WORLD SALT SYMPOSIUM

June 19-21, 2018 Park City UT, USA

Seismic monitoring of former potash mines in the south-hercynian mountains

Development of technology and activity

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K-UTEC SALT TECHNOLOGIES

Content

- Introduction
- Case I: Monitoring of seismic activity through active flooding of a potash mine
- Case II: Monitoring of seismic activity previous and after the safekeeping of a Carnallitite mining field
- Conclusions

Indroduction

- In 1896 the mining of potash salts in the south-hercynian mountains started.
- five large potash mines Bischofferode, Sondershausen, Bleicherode, Sollstedt and Volkenroda,
- partly continued the potash mining until 1992.
- After the discontinuation of mining and production of potash backfilling operations were realized by private companies.

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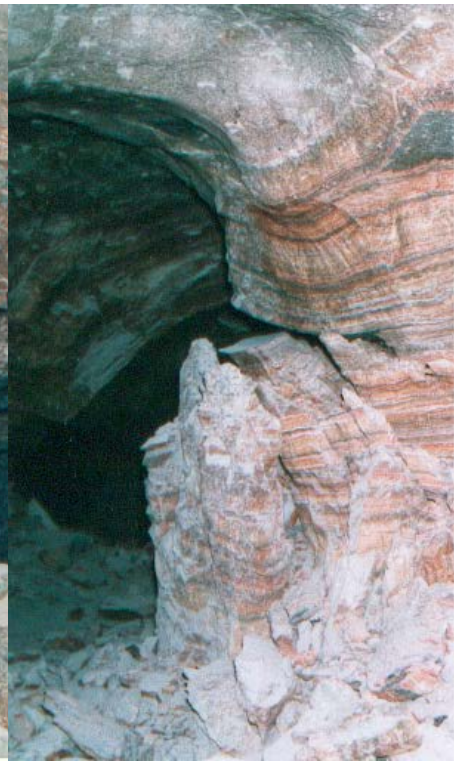
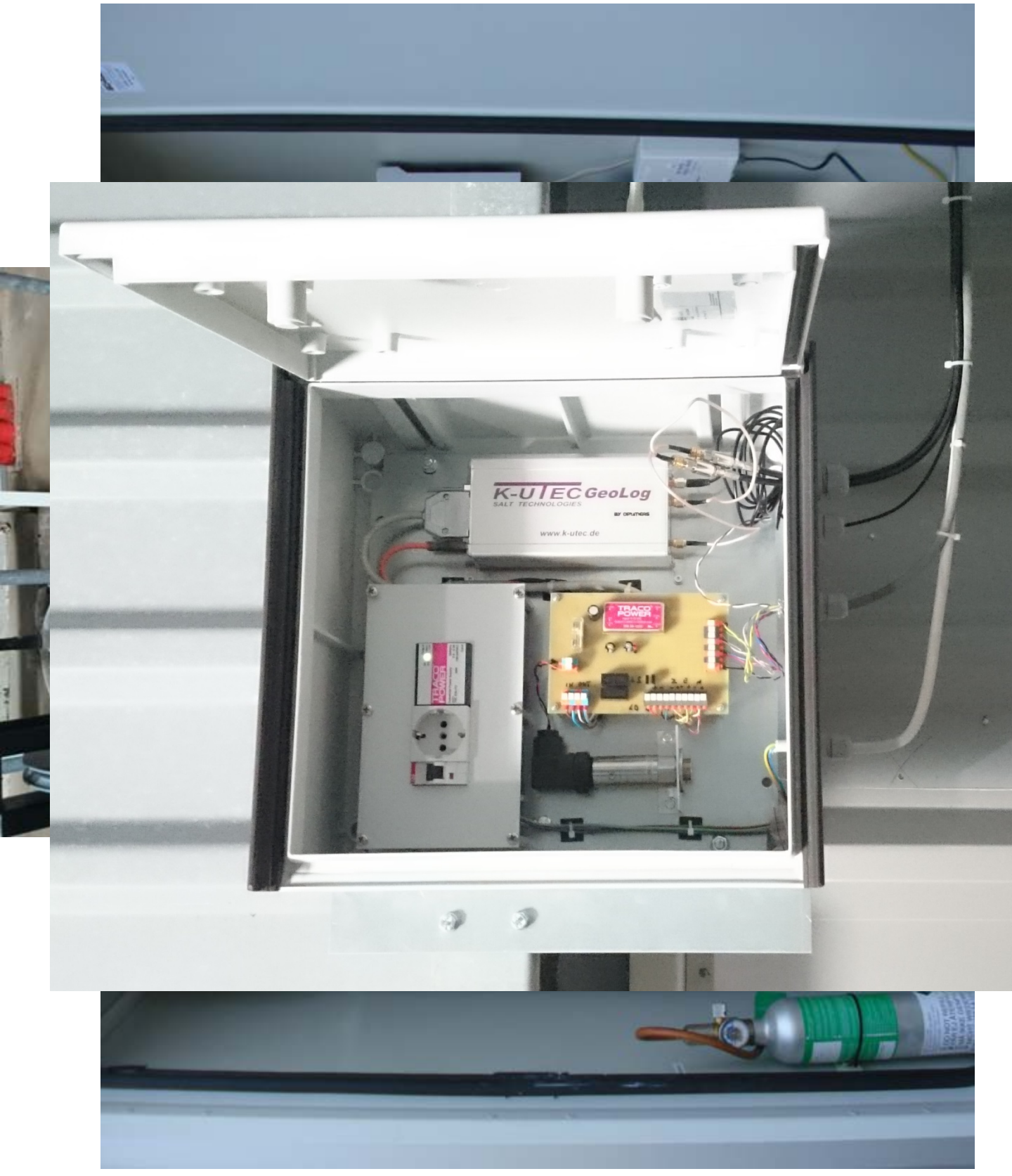
Indroduction

