Exploration for Base Metals in the Harz Mountains, central Germany

The Gosetal anomaly in the Harz Mountains, a Rammelsberg twin?
Executive summary

Harz Minerals GmbH, a fully owned subsidiary of Scandinavian Highlands Holding A/S in Denmark, holds an exploration license for a large part of the Harz Mountains in central northern Germany, covering ca. 1250 km²

A sizable, but previously unknown airborne TEM anomaly was found in the Gosetal, two kilometres west of the historic Rammelsberg mine.

The anomaly has the potential of representing a World Class Deposit

The TEM anomaly is located in the same middle Devonian stratigraphic sequence as the mineralisation in the Rammelsberg mine

Soil Gas Hydrocarbon geochemistry analyses from the Gosetal area give a strong indication of a SEDEX deposit

Geophysical and geological modelling suggested two alternative solutions for the TEM anomaly: a shallow conductor (100 - 400 m) or a deep conductor (500 - 800 m) with interference of surface infrastructure

Two phases of exploration drilling have been carried out. Down-hole geophysics is being carried out to define the next drill target
The Harz Mountains in central northern Germany

The Harz license is about 60 to 100 km southeast of Hannover in northern Germany
Introduction

The Harz is a very prospective region and mining for SEDEX and vein type mineralisations has occurred for more than 1000 years

The Harz Minerals licence includes the now exhausted World Class Rammelsberg mine

Airborne and ground EM surveys indicate the presence of a conductor in the same stratigraphic level as the Rammelsberg mineralisation, two kilometres west of the mine

The footprint of the Gosetal anomaly is of a similar size as the combined Rammelsberg ore bodies

The Gosetal anomaly lies in the same sub-basin on the margin of the Devonian Goslar Trough

The TEM anomaly (the Gosetal anomaly) coincides with a pronounced soil gas hydrocarbon (SGH) geochemistry anomaly that suggests the presence of a SEDEX mineralisation

The Gosetal anomaly has the potential of a World Class Deposit
The Harz license

The 1250 km² license covers much of the historic Harz mining district.

Several hundreds smaller historic mines in the area are not indicated.
Framework and setting of the exploration area

Very stable political and judicial environment in Germany

Positive local political attitude towards the project

The target area is located two kilometres south of the historic mining town of Goslar

Good infrastructure – industrial area and railway system within few kilometres

Some of the industries are remnants from the mining era
Rammelsberg mine

A classic SEDEX deposit, situated at a shelf edge on the transition between the Goslar Trough (Middle Devonian shales) and the West Harz Rise (lower Devonian sandstones and shales)

Source: Large and Walcher, 1999
Rammelsberg mine
More than 1000 years of mining history

Closed in 1988 after exhaustion of the resources
Last operated by Preussag Metal AG since the 1920’s
Now a UNESCO World Heritage site
Rammelsberg mine

Total production: 27-30 M tonnes ore
Average grade:
2% Cu, 6% Pb, 14% Zn, 1 g/t Au, 140 g/t Ag and 20% barite

(Large and Walcher, 1999)
Rammelsberg mine

Gross in-situ value
(total production – present day value):
26,8 billion USD
(= 894 USD/tons) – excluding barite

(based on spot prices,
LME, 2 March, 2011)
# Economic potential of the Harz project

<table>
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<th>Base case</th>
<th>Sensitivity analysis</th>
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<td></td>
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<td>Tonnage (Mt)</td>
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<td>13 404</td>
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<tr>
<td>Net smelter value: mill USD</td>
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<td>7 842</td>
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<td>Net CF before int &amp; tax mill USD</td>
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<td>Gross In-situ Value: USD/t</td>
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<td>Net smelter value: USD/t</td>
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<td>Net CF before int &amp; tax USD/t</td>
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Economic potential of a Rammelsberg-like deposit (based on spot metal prices of 2 March 2011)
The base case shows a net cash flow before interest and taxes (corporate tax and royalties) of USD 13 billion

*Barite is not given any value in this calculation
Classification of mineral deposits
Based on determined resources of 230 deposits (gold and base metals)
The Rammelsberg ore deposit

