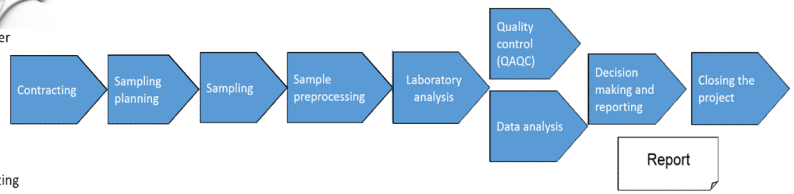
GEM web tool

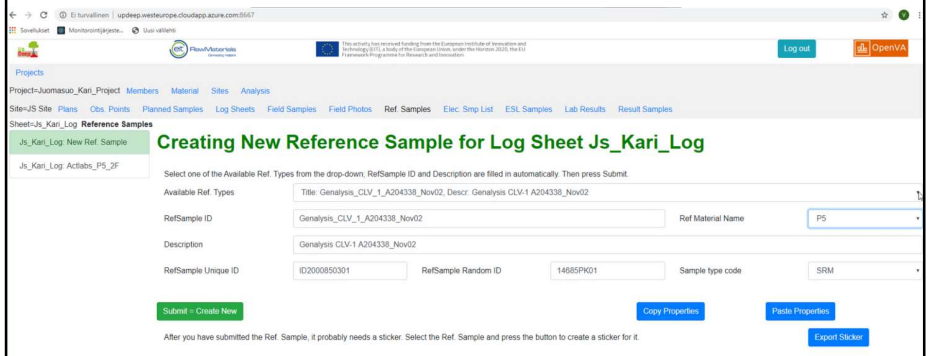
- Made to facilitate communication between an exploration geologist, a geochemical consultant and a field crew
- All information and data in digital format stored in a database
  - No files floating in emails nor on hard drives
  - Progress can be followed by the customer
- GEM web tool is installed on the consultant's server
  - Project members are given personal user names and passwords
- Can be accessed with all common browsers
  - No installations required
- Specific for soils and plants, NOT another GIS software

System components



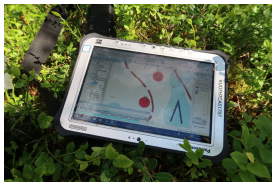
Steps of a surface geochemical survey

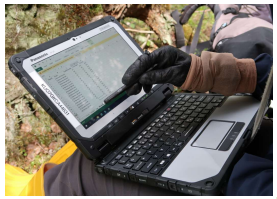


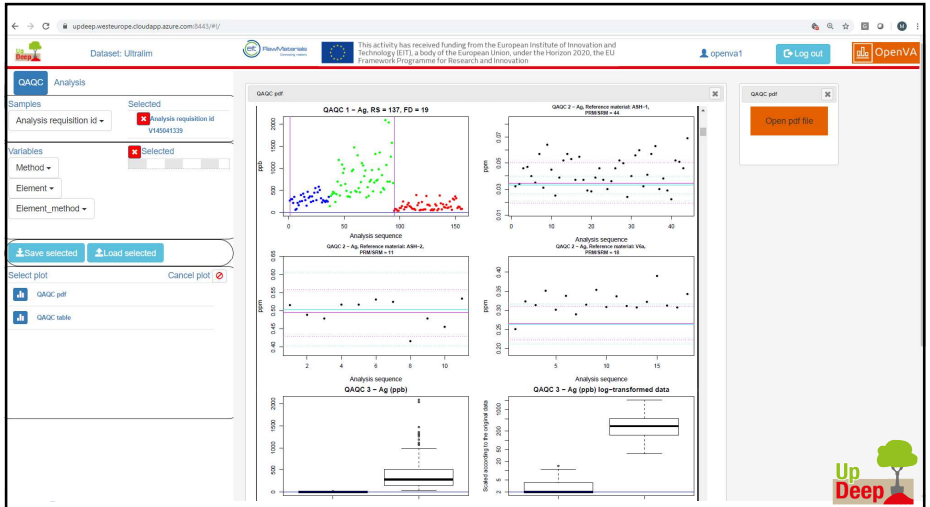


Field data collection

- Field observations and measurements can be stored digitally or manually
- Before field work
  - Export the planned list of samples (sample IDs) from the GEM web tool (.csv)
  - Save data onto variable fields of the 'GEM standard log sheet' format (.csv) with any geodata collection software
- After field work
  - Check that the format of your data is the same to 'GEM standard log sheet'
  - upload to the GEM web tool