As a result of the predominantly specific petrophysics and rock mechanics of the mines problems with contour fracturing and rock burst prevailed



Indroduction

- K-UTEC AG is operating 17 seismic monitoring systems in Germany and Europe
- four are installed within the south-hercynian
- monitoring is an essential part of the mining activity during:
  - the mining process,
  - the backfilling and sealing operations
  - as well as the post-closure phase.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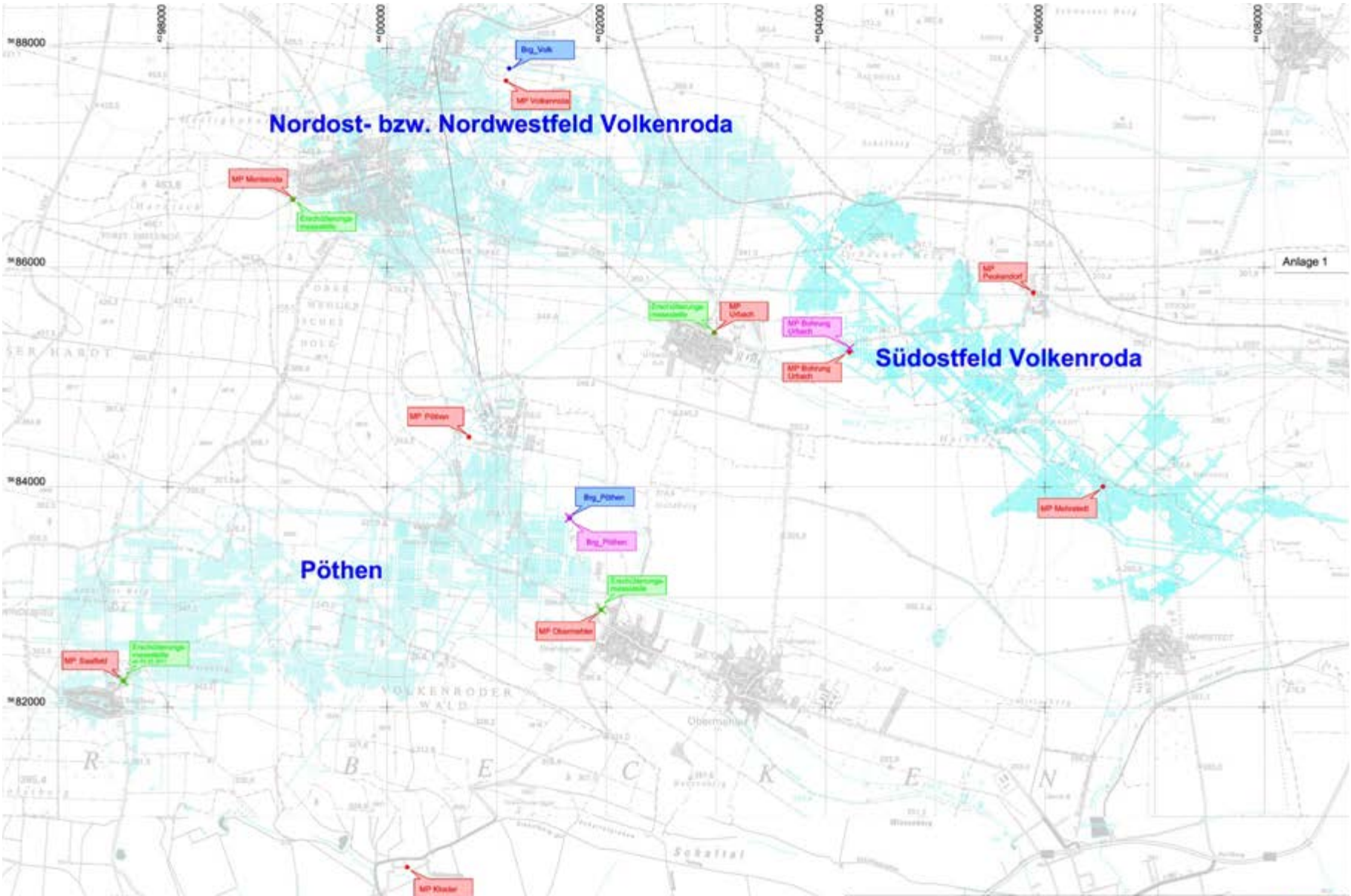
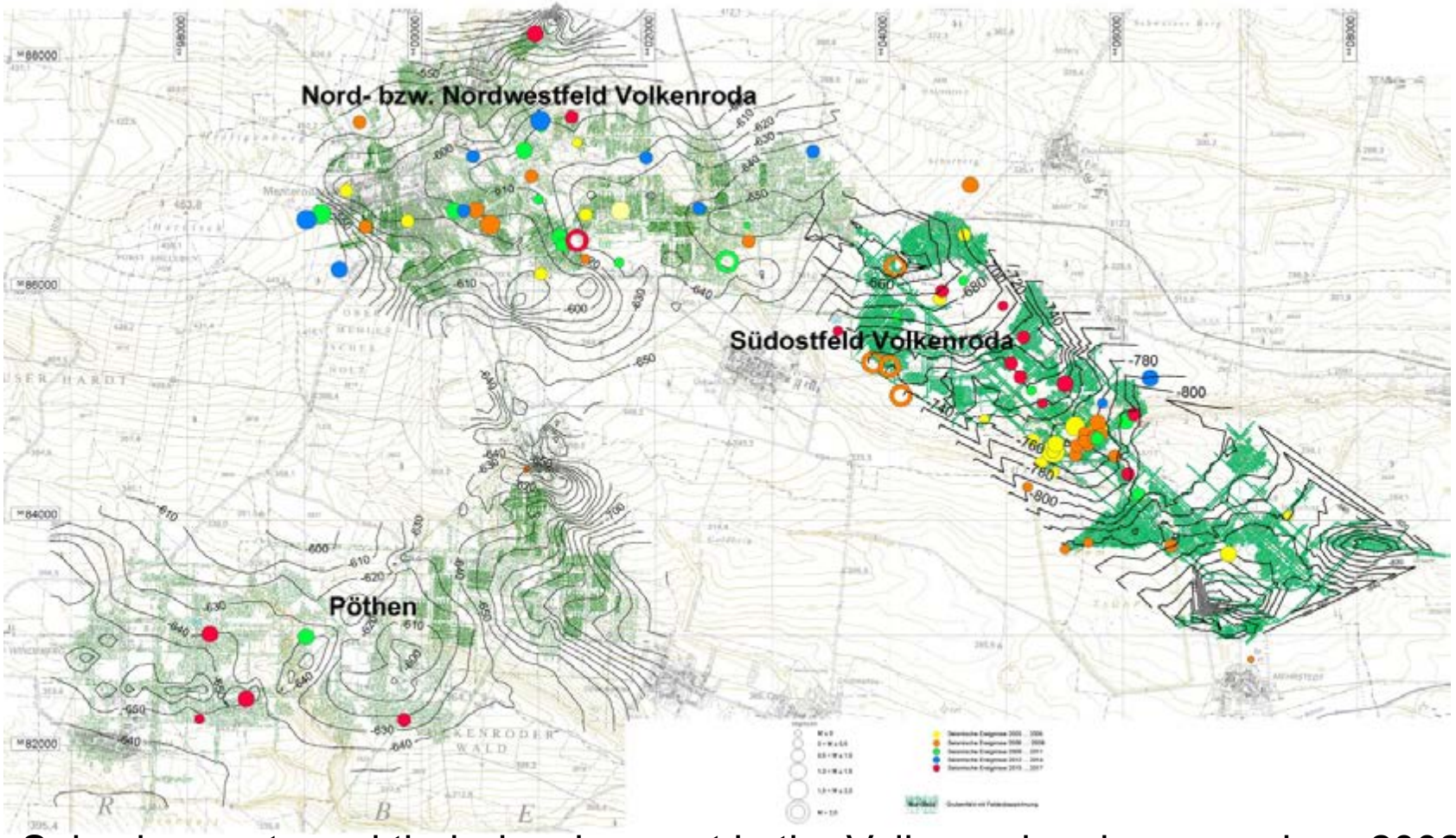


