Research and Educational Mine FLB Reiche Zeche in Freiberg, Germany

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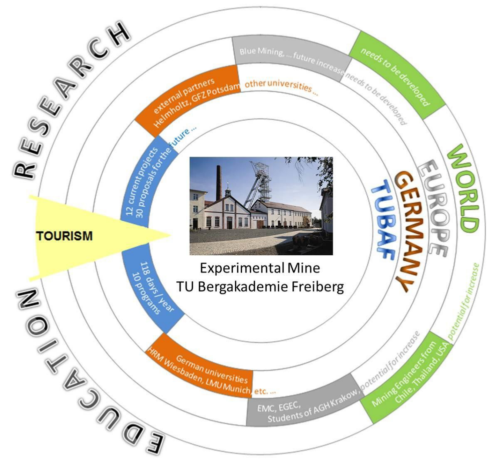
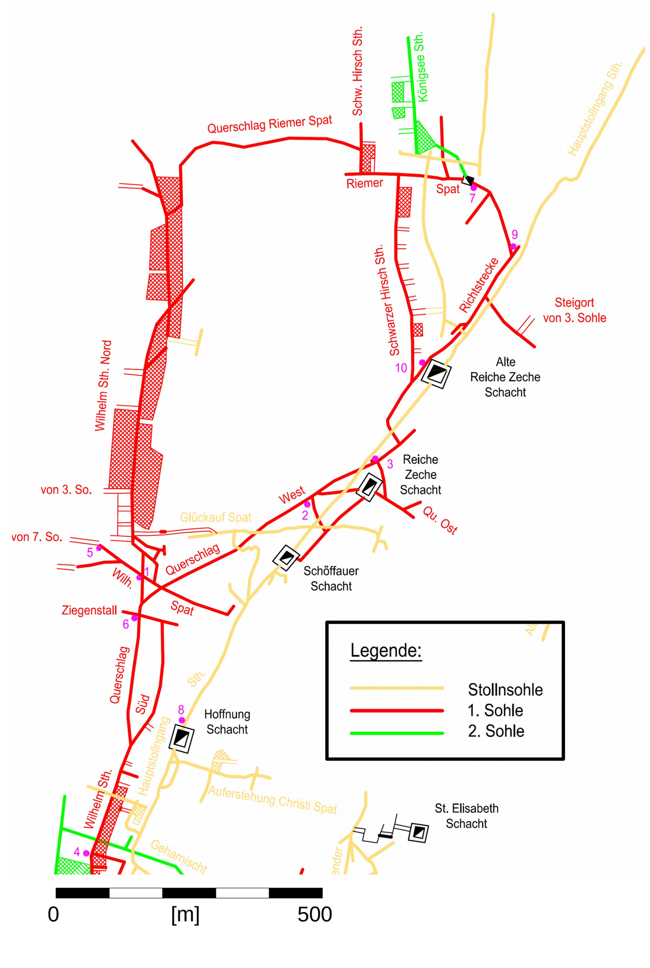
1) Introduction

- Geology:
  - Freiberg Gneiss with ore veins
  - lead-zinc deposit (mainly Galena, Sphalerite, Pyrite)
- Mining from 1168-1969
- Since 1919 belonging to TU Bergakademie Freiberg
- Drifts of ~130 km, of which 19 km safely accessible
- Main level 150 m below surface
- Further information: https://tu-freiberg.de/lfbw www.silberbergwerk-freiberg.de





Reiche Zeche shaft (photo Jürgen Weyer)

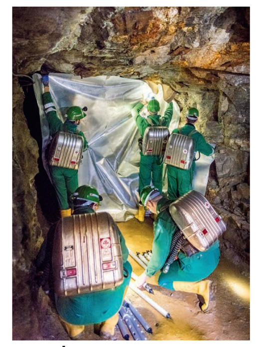
Ore vein (with camera lense cap, photo Vera Lay)

Reiche Zeche central drifts (after Grund, 2015)

2) Educational Activities

- Underground internships for students (internal and external) in diverse fields such as:
  - mining (including blasting, drilling,…)
  - geodesy / mine surveying
  - geology / minerology
  - geophysics
- Meeting / teaching room underground
- Mine rescue brigade (students)
- Touristic visits on oublic mine tours