The Rammelsberg ore (purple color) occurs in an overturned, isoclinal syncline. In the fold hinge, the ore body increases in thickness to ca. 40 m, from ca. 8 m on the limbs. (source: Preussag archives)

Section through the Rammelsberg mine (Preussag, 1984)
Recent exploration activities in the Harz

Data mining - 2008-2009
- acquisition of Preussag data
- collection, digitising and evaluation of data
- entering in GIS and database systems
- geological 3D modelling

Airborne TEM survey in the Goslar Trough and West Harz Rise – May 2008
- outlining of the Gosetal anomaly
- Ground inspection of the area – mapping and sampling
- Maxwell modelling of the TEM data

Soil Gas Hydrocarbon geochemistry – spring 2009

3D modelling of a shallow conductor in the Gosetal area – combining geological and geophysical data – spring 2009

Two phases of exploration drilling - three holes (245-372m) in the fall of 2009, two holes (677 and 750 m) in the winter of 2010/2011

Down hole TEM surveys during the drilling campaigns. Between hole IP survey in February 2011
Airborne TEM survey
140 km² survey of the Goslar Trough and West Harz rise, May 2008

= Rammelsberg
The Gosetal anomaly

Almost 2 km long footprint
1-2 km west of Rammelsberg
Strong conductor
Unique in the surveyed area

= Rammelsberg

1D inversion - Resistivity slice 200-220 masl.
The Gosetal anomaly lies within the Wissenbacher shales, similar to the Rammelsberg ore deposit. Geological map from Preussag archives, 1:5000.
New geological model

Observations:

The Rammelsberg ore bodies are bound to the north and south by two large faults, named the Eastern and Western Main Faults. Much of the Gosetala anomaly is constrained between the same two faults. The northern limit of the Gosetala anomaly coincides precisely with the Eastern Main Fault. The thickness of the middle Devonian sediments increases rapidly from north to south of the Eastern Main fault.

Model:

The new geological model assumes that the two main bounding faults are reactivated faults that formed the boundaries of a sub-basin within the Devonian Goslar Trough during deposition of the Rammelsberg ore.

The Gosetala anomaly (assumed mineralisation) and the Rammelsberg ore lie within the same sub-basin, at the eastern margin of the Goslar Trough.

EM, WM = respectively Eastern and Western Main Fault
The Gosetal Anomaly

One-two kilometres west of the World class Rammelsberg mine
Lies within the Wissenbacher shales, similar to the Rammelsberg deposit
Almost two kilometre long footprint
Strike-parallel with the geological layering
Strong conductor, unique in the surveyed area
Same depositional sub-basin as the Rammelsberg ore

One of the previously drilled holes intersected 20 cm with 4% base metals
Down-hole TEM surveys result in high signal strengths and decay curves not consistent with an empty half space

Harz 2008 SkyTEM resistivity slice 200-220 masl (ca. 200 m depth)
Integrated geological and geophysical modelling

Geological and geophysical modelling in an iterative process to approach each other within the boundary conditions of geological and geophysical data. Three dimensional Maxwell modelling of 3D conductor plates of the shallow conductor, based on the airborne TEM data.

TEM data along one of the flight lines as black lines. Red lines are calculated response based on the modelled plates A to G.
Low Frequency TEM anomaly at Gosetal

The profile with TEM data shows the same long wavelength anomaly.

Low-pass filtered TEM anomaly overlain on the geological map. Note that the footprint of the anomaly is much larger than the conductor.
The ore equivalent horizon can be recognised over a large area, many km away from the mine, in outcrop and in drill holes, and contains commonly up to 1500 ppm Zn+Pb. Restored depositional basin in the Lower Devonian.

4% base metal over 20 cm was found in the ore equivalent horizon in a Preussag drillhole in the Gosetal area in the 1980’s.
Two conductor models

Two alternative solutions consists for the collective data: a model with a shallow folded conductor, and a model with a deeper conductor of uncertain geometry

1) The model with the folded shallow conductor, focuses on the high frequency part of the data using Maxwell modelling. Peaks in the data are modelled as anticlinal fold hinges. The conductor needs to lie very shallow, in order to give the overall high TEM signal strength.