Case I: Volkenroda potash mine



Seismic events and their development in the Volkenroda mine area since 2002

Case I: Volkenroda potash mine

- The map shows the cause of the events.
- the main seismic activity until 2009 is concentrated within the eastern mining fields
- locations moved partly towards the west correlating with the flooding extent.

Case I: Volkenroda potash mine

- Flooding influence of the pillars of the hard salt area and the partly open pillar area with the underlying Carnallitite
- partly liquid-induced acceleration of the convergence within the deposit
- activating tectonic elements Schlotheimer Graben.
- For this reason seismic events up to a magnitude of M_L = 2.5 (Iida) occurred.

Case I: Volkenroda potash mine

- The seismicity is kept at a reasonable level because only saturated solutions flow
- Certain number of seismic events is perceived in southeastern area and northeastern area.
- Reason is strong tectonic precondition.
- This will last in parts after the safekeeping of the mine.

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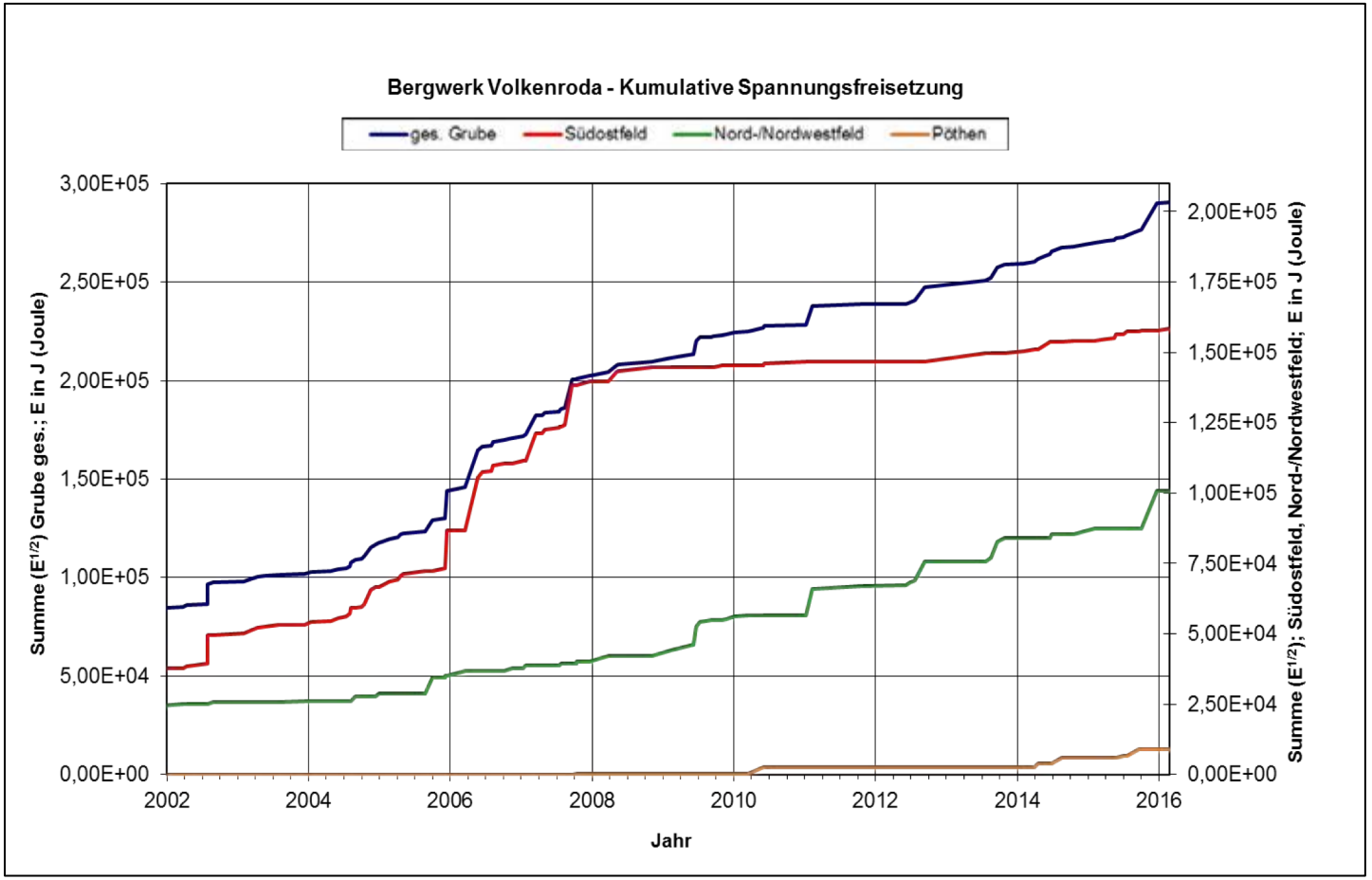
Case I: Volkenroda potash mine