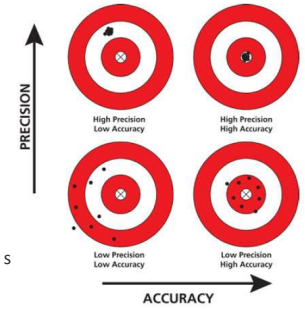




QAQC in the GEM web tool

- provides means for selecting elements relevant for statistical analysis
- A near-complete procedure is available in the UpDeep web tool

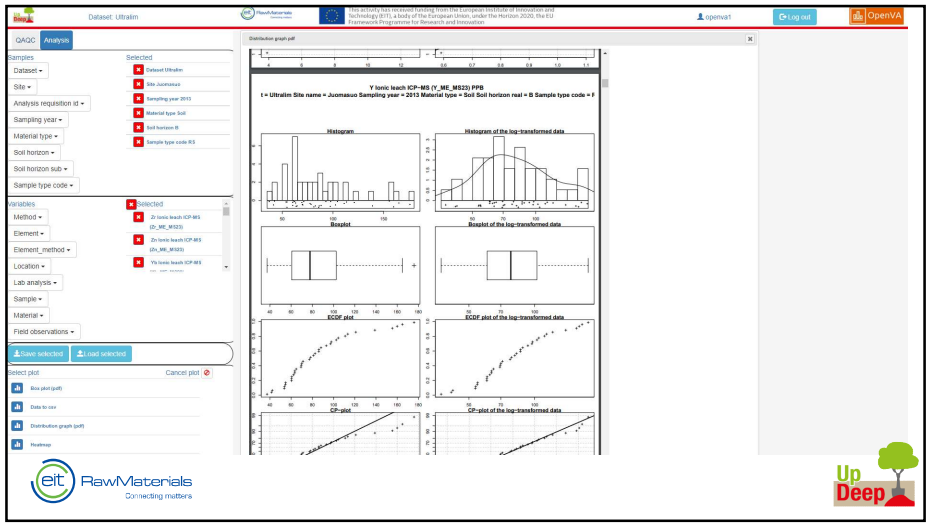
QAQC0	QAQC1	QAQC2	QAQC3	QAQC4	QAQC5
Data overview	Process quality	Lab accuracy, precision	Lab contamination	Lab precision	Field precision



- QAQC graphs and measures produced automatically
  - Running the QAQC procedure in the UpDeep Web Tool takes < 30 s
  - Interpretation takes app. 1 hour (64 elements)
  - Interpretation of quality can be stored in the QAQC.csv file and stored in the UpDeep database to keep note for future use

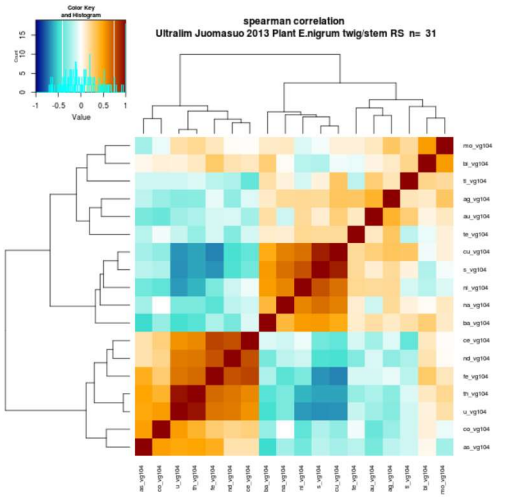
Purpose of surface geochemical data interpretation at target scale

- Find spatial patterns and association of elements vectoring towards a possible underlying mineralization
- **recognition of the significant anomalies** from the false or non-significant anomalies
  - avoid false positive targets, i.e. non-significant mineralizations
  - avoid false negative targets i.e. missing significant mineralizations



Correlation of elements

- ilr transformed
- Heatmap of spearman correlation coefficient
- Hierarchical cluster analysis



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Descriptive statistics

- Robust versions
  - MEDIAN as central value
  - Median absolute deviation (MAD) as spread = measure of average deviation from central value
  - Coefficient of variation (CVR%) as variance
  - Interquartile range (IQR) as range