Ventilation measurement exercise (photo TUBAF)

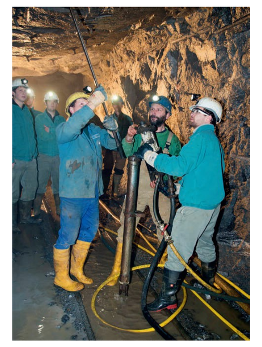


Student mine rescue team setting up a ventilation dam (photo Detlev Müller, TUBAF)

Rail tracks underground (photo Olaf Hellwig)

Seismic tomography (photo Eric Donner)

Geophysical underground practical (photo Vera Lay)

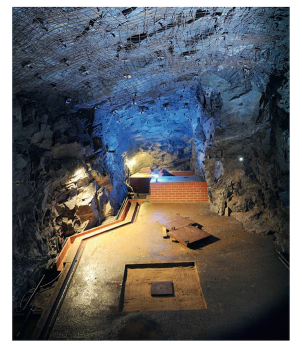


Drilling practical (photo Wolfgang Gassner)

3) Research Activities

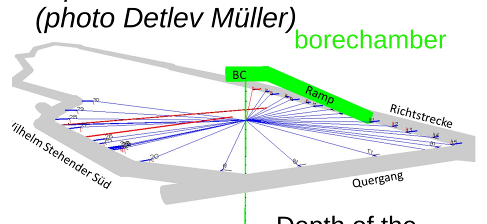
Recent research projects (details e.g. in Mischo, 2019)

- Sensor networks ("living lab")
- Robotics
  - e.g. including automatic sampling, navigation, communication
  - e.g. projects Mining-RoX, ARIDuA, UNDROMEDA
- Geophysical monitoring (see 4) and tool development (GFZ Underground Laboratory)
- New mining technologies
  - biohydrometallurgical mining, see 5
- Material Science:
  - blasting chamber for tests with shock waves and to create new materials
  - self-densifying concrete
  - synthetic fibre
- Underground geothermal energy system for cooling and heating
- Stimulation (thermic or hydraulic)
  - STIMTEC: EGU2020-8120; EGU2020-14117
- Underground laboratory network BSUIN (see 6 and EGU2020-2980)



Freiberg High Pressure Research Centre with explosion chamber (photo Detlev Müller)

Project ARIDUA: tests with the mining robot Julius, photo Eckardt Mildner



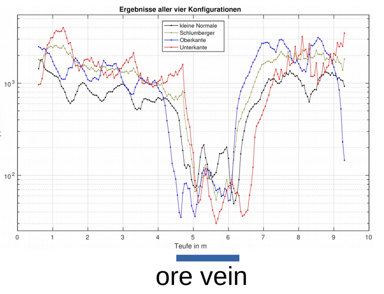
Depth of the vertical borehole: 70 m

Borehole chamber (left: sketch from Krauß et al., 2014; top: photo GFZ 2016)

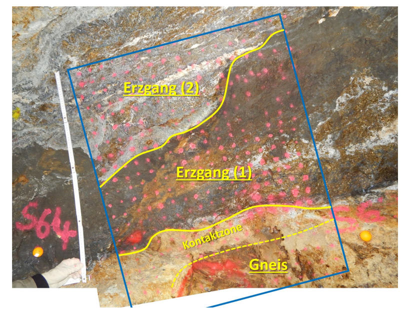
4) Geophysics to examine ore veins within the mine (examples)

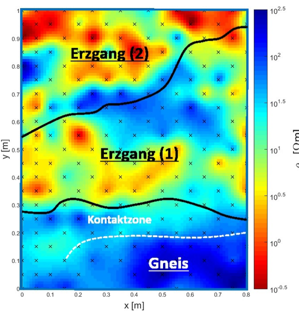
A) Laboratory values (e.g. Börner, 2018; Frühwirt et al., 2017): P/S-wave velocities (+anisotropy), density, permeability, electrical conductivity, …

