3–4 dimensional modelling principles

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Weihed firmly believes that the EU is strongly underexplored and that further initiatives related to understanding the mineral resource base of Europe will lead to reduced import dependence.
3–4 dimensional modelling, principles, WP2

Why?
What?
How?
and for whom…
Hi!
Did you know that each of us will, during our life time use...
...more than 1700 tonnes of metals and minerals!
High-density means a population density of 50 people/km² or higher. Share in world population: 13% industrial, high density, 6% industrial, low density, 62% rest of the world, high density, 6% rest of the world, low density. Source: Krausmann et al., 2008
Significant mineral deposits: World All years

Source: Richard Schodde, MinEx consulting, 2011
Why?

Significant mineral deposits: World Discovered since 2000

Source: Richard Schodde, MinEx consulting, 2011
District maturity and the need to chase deep targets
Depth to top of ore body for (>0.1 Moz) gold discoveries made in the Western World

Note: Chart refers to the initial discovery in a camp and so excludes subsequent brownfield discoveries which are often deeper

Source: Richard Schodde, MinEx Consulting Jan 10
Exploration investment, why is Europe lagging behind?

- European exploration approximately €400 million in 2011. An all-time high, but only 4% of global (RMG 2012)
- Sweden, Finland, Norway and Greenland and Poland, accounted for €288 million, or more than two thirds of total European exploration expenditure (RMG 2012)

Few majors active in Europe

- Access to land limited in many parts
- Social license to operate limited in many parts
- Legislation unclear in many parts
- Political support for mining lacking in many parts
- Better value for money elsewhere…
Non-ferrous Exploration expenditure 2011

Sources: Metals Economics Group, Raw materials Group, Wikipedia

Figures should be treated with care since the different sources have not exactly defined the geographical extent of the regions. In the EU figures also ferrous exploration is included.

Why?
• Fennoscandia: Skellefte-Vihanti-Pyhäsalmi
• Foresudetic monocline
• Hellenic belt
• Iberia

collectively contains bulk of European metal extraction
Lapland (Fe)

Skellefte-Pyhäsaimi (Cu, Zn, Au, Ni, Co)

Bergslagen (Fe, Zn)

Irish (Zn)

Foresudetic basin (Cu, Co, Pt, Re)

Carpathians (Pb, Zn, Au)

Balkans (Cu, Au, Sn)

Iberian Pyrite Belt (Cu, Zn, Sn)
active volcanism and deposition of massive sulphides on the seafloor!

1900 million years ago in the Skellefte district
volcanism ceased and massive sulphides were buried under deep sea sediments...

1850 million years ago in the Skellefte district
1700 million years ago in the Skellefte district

Deformation and magmatism...
Now in the Skellefte district…

a first 4D model!

Kristineberg: >20 Mton ore, known down to >1200m

and 1700 million years later after erosion…
Base metal ore in the Skellefte District, northern Sweden, divided into 50-meters depth intervals (mined and reserves)

Source: Boliden, L. Widenfalk
How?

- 3-dimensional database
- 3-dimensional modelling
- 4-dimensional modelling
- Predictive modelling
• **The database structure** for the 3D data was developed by TU BAF.
• A spin-off company now developed by former students from TU BAF.
• 3D Geoscience Information System GISTriX compiled previously by the Geoscience Mathematics and Informatics Group of TU BAF.
• Geo-models with spatial and non-spatial query functionality necessary to analyze and interpret 3D data and models.
• Plug-in for the 3D modelling software "gOcad 2.0" which will be the primary modelling software of ProMine.
• Combines modelling system with 3D GIS functions, data management using XML database server and spatial query computation supported by application server.
• The database model was uploaded to the Promine portal as deliverable 1.
The **Three-dimensional modelling** aimed to model the crust down to mineable depth, typically upper 2 000 m.

The modelling was carried out primarily in the gOcad software, but also in software such as GEMCOM Surpac.

The concept of compiling the 3D models were different in the different mineral belts mainly due to different geology, different availability of geophysical data, different spatial resolution of data and different access to data.

The basic principle for the modelling was to combine geological information from surface, drill cores/holes, underground exposures with geophysical data, both airborne, ground and drill hole measurements.

To simplify modelling workflows the regional scale modelling volume was split up into several semi-regional scale sub-projects.

For some belts we also developed uncertainty models.

The 3D models (some 3D-pdfs) for the different belts were uploaded to the Promine web GIS as deliverable 2.
• **4D-modelling** added the time aspect to the 3D-models and aimed at visualizing the geological history in the district as a support for ore targeting.

• Four-dimensional modelling was carried out utilizing the MOVE software package in the Skellefte district.

• In the Foresudetic monocline the 3D model was restored and decompacted using the surface Kine3d gOcad plug-in. Temperatures, pressures, hydro-fracturing probabilities, oil and gas maturation during the burying history had then been reconstituted using the PetroMode 1D software.

• Animations were uploaded in the Promine web-portal as Deliverable 3.
• **Three-dimensional predictivity** maps were the final deliverable of the work package.

• In the Skellefte district, in order to visualize the predictivity for VMS deposits, values from one to five were assigned on the relevant regions of the model, based on the correlation between distribution and shape of VMS deposits, and regional deformation patterns.

• For the Kupferschiefer area the predictive model was built using geological, structural and geo-variable descriptive predictors. Several predictive methods were compared including the Support Vector Machine (SVM) and the Logistic Regression Method (LRM).

• Some predictive models were uploaded to the Promine web portal (some IPR issues are at play for these models).
• The results from the three- and four-dimensional modelling in Promine are proof of concept.

• The results will be used by industry partners to better target new blind mineral deposits, they will thus help to improve both resource efficiency and energy efficiency in the exploration stage of the raw materials value chain.

• It is STRONGLY recommended that the 3-dimensional models are also utilized for land use planning by local, regional, national and EU-authorities.

• It is further recommended that the results form the point of departure in further pan-European initiatives on Raw Materials, i.e. EIP RM, EIT KIC RM, ERA-MIN a.o.

• Finally the results are a direct response the RMI first pillar on securing a sustainable supply of raw materials from domestic sources.
Conclusions…

- The results from the three- and four-dimensional modelling in Promine are proof of concept.
- We have shown that it is possible to build robust three-dimensional models of major mineral belts.
- By using different approaches it is also possible to carry out four-dimensional modelling to help exploration industry with better targeting.
- The three-dimensional predictive models for the mineral belts clearly show the potential of undiscovered resources in the various parts of Europe.
- The Promine project, with respect to the aims of WP2 to improve the knowledge base and resource base for major as well as minor commodities, has thus fulfilled its goals.
- The results serve as a baseline study for future, more full scale, pan-European projects that could be developed, for instance, in the EIP on Raw Materials.
The Promine WP2 team firmly believes that the EU is strongly underexplored and that further initiatives related to understanding the mineral resource base of Europe will lead to reduced import dependence...

and Promine has provided a starting point for a future 3D Europe...

Thank you all, and many thanks to GTK who dared to coordinate this project!