Element,	Unit	%<LDL	N LDL	%>UDL	N UDL	Min	Q5%	Q25%	Mean	Median	Q75%	Q87%	Q93%	Q95%	Q96%	Max	Range	Std	MAD	IQR
Ag	PPB	0	0	0	0	0.3	0.4	0.5	1.071053	0.75	1.2	1.738	2.023	2.47	3.136	4.4	4.1	0.887726	0.37065	0.7
As	PPB	5.26	2	0	0	1	2.7	5	6.289474	6	7	10	10.41	11.15	11.52	13	12	2.700429	1.4826	2
Au	PPB	0	0	0	0	0.03	0.05	0.08	0.172895	0.125	0.2025	0.24	0.4451	0.525	0.562	0.82	0.79	0.16316	0.088956	0.1225
Ba	PPB	0	0	0	0	30	58.5	160	298.9474	265	430	515.7	570	577.5	596	720	690	177.1057	185.325	270
Be	PPB	2.63	1	0	0	0.1	1.62	3.95	5.181579	5.4	6.075	7.057	7.723	7.975	8.16	13.7	13.6	2.321679	1.63086	2.125
Bi	PPB	100	38	0	0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0	0	0	0
Br	PPM	2.63	1	0	0	0.025	0.107	0.205	0.282763	0.255	0.345	0.4719	0.5205	0.559	0.5812	0.61	0.585	0.139278	0.111195	0.14
Ca	PPM	0	0	0	0	1	2.065	4.225	12.33947	5.8	12.05	18.917	36.353	57.26	60.368	84.3	83.3	17.7388	3.7065	7.825
Cd	PPB	36.84	14	0	0	0.5	0.5	0.5	2.289474	2	3	4	5	5	5	7	6.5	1.71098	2.2239	2.5
Ce	PPB	0	0	0	0	27.4	56.945	142	216.1079	208.5	262.75	346.85	389.27	427.2	452.36	587	559.6	119.9153	95.6277	120.75

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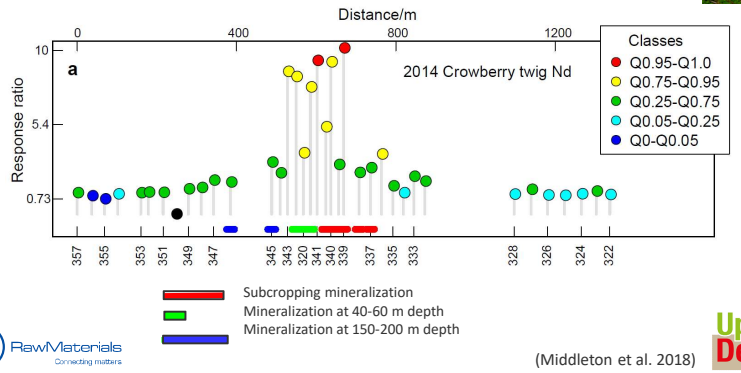
Lineplots



(Middleton et al. 2018)

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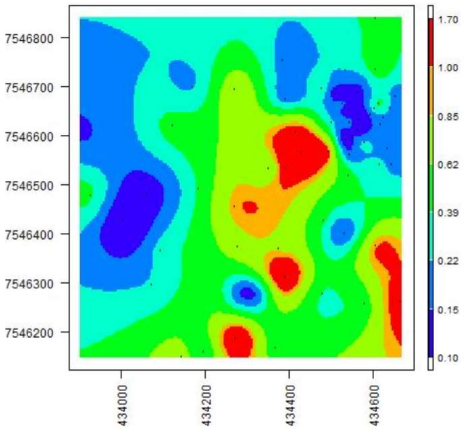
Grid plots

- Dot maps and IDW interpolated maps
- Absolute concentrations with percentile stretching
- Log(abs)
- clr
- Response ratios
- Files can be exported as pdfs



Tiira Au-prospect,
Kittilä,
Common juniper,
Needle,
2015,
As (ppm)

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Questions?

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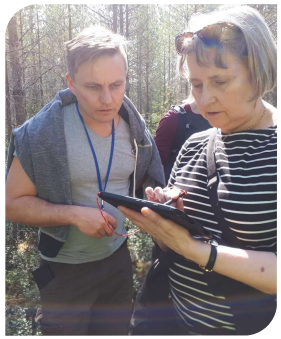
Up Deep

Development of GEM web tool

- **Specifications** by Scandinavian GeoPool, GTK, TUWien, VTT
- Coding of the **data collection** part from scratch by VTT
- **Data analysis** part is based on R-codes by Vienna University of Technology and GTK, sitting on OpenVA platform
- Future functionalities
  - Expand the usability of wider range of sampling materia
  - Bring in the more advanced multi-variate compositional data analysis tehniques
  - Interactivity between maps and diagrams



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Surface geochemistry in exploration: some thoughts on practical approaches

Nick Cook
President Exploration
Mawson resources Ltd.
Brisbane, Australia

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Up Deep

"Not Europe"….. !!

Reality for Mawson…..

Reality for Mawson…..