B) DC-Geoelectrics: lower resistivity at ore veins within boreholes and within resistivity mapping (Römhild, 2017)



Borehole geoelectrics (Bär and Scheunert, 2018)

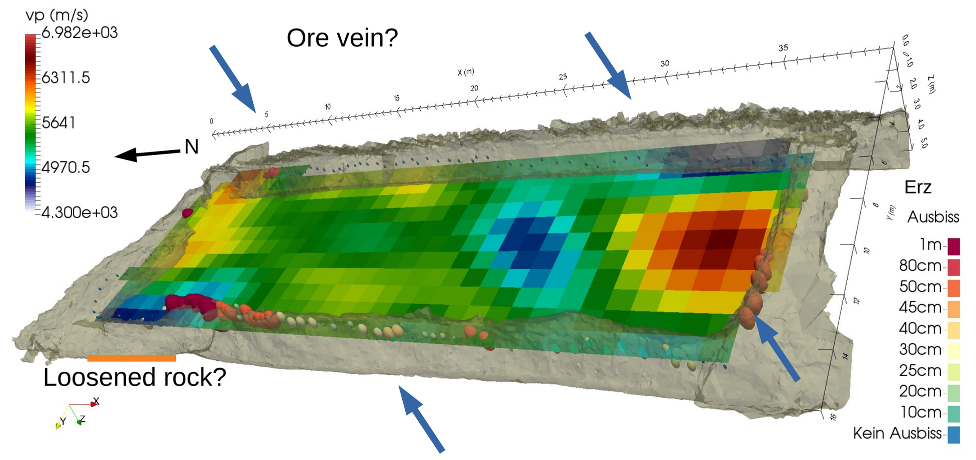




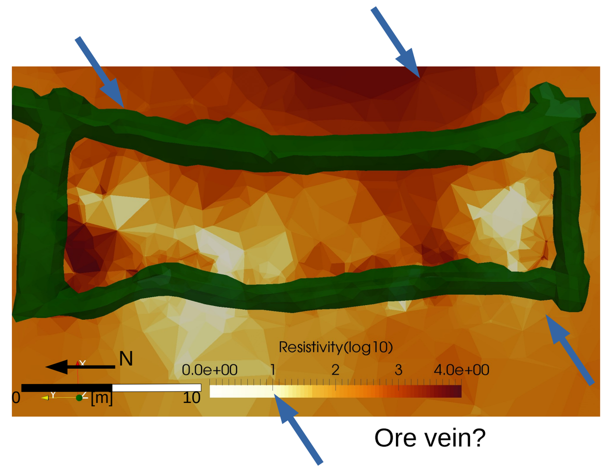
Geoelectrial mapping of ore veins: geology (left) and electrical resistivity (right), Römhild (2017)

C) Tomography (Seismic and Geoelectrical)

- e.g. at Biohydrometallurgical Center for Strategic Elements (BHMZ, see 5)
- Seismic tomography (Winter, 2016) shows higher P-wave velocities, geoelectrical tomography shows lower resistivity (Pötschke, 2017); potential correlation of both with ore veins



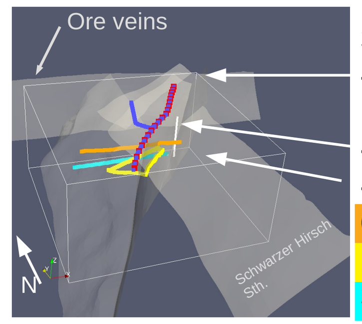
Seismic tomography: P-wave velocities and ore vein outcrop (Winter, 2016)



Geoelectrial tomography (Pötschke, 2017)

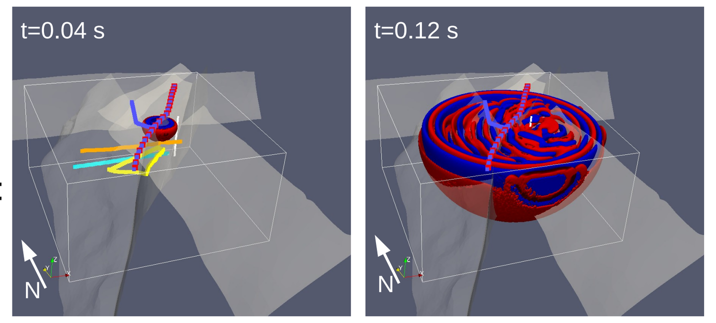
D) Elastic FD modelling

- Elastic finite difference modelling of seismic wavefields from recordings in the mine and at the surface using existing roads / drifts (Hellwig and Buske, 2020)

