A pan-European Potential Map of Reserves in Copper Base Metal associated to Kupferschiefer in Central Europe

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Why a Pan-European Potential Map of Reserves?

EU consumes 20 - 35% of the most important base metals in the world

<table>
<thead>
<tr>
<th>Metal</th>
<th>% Global</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>9.4</td>
</tr>
<tr>
<td>Titanium</td>
<td>8.7</td>
</tr>
<tr>
<td>Lead</td>
<td>7.3</td>
</tr>
<tr>
<td>Copper</td>
<td>6.0</td>
</tr>
<tr>
<td>Chromium</td>
<td>5.6</td>
</tr>
<tr>
<td>Iron</td>
<td>2.2</td>
</tr>
<tr>
<td>Aluminium</td>
<td>2.2</td>
</tr>
<tr>
<td>Nickel</td>
<td>1.7</td>
</tr>
<tr>
<td>Gold</td>
<td>0.8</td>
</tr>
</tbody>
</table>

EU’s own mine production

EU’s import of metals and minerals is € 23 billion

More information at: [http://www.ngu.no/](http://www.ngu.no/)
Europe import dependence is over 80%
Ore Kupferschiefer
Sediment-hosted polymetallic deposit

Mineralization (copper sulfides)
Basement-cover interface
Black shales and Red beds
Thickness of ~1 meter.

Lubin-Sieroszowice mining
Fourth copper source in the world
and the first in silver.
Distribution of Cu tonnage vs. ore grade

High grades

Kupferschiefer

Medium grades

Sulmierzyce

Low grades

Porphyries

Porphyries

Low grades

Porphyries

Medium grades

Sulmierzyce

High grades

Kupferschiefer

Grade (%Cu) vs. Million tons of Cu

100
10
1
0.1
0.01
10,000
1,000
100
10
0.1
0.01
0.1
1
10
100
1,000
10,000
100,000

ProMine April 2013, Levi (Finland) - 3&4D Geo modeling New Tool for Targeting Mineral Deposits
A regional scale 4D reconstitution of the North German-Polish Depression was made to better understand the burial, deformation and natural hydro-fracturing history of the intra-basin sediment-hosted ore deposits of the Kupferschiefer (Lubin, South-West Poland).
4D modeling of the Kupferschiefer

- Middle Odra Fault System
- ForeSudetic Monocline
- Lubin Deposit
- Cenozoic rocks
- Triassic rocks
- Zechstein
- Rotliegendes
- Carboniferous

Map legend:
- Cretaceous
- Trias
- Zechstein
- Rotliegendes
- Lower Paleozoic

ProMine April 2013, Levi (Finland) - 3&4D Geo modeling New Tool for Targeting Mineral Deposits
What is 3&4 Modeling?

Mejia et al (2012)

2.5D restoring

Removed layer

1D decompaction

V.W

V.W

V.W

Decompacted layers

2.5D decompaction

Solid phase mass balance equation

Gopy routine
Kine 3D-2 reconstitution of the burial history

Hydrofracking Index $HF$

$$HF = P_f - (T + \sigma_n)$$

$P_f$ = fluid pressure
$T$ = rock cohesion
$\sigma_n$ = normal stress

Mejia et al (2012)
If HF > 0 => mineralized zones in Cu in the Zechstein series
1 – Basin subsides
2 – Trapped Pressure $P_f \uparrow$
3 – Basin uplift $\Delta P_f \uparrow$
   $\Delta P_f - (T + \sigma_n) > 0$
   rock cohesion
4 – Hydro-fracking
5 – Fluids expel
6 – Hydrothermal cells kept under the evaporite cap
7 – Metal remobilization by salted brines and sulfur reduction

Thermal basin reconstitution using PetroMod
Over-pressure conditions using PetroMod
• 3D models coupled to 4D restoration help in understanding the formation of deposits

• Hydro fracturing index estimated from the failure conditions induced by over-pressured trapped fluids seems to correlate with mineralized zones, and can be used as target new potential areas

• The Zechstein evaporitic series behave as an impermeable screen preventing the fluid from being expelled during the formation of the deposits, forcing hydraulic fracturing to occur in the lower layers
How to Estimate the Potential in Cu for Europe

- Use results obtained from the 3&4 Modeling
- Define predictive variables (i.e. geology, rock types, structural and favorable environments)
- Use this knowledge to predict potential in under explored areas in Europe (Pl, D, Dk, …)
- Estimate potentiality using occurrence probability
- Estimate in-situ potential ore tonnage & values
Comparing Several Predictive Models

- Purely statistical approach
- Weight of evidences
- Logistic Regression Method (LRM)
- Support Vector Machine (SVM)
Potentiality

Potential Resources in Cu kg/m²

Cu value
In kg/m²

- < 25
- < 50
- < 100
- > 100

150km

After Mejia et al. (in preparation) (In coll. J. Hartsch, A. Zielinska, JJ Royer)
Values

Values in Billion €

Σ = 2,100 G€

(After Oszczepalski & Speczik, 2011)
Weights of Evidences

After Mejia et al. (in preparation) (In coll. J. Hartsch, A. Zielinska, JJ Royer)
Map of Predictors for the training area

After Mejia et al. (in preparation) (In coll. J. Hartsch, A. Zielinska, JJ Royer)
List of Predictors

- Moho Depth
- Distance to erosion surface
- Distance to Faults
- Zechstein thickness
- Rötliegend Depth
- Anomalous maps (Pb, Zn)
- Base of the Zechstein

Restricted to Germany and Poland due to lack of reliable information

Software development: Prediction maps built in Gocad, SVM performed in a Gocad plug-in using R and Python
Predictive Map obtained using Logistic Regression (LRM)

