RUHR-UNIVERSITÄT BOCHUM

Spatio-temporal distribution of induced seismicity in flooded mines in the Ruhr area – interpretation by geomechanical numerical modelling

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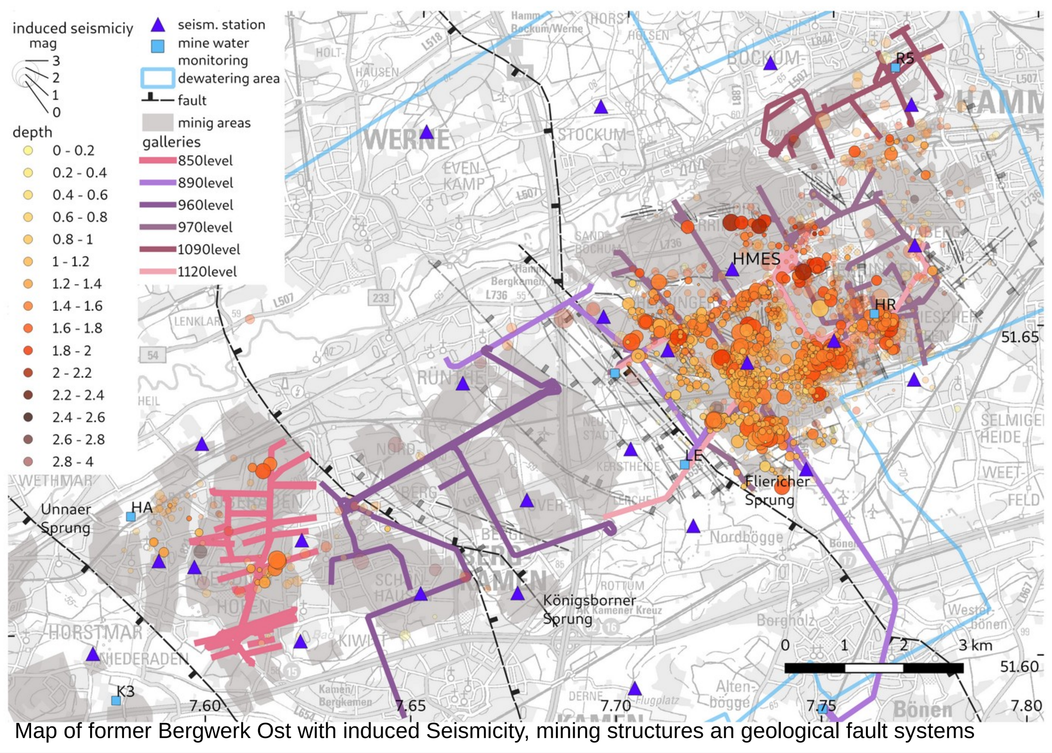
Network and seismicity

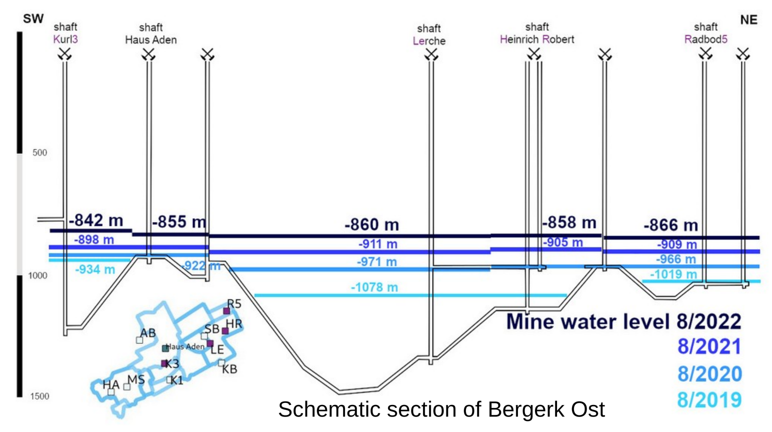
Using a measuring network of up to 30 short-period seismometers, we monitor the microseismicity in the area of the Haus Aden (eastern Ruhr Area, Germany) dewatering area during the flooding of the mines. Since the start of the flooding in 2019, more than 2300 microseismic events in the magnitude range between -0.8 and 2.6 M_{LV} have been localised.