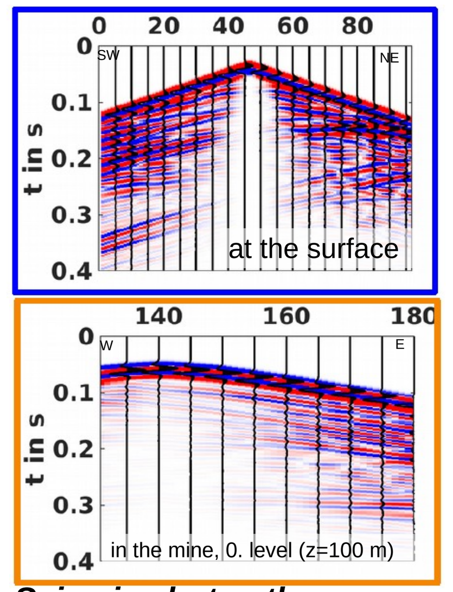


3D mine model
- surface: source and receivers
- shaft
- underground receivers:
0. level @z=100 m
1. level @z=148 m
3. level @z=218 m

3D mine model with several ore veins



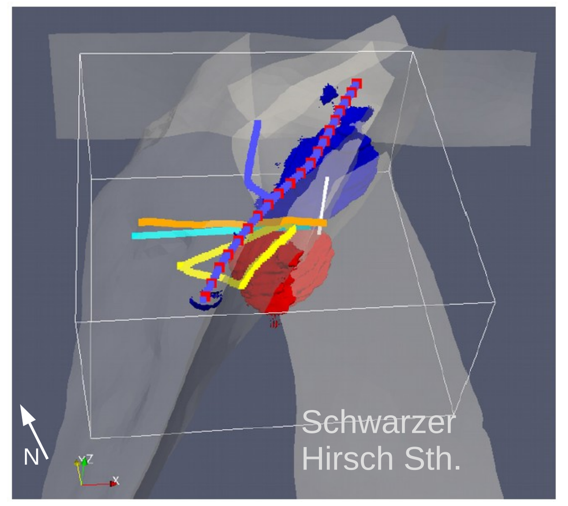
3D mine model with P-wavefield **snapshots**

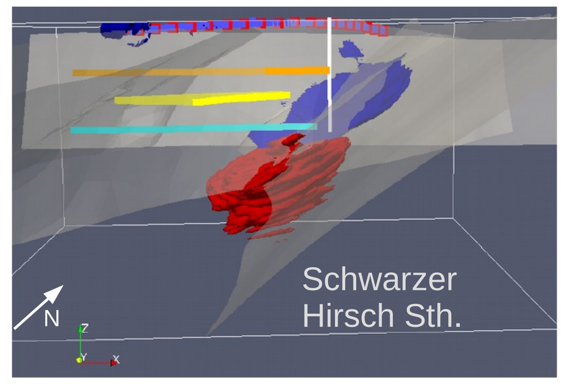


Seismic shot gathers

- **Seismic imaging:** Focusing pre-stack depth migration (Fresnel volume migration) of data recorded at the surface and in the mine for imaging the ore vein „Schwarzer Hirsch Sth." at shallow depths (using surface receivers) and greater depths (using underground receivers)

→ Real test measurements planned.