cumulative energy release for the Volkenroda mine 2002 –2017

Case I: Volkenroda potash mine

- Benoiff-curve shows the cumulative energy release as a sum curve over time
- Connection between flooding and seismicity is clearly visible
- It shows the success of the mine's safekeeping by flooding.
- The seismic activity decreased and reached a reasonable level of energy release

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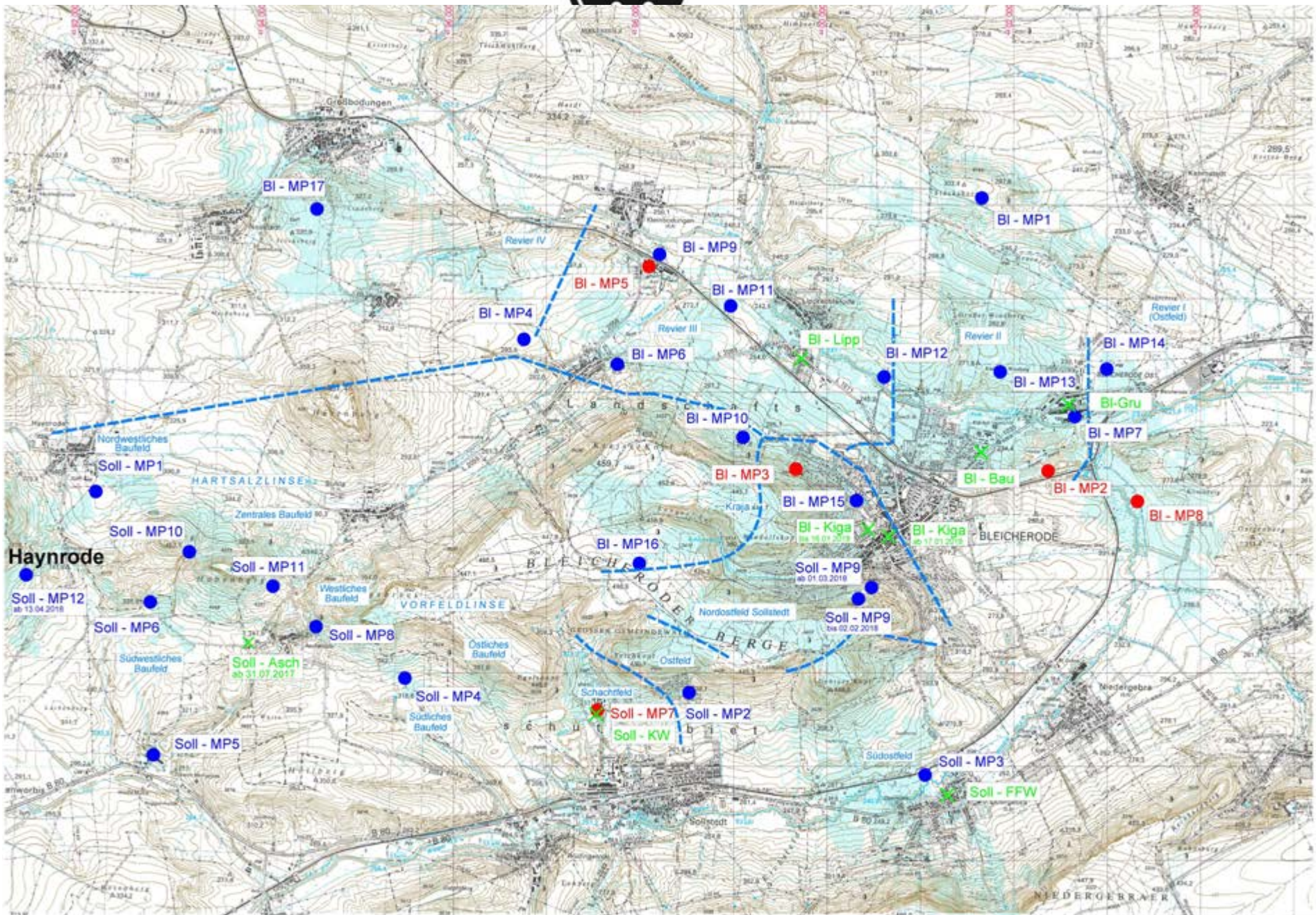
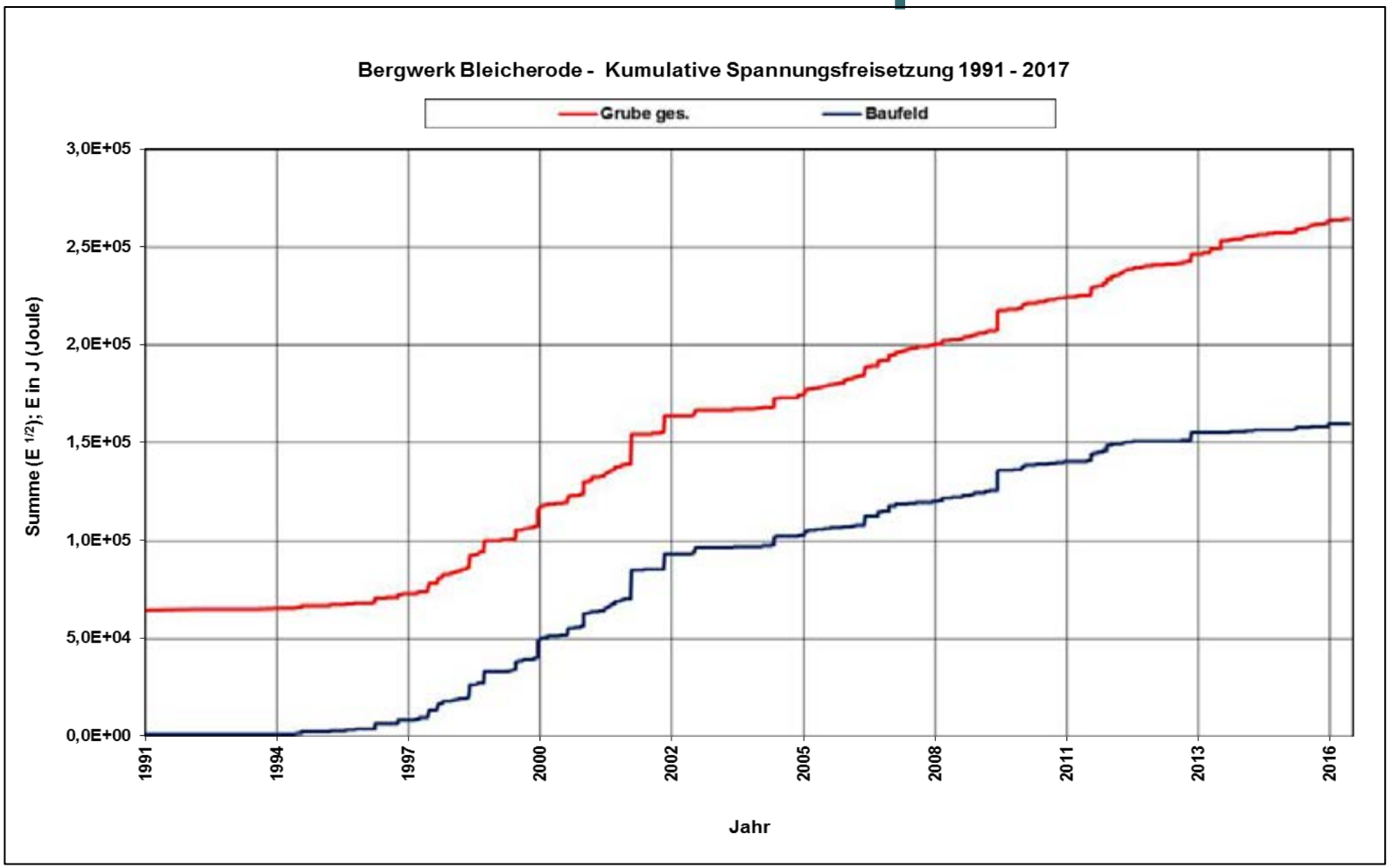