2) The model with the deeper conductor is mainly based on the low frequency (long wavelength) TEM anomaly. This is difficult to model exactly. The presented model connects this anomaly with the ore-equivalent horizon, of which the position at depth was approximately known prior to the drilling, based on Preussag drilling data. In similarity with the Rammelsberg deposit, the core of the syncline in the Gosetal area was chosen as the most likely target.
Geological profile along one of the TEM flight lines. The two potential targets, an upper modelled conductor (blue dashed line) that forms a synform-antiform pair at 100-400m depth, and a deeper target formed by the ore equivalent layer (same stratigraphic level as the Rammelsberg ore) at greater depth in red. A deep synform with the ore-equivalent layer was intersected in a near-by Preussag drill hole from the 1980’s.
Two alternative solutions in which geological/geophysical profiles of the each conductor were combined in a 3D model of the folded conductor. Model seen viewing towards the northeast.

Folded mineralised layers form overturned anti- and synclines, plunging shallowly to the southwest and south. The upper target lies between ca. 100 m and 400 m depth. The lower target lies between ca. 500 m and 700 m and coincides with the regionally-recognised ore-equivalent layer.
The concentric ellipses indicate a nested halo anomaly, and mark a redox cell above a SEDEX mineralisation. The white lines are the contoured TEM anomaly, of which the western part coincides with the SGH anomaly. The SGH anomaly is rated 6 out of 6, i.e. it strongly suggests a SEDEX mineralisation.
The core of the SGH anomaly is projected down as an elliptical cylinder. It coincides with the steep limb of the syn-/antiform pair of the upper target.
**Exploration drilling**

**Phase 1** - October to December 2009: three holes were drilled to 245-372 m depth to test the model of an upper folded conductor. Two holes intersected the steep to overturned limb of the modelled fold. The third hole intersected the synform.

**Phase 2** – November 2010 to January 2011: Re-entry of one of the existing holes, drilled to 677 m. One new hole drilled to 750 m. These holes intersected the ore-equivalent layer of the Rammelsberg ore, but without mineralisation.

Down hole EM surveys in the drill holes

Ground EM surveys along lines crossing the TEM anomaly
Exploration drilling, phases 1 and 2: testing the targets

Drill holes of the first phase (red) testing the shallow target with a depth of 245-372 m, and the second phase (green) testing the deep target, 677 and 700 m deep.
Drill hole hits fault before the modelled conductor

The drill hole targeting the synform core hits a fault, which truncates the synform
Ground geophysics

**Drilling phase 1** – fall 2009: down-hole and ground TEM geophysical surveys revealed no conductors in the vicinity of the holes.

**May 2010**: renewed down-hole TEM confirmed previous results. Down-hole IP and resistivity measurements indicate that the airborne anomaly is not a result of conductive shales. A 2 km long CSAMT survey was unsuccessful as a result of high noise levels.


**February 2011**: Between-holes IP survey to test for non-conductive ore bodies (e.g., disseminated ore, sphalerite-rich ore). An IP anomaly exists between the two deep holes, final results are pending.
Results of the first two drilling phases

The folded structures were confirmed

Two significant thrust faults were discovered

The folded conductor at 100-400m depth was not found

EM surveys found no conductors close to the drill holes or in the upper 200 m in the vicinity of the holes

The high frequency part of the airborne TEM signals, on which the shallow model was based, are now assumed to be an interference of a buried conductor and surface infrastructure

A strong EM signal in the area and EM soundings in the drill holes suggest the presence of a buried conductor
Several solutions for ore-equivalent horizon (magenta) in the central synform. The ones on the left are the most likely.
At 580 m the drillhole intersects a major fault which displaces the core of the syncline.
Present status of the project

The shallow folded conductor model has been tested and rejected.

A first attempt to intersect a deep conductor was not successful.

Down-hole TEM surveys show no sign of a near-by large conductor, but measured EM levels are high and decay curves are not consistent with an empty half-space.

Preliminary results of between-holes IP survey show an anomaly between the two drill sites of 2010. Modelling of the results is ongoing.

A third drilling phase will depend on the final outcome of the IP survey.
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