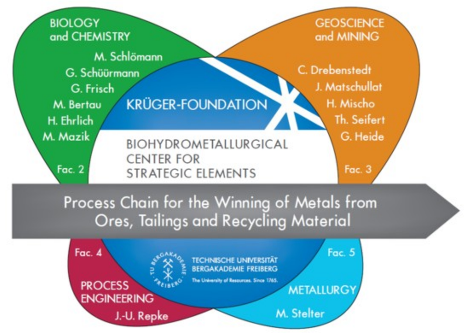


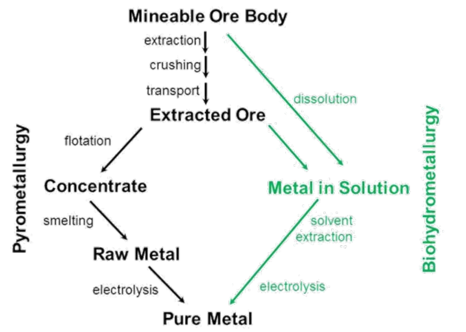


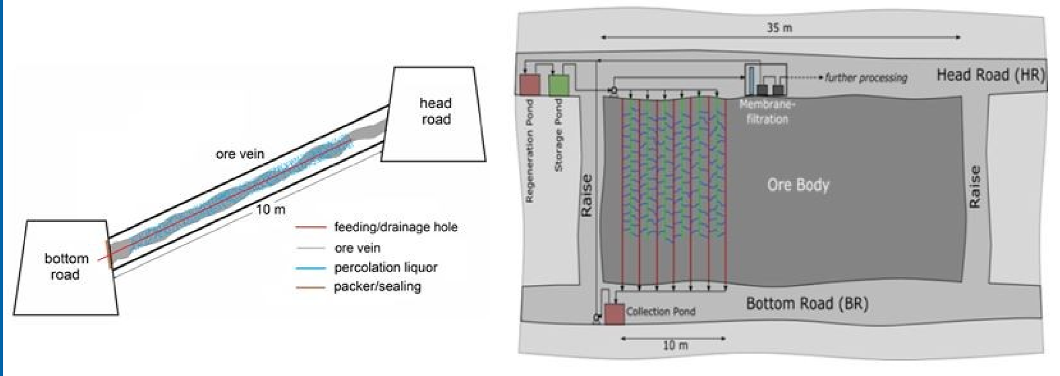
***Seismic Imaging**: Data analysed from **surface** / **underground**; top view (left) and view from the side (top)*

5) Biohydrometallurgical Centre (BHMZ) for bio in-situ leaching

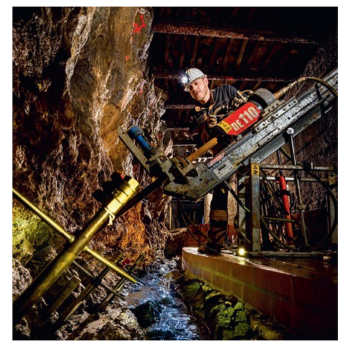
- **Motivation:**
  - Challenges in mining: e.g. more complex mineralization, irregular deposit shapes, narrow veins and deposits with low grades
  - Solution: new mining technologies and production of critical raw materials such as Indium and Germanium using low grade ores with with minimal technical mining effort for sustainable mining
- **Main Idea** (Krichler et al., 2020)
  - use bacteria for in-situ leaching
  - produce concentrated fluids and reduce transported material
  - underground tests at ore vein (see also 4C) with 0.1-1 m vein thickness; dip of ~50°



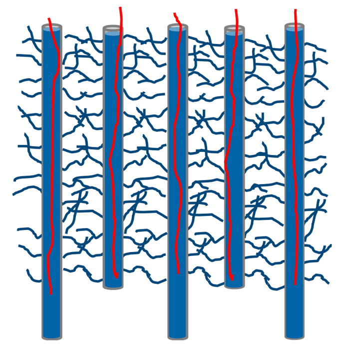




Sketch of BHMZ centre (Krichler et al., 2020)



Drilling activity, photo Detlev Müller



Sketch of conditioning to increase faces (Schlüter, 2018)

- **Operation:**
  - Preparation: drilling of boreholes (distances 0.2-0.5 m; diameter 53 mm)
  - Conditioning: create many dense fractures with high increase in faces (hydraulic fracturing by blasting)
  - Technical installations
  - Permanent service (above all leakages)
  - Filtering with membrane plant to monitor mineral content
- **First Results:**
  - successful enrichment of minerals (e.g. manganese, zinc)
  - first problems fixed to allow for long-term tests
  - hydraulic fracturing by blasting better than pure hydraulic fracturing to create good conditioning
  - more research necessary on influences of circumstances