Goals of the UpDeep project

- **Create surface geochemical exploration consulting service business to Europe aiming at deep exploration**
- Promote the geochemical deep exploration concept using selective and weak leaches of soil horizons and plant tissue
- Facilitate the use of surface geochemistry in exploration companies
- Provide geochemical methods for green field exploration
- Facilitate ore discoveries at depth

Goal for Mawson: drill lower risk targets with minimal impact

Outcomes

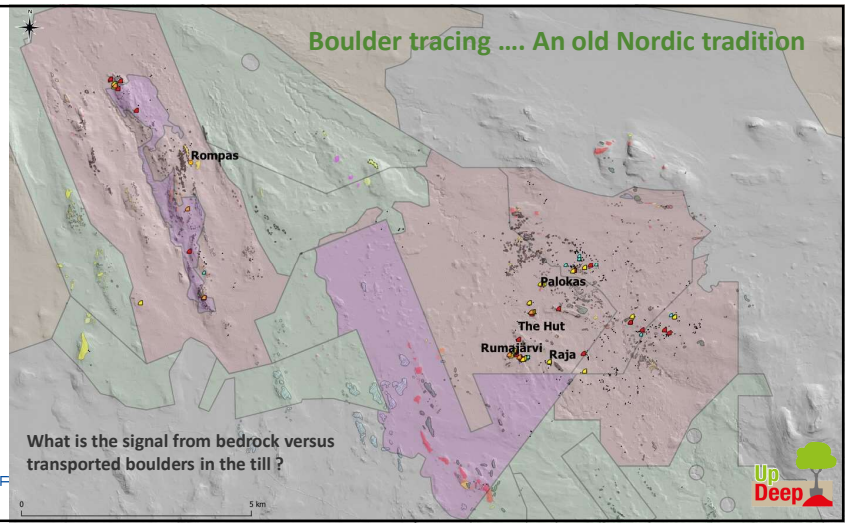
- Surface geochemical consulting service
- Streamlined sampling and sample preparation protocols
- Protocol for standard reference material bank
- UpDeep Web Tool for exploration data management and analysis
- UpDeep Online Statistics Tool

Some considerations...

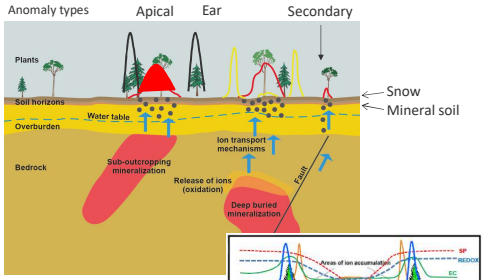
"Weathering" – chemical dispersion

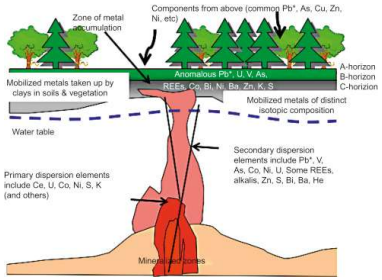
Effect of glaciation - Physical dispersion

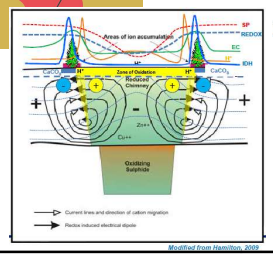
Boulder tracing …. An old Nordic tradition



"Standard models" – thanks Pertti !



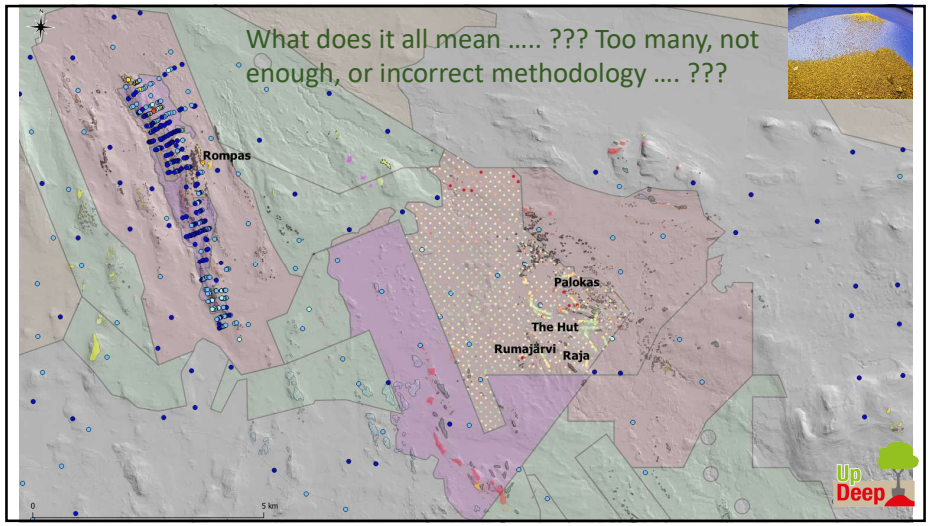




https://www.sciencedirect.com/topics/engineering/uranium-deposits

Mawson's measurements…..