Case II: Bleicherode potash mine

- complex seismic, geotechnical and geodesic monitoring
- collapse of the pillars in the Carnallitite mine field with sudden subsidence were expected
- sudden energy release through seismic events up to a magnitude of M_L = 3.5 to 4.
- mining authorities declared that backfilling is mandatory for safekeeping of the hazardous areas.

Case II: Bleicherode potash mine

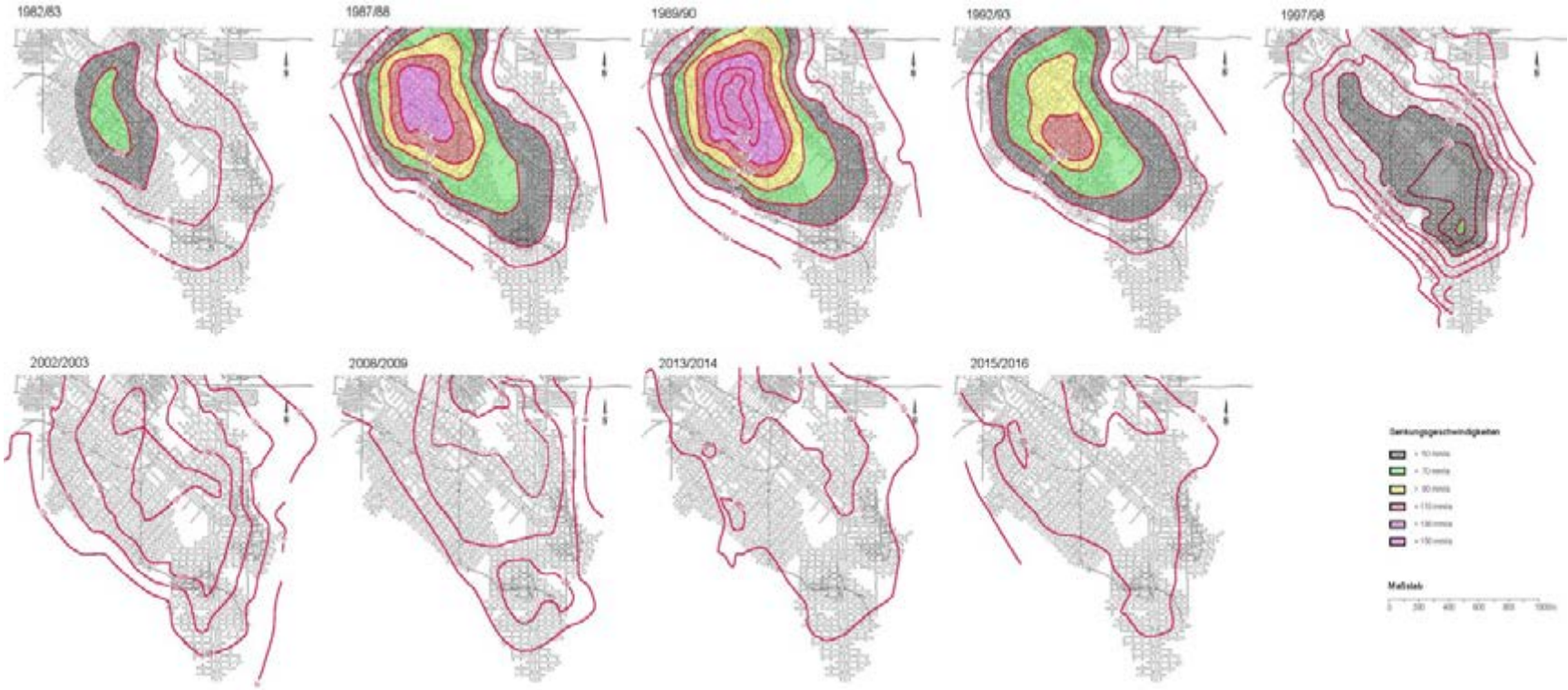


cumulative energy release of the Bleicherode mine 1991-2017

Case II: Bleicherode potash mine

- Starting 1990's the seismic activity was increasing
- Magnitudes from $M_L \leq 0$ to strong rupturing with $M_L = 2.3$.
- 1995 to 2017 nearly 1400 seismic events
- With ongoing backfilling into northern direction also a northwards movement of seismic events was observed.

Case II: Bleicherode potash mine



subsidence rates on the surface for the Carnallitite field of the Bleicherode mine from 1982-2016

Case II: Bleicherode potash mine

- Since 2012 seismic activity is reduced
- Positive stabilizing effect of backfilling is proved by reduced seismicity.
- Subsidence rates were reduced from 150 mm/a in to about 20 mm/a
- Total subsidence now reached 2.40 m