Technical installations for leaching (photo Ralf Schlüter)

Membrane plant (top) and sensor (right), photos Tobias Krichler

6) BSUIN network

www.bsuin.eu

- = Baltic Sea Underground Innovation Network
- 14 project partners, 18 partner organisations
- 6 involved underground laboratories
- Goals
  - Build a strong network of underground laboratories
  - Making underground laboratories more accessible for innovation, science, business and economical development
- Methods:
  - characterization:
    - geophysics / geotechnics
    - natural / radioactive radiation
    - structure, organisation, work processes
  - business analysis and design

→ final goal: develop strong network of underground laboratories with a specific and common service offerings to enhance the usage of underground space

Underground laboratories in the BSUIN project

7) Conclusions

- The research and educational mine of the TU Bergakademie Freiberg offers diverse options for research and education.
- Unique underground conditions further unified within BSUIN project to strengthen underground laboratories in a combined network providing information, services and future potential.
- We welcome new cooperations! (E-mail: Helmut.Mischo@mabb.tu-freiberg.de)

References:

- Bär, M. and Scheunert, M.(2018): Untertagepraktikum 2018 – Bohrlochgeoelektrik, internal report, TU Bergakademie Freiberg, Institute of Geopysics and Geoinformatics
- Börner, J. (2018): Petrophysical measurements, internal report, TU Bergakademie Freiberg, Institute of Geopysics and Geoinformatics
- Frühwirt et al. (2017), unpublished laboratory tests, TU Bergakademie Freiberg, Institute of Geotechnics, chair of geomechanics, rock mechanics/rock engineering
- GFZ German Research Centre for Geosciences. (2016): GFZ Underground Laboratory in the Research and Education Mine "Reiche Zeche" Freiberg. *Journal of large-scale research facilities*, 2, A68. doi:10.17815/jlsrf-2-131
- Hellwig, O. and Buske,S. (2020): Simulation einer Seismikmessung mit kombinierter Über- / Untertageakquisitionsgeometrie zur Abbildung eines steilstehenden Erzgangs, DGG Arbeitskreis Seismik meeting 2020 Schneverdingen.
- Krauß, F., Giese, R., Alexandrakis, C., and Buske, S. (2014): Seismic travel-time and attenuation tomography to characterize the excavation damaged zone and the surrounding rock mass of a newly excavated ramp and chamber. *International Journal of Rock Mechanics and Mining Sciences*, 70, 524-532.
- Krichler, T., R. Schlüter, and Mischo, H. (2020): How to manage sulfide ores without flotation – The biohydrometallurgical centre (BHMZ) for bio in-situ leaching at TU Bergakademie Freiberg. SME Annual Conference 2020, Phoenix (USA)
- Mischo, H., Dietze, A., Noll, S., Becker, S., Schlüter, R., Müller, T., Amro, Moh'd M., Freese, C., Rose, F., Muschalle, T. & Martienßen, T. (2016): Das Forschungs-und Lehrbergwerk Reiche Zeche. Glanzlichter der Forschung an der TU Bergakademie Freiberg - 250 Jahre nach ihrer Gründung, Edition: 1, Editors: U. Groß
- Mischo, H.(Hrg) (2019): Entdecker Unter Tage 1919-2019: 100 Jahre Forschungs- und Lehrbergwerk, Mitteldeutscher Verlag, Halle.
- Römhild, L. (2016): Kleinskalige geoelektrische Kartierung an einem Erzgang in der Reichen Zeche (Freiberg). Bachelor Thesis TU Bergakademie Freiberg
- Pötschke, D. (2017): Geoelektrische Tomographie an einem Erzgang im Bergwerk Reiche Zeche (Freiberg). Master ThesisTU Bergakademie Freiberg
- Winter. S. (2016): Seismische Tomographie am BHMZ Versuchsstand des Lehr- und Forschungsbergwerks Reiche Zeche. Master Thesis TU Bergakademie Freiberg

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