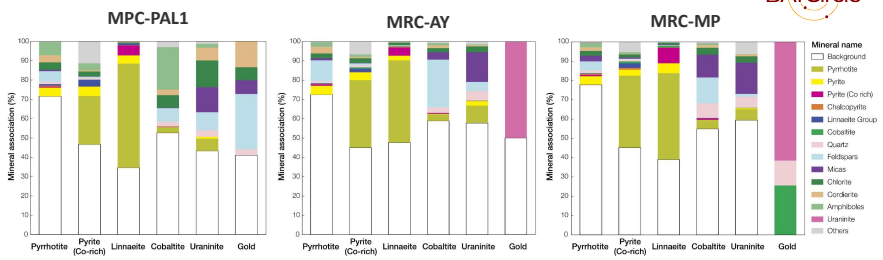
"Ah"
Till sampling
Base of till drilling
Rock chips
Panning
"Microbiological gold"



Mineral associations by ore-type

GTK

BATCircle



How should we use these data in understanding the "weak geochemical response" ??

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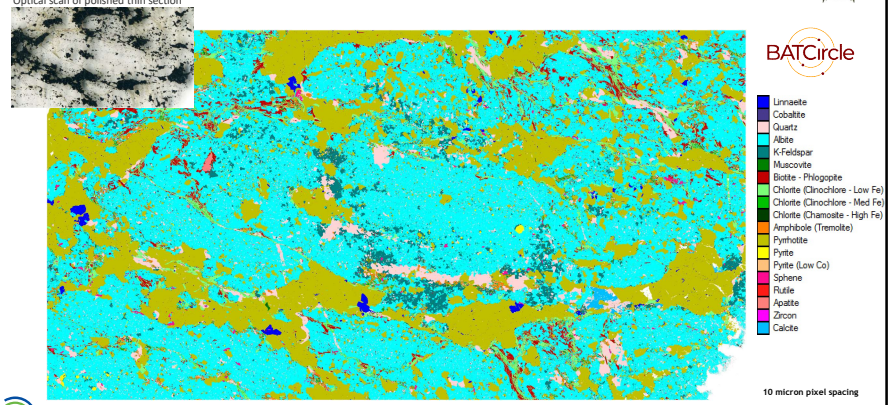
A step to a rock ….. a mineral map

GTK

BATCircle

Optical scan of polished thin section



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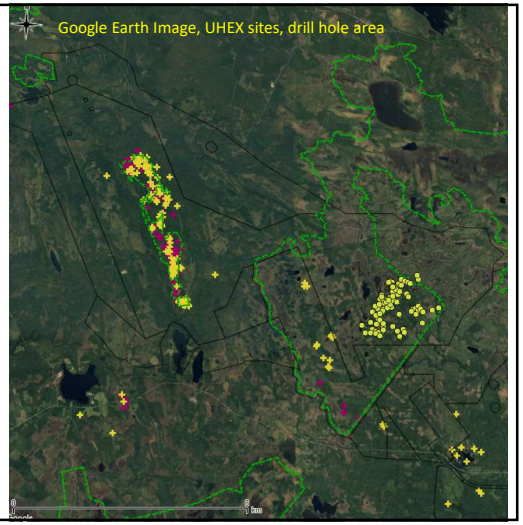
A diversion to plants...

Note the location of the UHEX listed plants (in this case orchids that grow on alkaline ground conditions – "+" markers). Planned drill sites for one season as yellow dots



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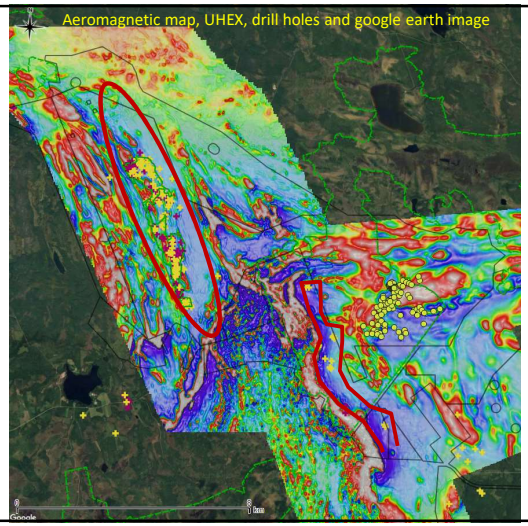
A diversion to plants...

Airborne magnetic image over google earth.

Note that the lines of UHEX sites closely follow the trends in the magnetic data – this reflects the different rock types and shows where similar rocks may occur.