The seismicity clusters mainly in the area of the former Heinrich Robert colliery in the eastern part of the study area. The depth distribution shows a concentration between 1200 and 1500 m depth. Mine water monitoring (RAG BID) in open shafts provide information on the rise of mine water.



Map of former Bergwerk Ost with induced Seismicity, mining structures an geological fault systems

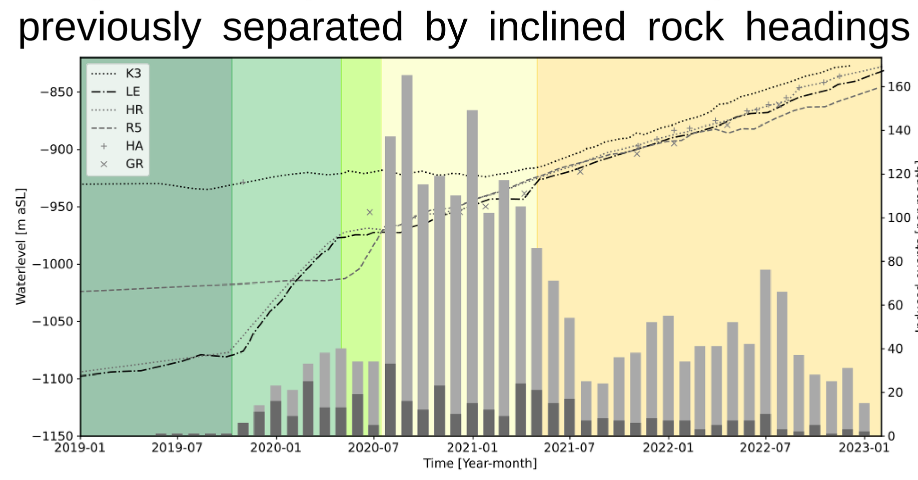
Minewater rise and spatio-temporal distribution of induced seismicity