Mineralized locations (training dataset)

Predicted value
Pr(Cu > 10 Kg/m²) > 90%

Mineralized locations (cross-validation)

Cu contents (2-10 Kg/m²)

100km
Predictive Map obtained using Support vector Machine (SVM)

Graben of Schneverdingen

Germany

Aderstedt -Bernburg

Korbach

Richelsdorf

Rhön-Spessart

Mansfeld -Sangerhausen

Dahme

Spremberg -Weißwasser

Boleslawiec -Zlotoryja

Lubin -Sieroszowice

Poland

Error type I (%) = 21.4
Error type II (%) = 2.1

Mineralized locations (training dataset)

Predicted value
Pr(Cu > 10 Kg/m²) > 90%

Mineralized locations (cross-validation)

Cu contents (2-10 Kg/m²)
ProMine April 2013, Levi (Finland) - 3&4D Geo modeling New Tool for Targeting Mineral Deposits
# Cu, Ag, Re potential in Central Europe

<table>
<thead>
<tr>
<th></th>
<th>Area</th>
<th>Tonnage in Metal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface (in km²)</td>
<td>Cu (in Mt)</td>
</tr>
<tr>
<td>Known deposits</td>
<td>2,640</td>
<td>26.4</td>
</tr>
<tr>
<td>Potential¹ &gt; 10kg/m²</td>
<td>13,400</td>
<td>134.0 ±50</td>
</tr>
<tr>
<td>Potential² 2-10kg/m²</td>
<td>63,715</td>
<td>318.6 ±250</td>
</tr>
<tr>
<td>Total</td>
<td>79,755</td>
<td>479.0 ±300</td>
</tr>
</tbody>
</table>

Assuming: a constant Ag/Cu ratio at 5,417ppm; 50ppm of Re per Cu metal.

¹Equivalent in size to two El-Teniente (Chile), ²Equivalent to five El-Teniente deposits!
# Metal potential Values in Central Europe

<table>
<thead>
<tr>
<th></th>
<th>Value of Metal</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cu (in G€)</td>
<td>Ag (in G€)</td>
<td>Re (in G€)</td>
<td>Total (in G€)</td>
<td></td>
</tr>
<tr>
<td><strong>Known deposits</strong></td>
<td>152</td>
<td>128</td>
<td>42</td>
<td>322</td>
<td></td>
</tr>
<tr>
<td><strong>Potential &gt; 10kg/m²</strong></td>
<td>775 ±290</td>
<td>648 ±240</td>
<td>213 ±80</td>
<td>1,636 ±610</td>
<td></td>
</tr>
<tr>
<td><strong>Potential 2-10kg/m²</strong></td>
<td>1,840 ±1,445</td>
<td>1,540 ±1,210</td>
<td>507 ±400</td>
<td>3,887 ±3,050</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2,767 ±1,735</td>
<td>2,316 ±1,450</td>
<td>762 ±480</td>
<td>5,845 ±3,660</td>
<td></td>
</tr>
</tbody>
</table>

Assuming: Cu price at 7,500$/tCu; Ag price at 892$/kg; Re price at 4,100$/kg.
Comments

• Known mining areas predicted by the SVM
• Discovery of new potential (Schneverdingen Graben)
• Demonstrate the reliability of the SVM method
• Large areas (Germany, West of Poland) are pointed out as potential (Cu >10kg/m²)
• Several large areas appear to have potential but with lower copper content (< 10kg/m²)
Recommendations & Messages

• **To the industry:** Take claims in prospective areas before other actors do!

• **To politics & stakeholders:** Urgent need to lower the price of energy in order to restart industry in Europe (like in USA)

• Only the upper 200m subsurface have been exploited in the past in Europe. So it remains ore at least down to 1000m to be explored! (five times what has been extracted since the beginning)

• Restart exploring Europe!
Exploitation Plan

- Explore new technologies for in-situ bio-leaching recovering of metal in deep areas
- Road map for exploring the new targets point out during this project
- Agreements with partners such as Lunding Mining, INMET, and KGHM, ...
- On going plan to exploit results obtained during the training courses (discussion with Paradigm) for industrialization of the lecture course material (Planning 1 year and half from now)
- Publications plan for diffusing the results obtained to the scientific community, stake holders and government
• Benefits to the public at large – the project demonstrates that European lands host in-situ mining treasures evaluated at over than 5,000 billion euros
• Return on investment - Compared to this valuable potential discovery, the EU money invested in the research project was maximized (less than 2 million euros with a EU contribution of 50% i.e. less than 1/5,000,000 of the in-situ values)
• Creation of a start-up with 7 employees (Freiberg, D)
Future Action Plan

- Many European environmentalists & activists are surfing on fears of the public trying to ban every activities which can restart European industry. They have a strong influence in the European Parliament.

- Scientists have the duty to raise their voices and tell the truth based on facts and not on believes, must encourage action to inform the public at large about the reality and must fight these “obscurantist” & “religious attitudes”

- Needs for action plans to convince European parliamentary that extractive activity and mining are not yet dead in the EU but that there still exists plenty of valuable targets and new opportunities.
• Finland and Sweden reach the first rank in the world classification of best secure investment countries (FORBES). Quebec, the first one last year, falls to the 11th rank due to uncertain mining regulations due to activists pressures.

• Foreign companies (Australian, Canadian, etc…) are investing in mining activities in Europe and targeting areas such as Fenno-Scandinavia, Central Europe and Iberian belts, among others.

• New technologies (and research) are needed to meet the public and industrial requirements especially in the mining industry (“green mining”)
Conclusions (II)

THANKS!