Note the distribution of orchids in the red outlines – parallel to the magnetic lines evident in the image



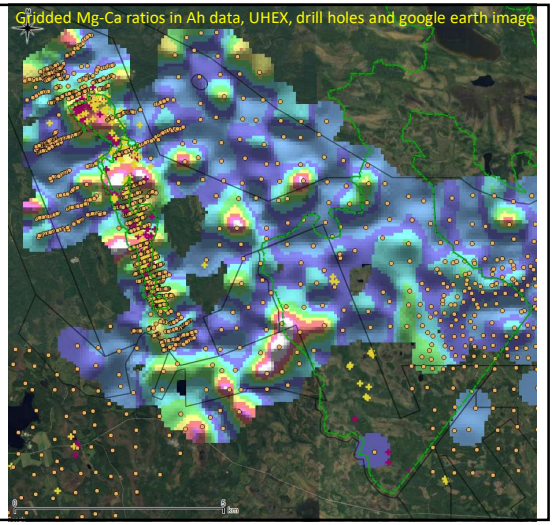
Little bugs and metals ... microbial activity

We know this can work on a large scale....

A diversion to plants...

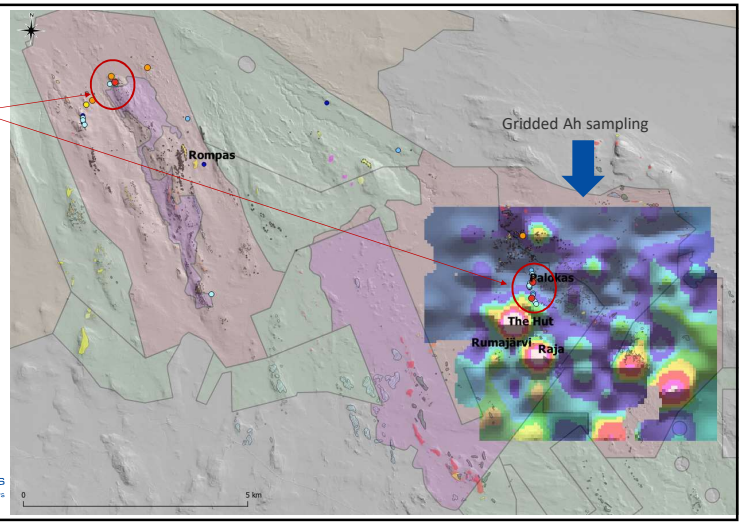
This image shows the distribution of Mg-Ca in near surface samples (Ah). The dots represent the sample sites and yellow-red-white are the highest areas. Note the strong trend at Rompas and the lack of any high values in Kairamaat.

The high Mg-Ca reflects dolomite in the bedrock and produces more alkaline conditions in the mires and soils.

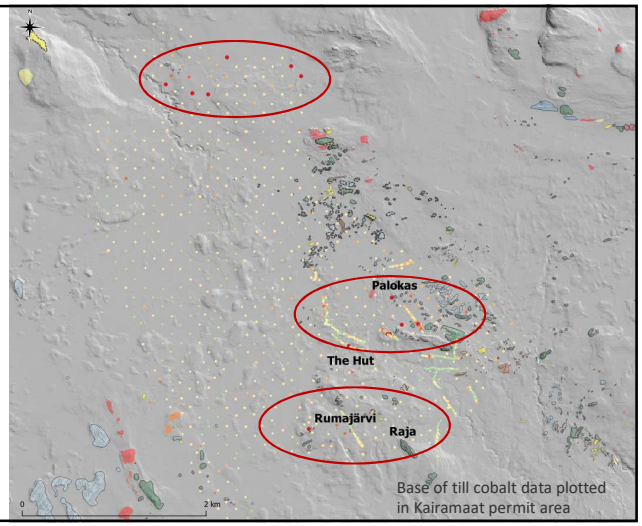


Microbial sampling for gold....

But, we knew it was there!



- Reconsider these data from BOT drilling – do physical or chemical processes dominate the signal ?
- How do we normalise the results?

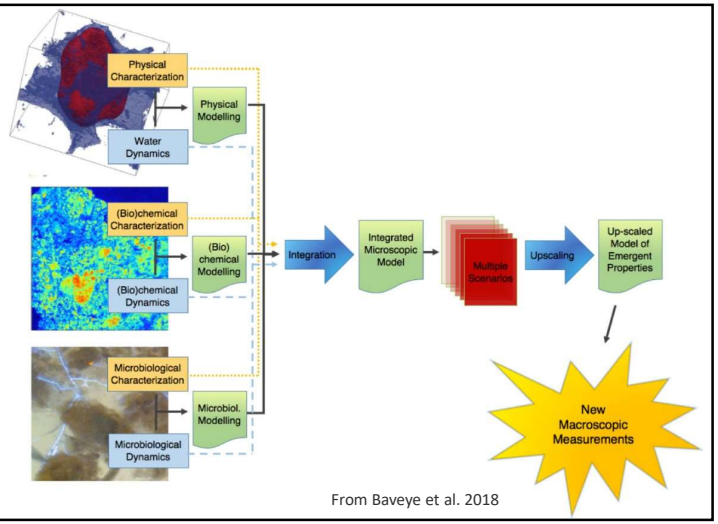


Base of till cobalt data plotted in Kairamaat permit area

What do I see as the next key aspects to understanding low level geochemical sampling?