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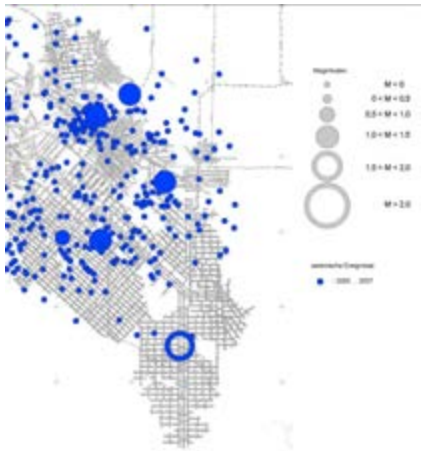
Case II: Bleicherode potash mine

1999-2001

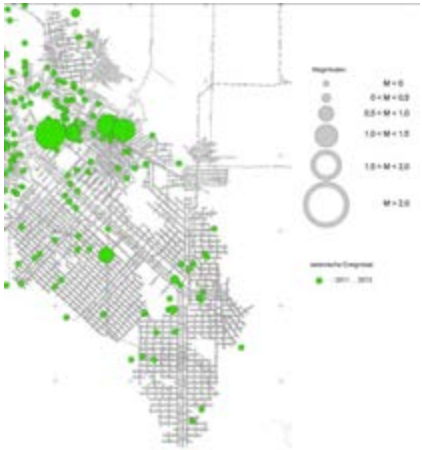
2002-2004

2005-2007



2008-2010

2011-2013



2014-2017

Conclusions

- A complex seismic and geomechanical monitoring gives the tools for a reliable estimation of potentially hazardous conditions for stability of a whole mine or parts of it as well as for controlling of later redevelopment measures for removing or minimizing sources of danger.
- This technique is successfully used in the south-hercynian potash mine area since decades in the mining, backfilling and post-closing phase.

Conclusions

- Evolving destabilizing moments and the resulting static and dynamic implications as well as the stress at the surface or on the mine's structure can be accurately assessed with the monitoring.
- It's possible to induce timely measures for safekeeping and to control them in the right priority.

Conclusions

- In the post-mining phase seismic monitoring gives the possibility for prove of long-term safety.
- One key advantage of this method is operation over long periods without even entering or driving at the surveyed area.


Thank you for your attention