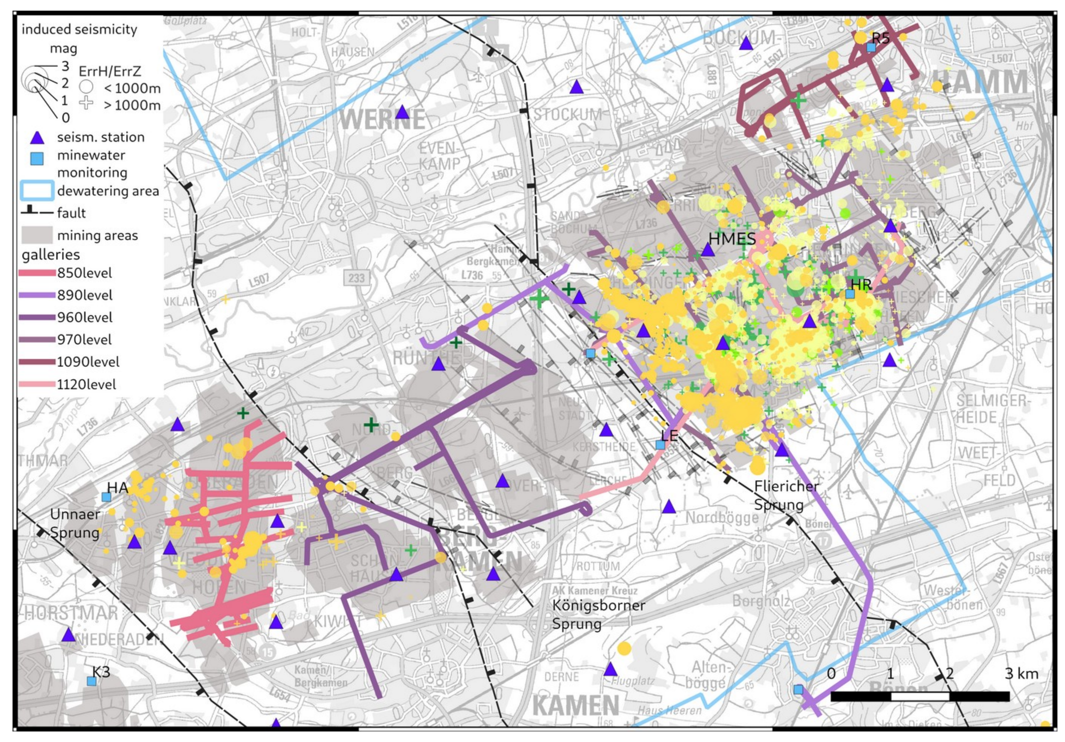
Schematic section of Bergerk Ost

A schematic section through the mine workings shows the deepest sections that serve as the main waterways and different mine water levels.

The rise of the mine water can be divided into different phases, in which different rates of rise can be seen at the different monitoring points. These phases are compared with the rate of recorded microseismicity. From 10/2019 onwards, the pit water rises sharply in the HR/LE area and microseismicity sets in. The highest activity in the microseismicity is shown after areas of the mines previously separated by inclined rock headings have been hydraulically connected. The main activity in all phases can be seen in the eastern part of the survey area. In the last phase, microseismicity also occurs in the western area of Bergkamen and a concentration in the western area of the Heinrich Robert mine can be seen.



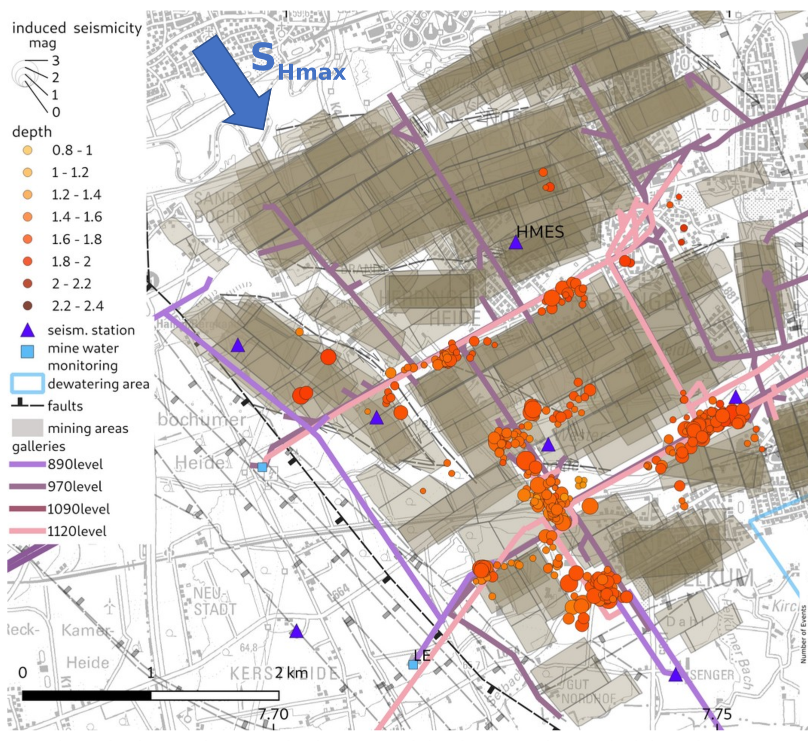
Phases of minewater rise combined with number of detected microseismic events



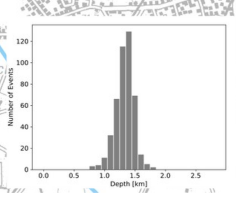
Spatio-temporal distribution of induced seismicity, events are color-codes for different minewater phases