- The most obvious is to continue to increase the signal to noise ratio
  - It is exciting to see UpDeep developing such methods
- More detailed use of rock weathering studies to determine and calibrate release of metals into the water column
- Understanding the localised geochemical and microbial controls in soils and around root structures of "the best trees for sampling"
  - What are the variables in the control of uptake of metals by the roots ?
- An efficient method to normalise anomalies on the basis of:
  - Plant species
  - Local pH
  - Bedrock control
  - Any others ?
- How are we going, and are we getting there ?

Do we have to go to this level NEXT?



From Baveye et al. 2018

Thanks to the UpDeep team, and my best wishes to all

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Questions?

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UpDeep in the context of EIT RawMaterials

25 March 2020 | Olli Salmi and Patrick Nadoll

EIT RawMaterials is supported by the EIT, a body of the European Union

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UpDeep project from the perspective of the EIT Raw Materials

Olli Salmi
Senior Scientist
Baltic Sea Co-Location Centre, EIT Raw Materials
Espoo, Finland

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KEY FOCUS: LIGHTHOUSE PROGRAMMES

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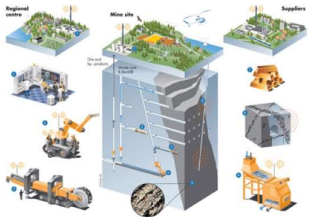
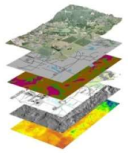
SUSTAINABLE DISCOVERY AND SUPPLY

- **Challenge:** European Industries depend on raw, processed and advanced materials but these are not produced locally therefore the EU has a significant import dependency and is vulnerable to scarcity and supply shortage. Resources, both primary and secondary, exist in Europe but these are not fully exploited because of public concern over the sustainability of exploration, mining and processing operations.
- **Approach:** Provide technological innovation to develop exploration, mining and processing capabilities. Focus on exploration, mining and processing of primary and secondary raw materials, and on public acceptance.
- **Impact:** This Lighthouse will promote the benefits of a strong minerals and materials sector in modern society and a transition towards a green and circular economy.





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Sustainable Discovery and Supply – Portfolio Analysis

Themes	Existing Up-scaling and Education (red) projects that match specific topics.
Geology	MAP GeoKTPro 2.0 +3 2D3Dscopy, EnEx, SIT4ME, **UpDeep**
Technology	RAMES EuGeLI, LiRef, Micor Ecos, Morecovery, RedScope, Rostar, ATHY, X-TRIM Avar, Rigat, Reclamet, Silesi, COPPLEX, FLAME, NITREM OPMO AutoBoltReload, HARSHWORK, HoloMine Monicalc, GREENY, Whisper BlueHarvesting MiReBooks, VR-Mine, SmartHub Supply chain, logistics MaMMa, Rock Vader ANCORELOG AMCO, R2R=GeoMet, RawMatCop, MULSEDRO, UNDROMEDA
Environment, Legislation and Society	MineService Closurematic, STINGS EWT-Cyncor, SERENE, SO4Control FIREM-II MINERS, SafeMine, SafeDeepMining, Iris New Eco, Go 4-0
Economy	InvestRM, RESEERVE, RE-ACTIVATE Lobbying to support price of reprocessed resources
Education	TrainCall Create know-how BRIEFCASE TravelEx, RawMatCop, AWARD Regulation Innovation skills Understand the product and the process EMC-GCP

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SUSTAINABLE DISCOVERY AND SUPPLY – PORTFOLIO THEMES & TOPICS

Themes	Specific topics
Geology	Resource assessment Enhanced exploration and resource characterization
Technology	Create new equipment/new process Waste collection, By-product and reprocessing Improve current process cost Mining & Processing 4.0 Improve the operation by decreasing the amount (E &W) Digitalisation Supply chain, logistics Mobile equipment, produce close to resources Drilling and core logging IT tools, online analysis Remote Sensing & Drones
Environment, Legislation and Society	Engaging with authorities Tailing management and valorization Treat water for reuse Health and Safety Use excess of Energy in the process Industrial Symbiosis
Economy	ESEE develop markets & Networking Lobbying to support price of reprocessed resources
Education	Adapt skills to 4.0 Create know-how Awareness of stake holders Outreach Regulation Innovation skills Understand the product and the process Create education program fitting the needs

