Ergebnisse der Auswertungen flutungsinduzierter Seismizität aus dem Bergbaurevier Schlema/Alberoda

Evaluation of flooding induced seismicity in the mining area Schlema/Alberoda (Germany)

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The uranium mine Schlema/Aberoda

- production from 1949 till 1990
- hydrothermal vein deposit
- roof mining technique
- total production 800,000 t uranium

After mining activities the mining concern converted from SDAG Wismut to recultivation concern named Wismut GmbH. Today's tasks are: secure the mine, clean the mine water before discharging in a nearby river, and recultivate the mine heaps.

Source: Wikipedia → Wismut(unternehmen)
Historical earthquake situation

Source: BGR
Geological situation

Conjugated faults

Mining

Roter Kamm

LfULG(2010)
Stations of operators network (in 2012)

- At surface (red)
- Underground (blue)
- Hydrophone (green)

Source: O. Wallner (Wismut GmbH)
Stations of University of Freiberg network (in 2012)

- All at surface
- Actual operating (red, green)
- Closed site (yellow)
Data over a period of approx. 20 years
Flooded hollow space approx. 34 Mio m³
Seismological data during flooding

**Magnitude-frequency distribution of granite**

![Diagram](image1)

\[ N = 1315 \]

**Magnitude-frequency distribution of schist**

![Diagram](image2)

\[ N = 111 \]
Estimated maximum magnitude for induced seismicity $M_L=2.4$
Source radius vs. magnitudes

Calculated with Mardariaga source model (circular fault)
Dislocation vs. magnitudes

Dislocation over magnitudes for $M_L \geq -1$ in granite

Calculated with Mardariaga source model (circular fault)
Correlations (hypocenters in granite)
Correlations (hypocenters in shists)

Correlations of induced seismicity with flooding for hypocenters in shists

- Correlation: Hydrostatic pressure / Cumulative seismic energy
- Correlation: Pressure change (dP/dt) / Seismic power (dE/dt)

Cf = 0.99, 0 days

Cf = 0.52, 17 days
Peak ground velocities (PGV) 1500m

Estimation of $M_L$ from normed PGV-values (1500m) for events in granite

- Events $z=-1500$ m and $-1800$ m below surface
- Haired event
- Regression
- $3\times$ standard deviation

![Graph showing estimation of $M_L$ from PGV values for events in granite](image-url)
Peak ground velocities

Place of origin

Way through the media

DIN 4150
Place of impact

Bildquelle: K. Meskouris et al., Seismologische Grundlagen
Peak ground velocities (PGV)

\[ A(x) = A_0 \cdot e^{-\alpha(x-x_0)} \cdot \frac{X_0}{X} \cdot f_{(\text{Reflectionen})} \]

With neglected reflection function and \( \alpha \) assumed as constant:

- Determination of \( A_0 \) and \( \alpha \) from dataset
- Determination of a relation \( A_0 \) and \( M_L \)
- 540 datasets with PeakGroundVelocity (PGV)

\[ \text{PGV}(x) = f_{(M_L)} \cdot e^{-\alpha(x-x_0)} \cdot \frac{X_0}{X} \]

\[ f_{(M_L)} = 10^{0.873 \cdot (M_L) + 8.8} \]

\[ \alpha = 0.000578 \]
Prediction of PGV
Prediction of PGV on map

hypothesized earthquake
depth = 1.7km
magnitude = 2
• 9 joint systems
• 2 types of rock
• 53 regions
• Frame for regional stress field (not visible)
Numerical modelling results (3DEC)

Joint movements during mining phase

Joint movements during flooding phase

Symbol: cube
- Slipping now
- Slipped (past)
- Tensile failure
Conclusions

• The maximum magnitude for induced seismicity is predicted with $M_L=2.4$. Mainly responsible for this maximum magnitude are the events in the granites.

• The correlations show a coherence of flooding and induced seismicity.

• The numerical simulations prove the coherence of flooding and induced seismicity.

• Prediction of PGV is possible but the damping parameter and the rock distribution in the underground has to be known well to get reliable results.
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