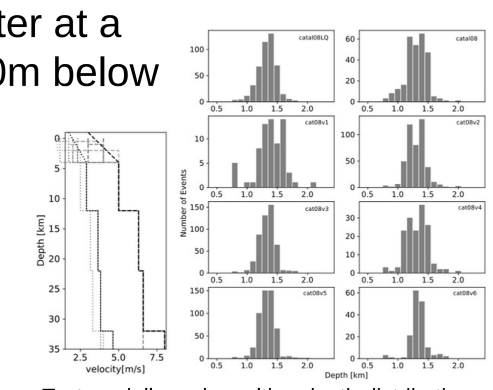
Relocation of microseismicity

In order to correlate the distribution of microseismicity with geological and mining structures, a high localisation accuracy is required. To achieve this, a relocalisation of the events was carried out. With about 450 events we were able to achieve an accuracy of less than 100 m error in XYZ. These events cluster at a depth between 1200 -1500m below the deepest parts of the mine in the area of the pillars. We were able to confirm this depth by testing with different velocity models.



Location of relocated events in the area of the former mine Heinrich Robert

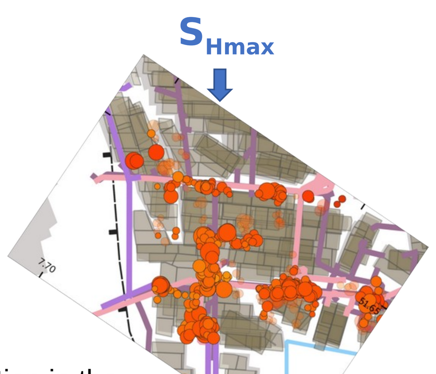

Depth distribution


Test modells and resulting depth distribution

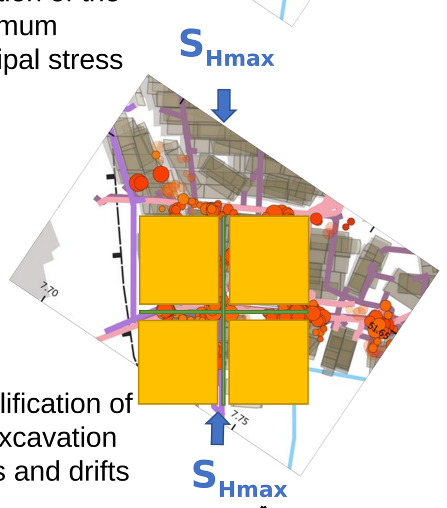
Numerical modelling

A stress model was created for a section of Heinrich Robert. For this purpose, the area was first rotated in the direction of the maximum principal normal stress and then, with simplified geometry, three mining areas at a depth of 1000m and one at a depth of 800m, drifts at 1000m and a shaft were implemented in the model. Literature values (Kruszewski et al.2021, 2022) were used as initial parameters for the modelling.

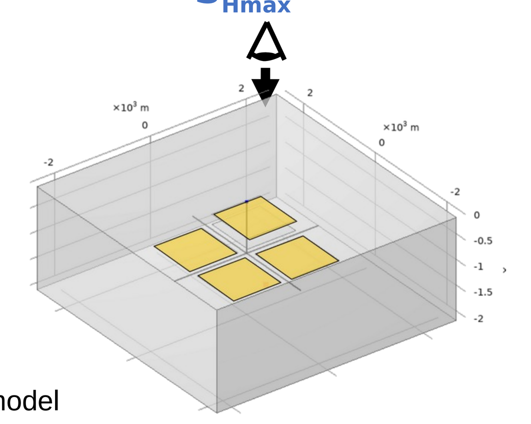
The mining-related stress concentrations affect different areas due to the stress orientations. However, they are observed most strongly in the vertical stress. This is especially true for the area below the deepest levels.