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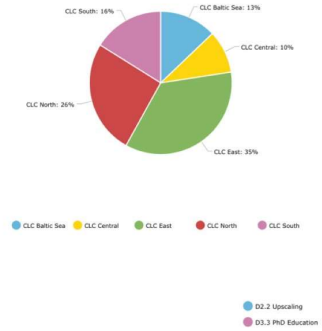
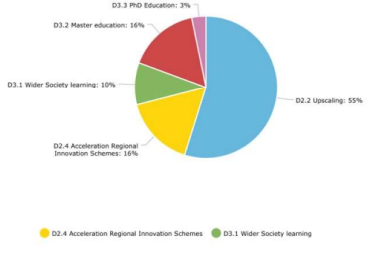
LIGHTHOUSE PORTFOLIO – EXPLORATION PROJECTS





D2.2 Upscaling
D2.4 Acceleration Regional Innovation Schemes
D3.1 Wider Society learning
D3.2 Master education
D3.3 PhD Education

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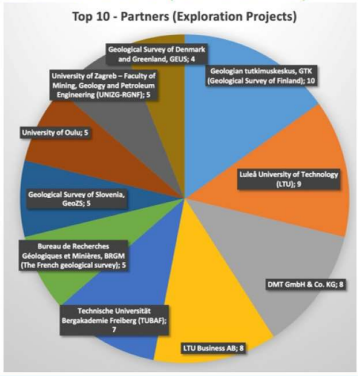
LIGHTHOUSE PORTFOLIO – EXPLORATION PROJECTS (ONGOING)

Short Title	Title
2D3Dscopy	Resource Characterization: from 2D to 3D microscopy
ANCORELOG	ANCORELOG - Analytical Core Logging System
EC-Geo-Sustain	European MSc in Geomatics for Sustainable Mineral Resource Management
EnEx	Enhanced exploration
ENGIE	Encouraging Girls to Study Geosciences and Engineering
ExpCORE	ExpCORE Masters programme in exploration
FARMIN	Field augmented reality in mineral exploration and mining
I-EDDA-RS	Innovative Exploration Drilling and Data Acquisition Research School: I-EDDA-RS
I-EDDA-TC	Innovative Exploration Drilling and Data Acquisition Test Center
InnoLOG	Innovative geophysical logging tools for mineral exploration
inSPECtor	Integrated spectroscopy sensor system for laser-induced fluorescence and hyperspectral imaging
InvestRM	Invest RM: Multifactor model for investments in the raw material sector (EIT RIS activity related to action line II)
iTARG3T	Innovative targeting & processing of W-Sn-Ta-Li ores: towards EU's self-supply
MAP	Mineral Resource Assessment Platform
MArctic	Master in Arctic Mineral Resources
MineHeritage	Historical Mining – tracing and learning from ancient materials and mining techn
MinExTarget	Enhanced Use of Heavy Mineral Chemistry in Exploration Targeting 20190111_140041
MULSEDRO	Multi-sensor drones for geology mapping
MuVerDrone	Multi-Versatile Exploration Drone (MuVerDrone)
OpenYourMine	A Master education project dedicated to mineral resources and sustainability
PAIRED-X	Portable Analyzer combining fluoREscence and Diffraction of X-rays
RAMES	Raw Materials Exploration and Sustainability (RaMES)
RAMSES-4-CE	RAMSES - Raman spectroscopy integrated sensor system for the CE
REEBAUX	Prospects of REE recovery from bauxite and bauxite residue in the ESEE region (EIT RIS activity related to action line II)
RESEERVE	Mineral potential of the ESEE region (EIT RIS activity related to action line II)
RIS-CuRE	Zero waste recovery of copper tailings in the ESEE region
SIT4ME	Seismic Imaging Techniques for Mineral Exploration
TravelEx1	Underground resources travelling exhibition
T-REX	Timegated Raman for Exploration
UNEXUP	UNEXMIN Upscaling
UpDeep	Upscaling deep buried geochemical exploration techniques into European business



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Questions?

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Questions and comments

Moderator

Vesa Nykänen
Research Professor, Geoinformatics
Information solutions, GTK
Rovaniemi, Finland

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Closing words

Vesa Nykänen
Research Professor, Geoinformatics
Information solutions, GTK
Rovaniemi, Finland

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Up Deep

Thank you for you attention!

- Business
  - Jens Rönnqvist, jens.ronnqvist@geopool.com
- Project management
  - Vesa Nykänen, vesa.nykanen@gtk.fi
- Science
  - Maarit Middleton, maarit.middleton@gtk.fi

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geopool LTU BUSINESS AB

http://projects.gtk.fi/updeep

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