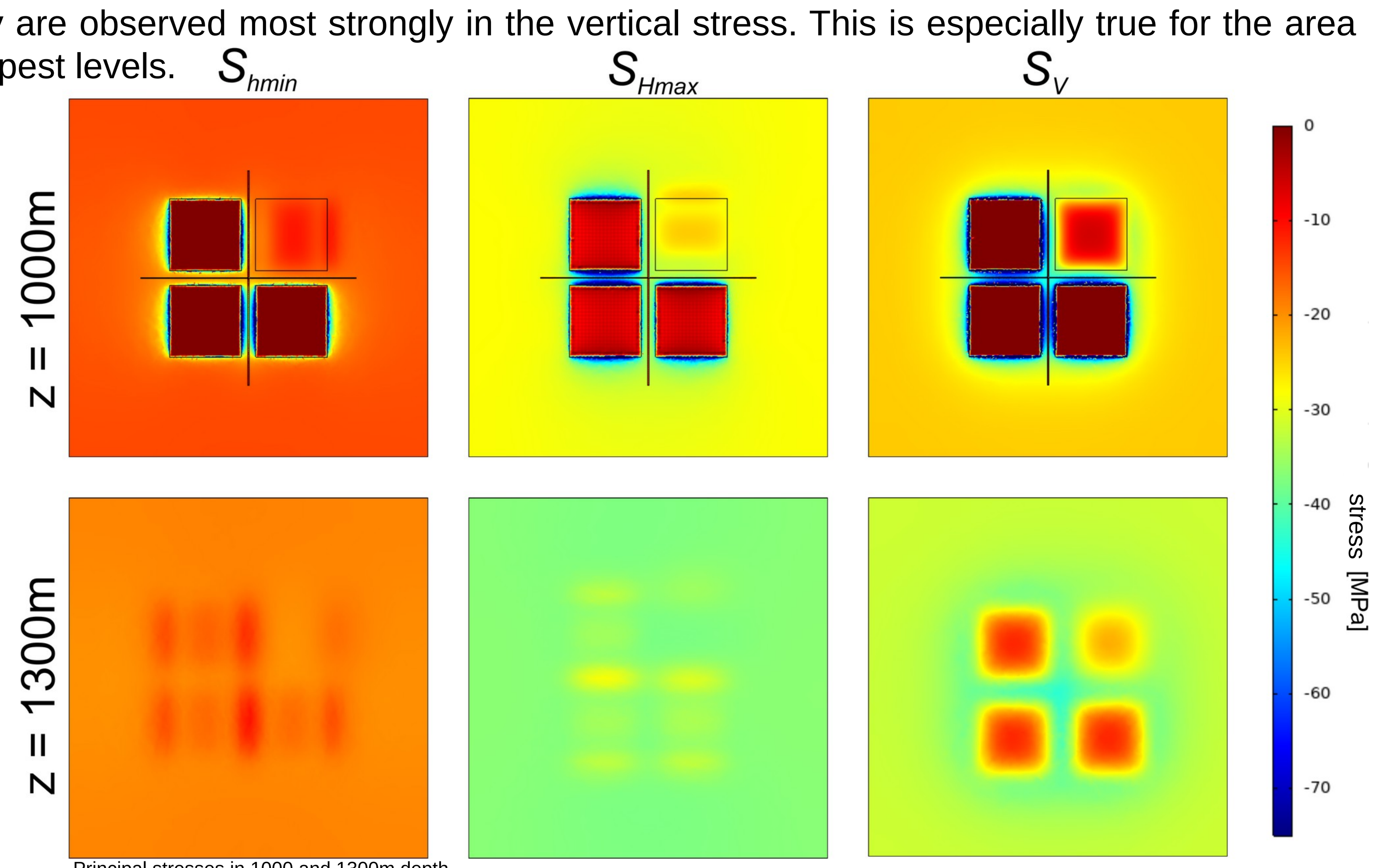


Rotation in the direction of the maximum principal stress



Simplification of the excavation areas and drifts


3D model



Principal stresses in 1000 and 1300m depth

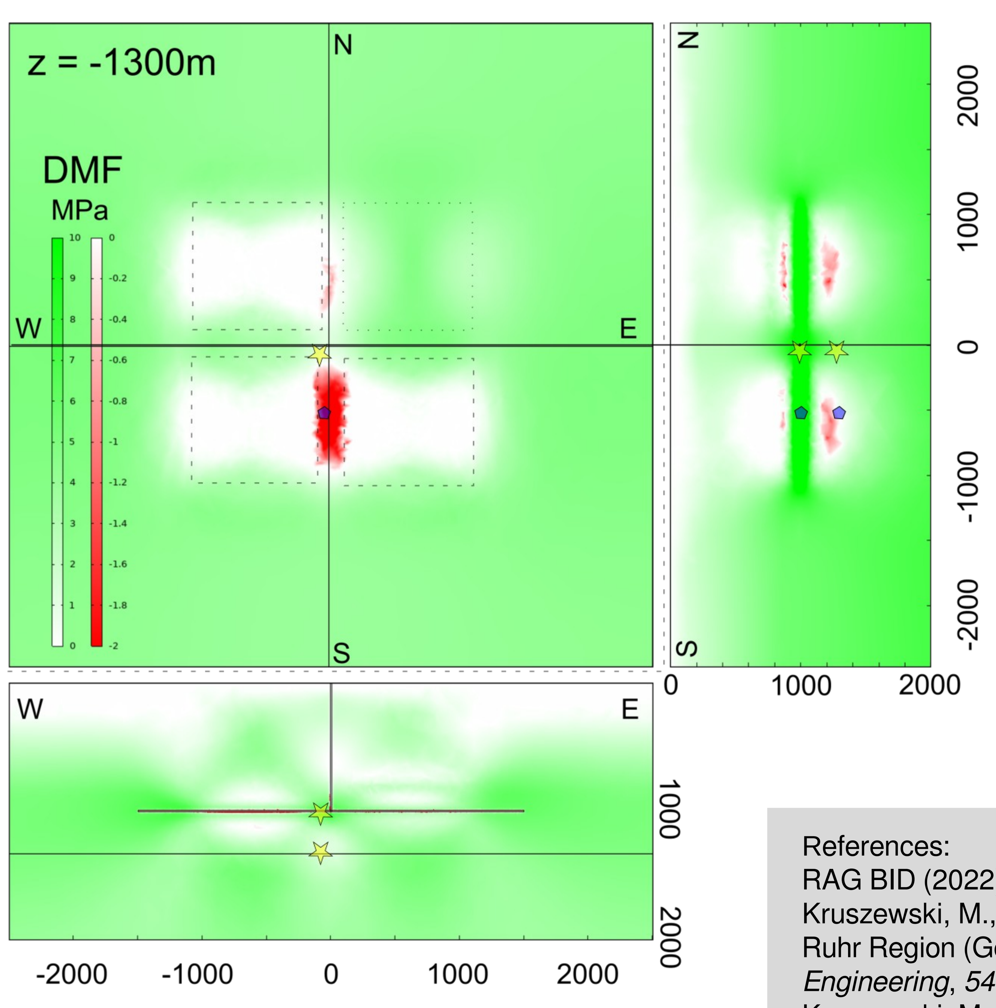
Conclusions

- Microseismicity correlates spatially and temporally with the mine water rise
- in the depth distribution of microseismicity, however, no upward trend with the mine water rise can be observed
- the numerically modelled stresses are concentrated on the areas of the pillars about 300 m below the deepest sections
- the observed concentration of microseismicity corresponds to the modelled stress concentrations
- in the study area, it is not the large fault areas that are reactivated, but smaller structures

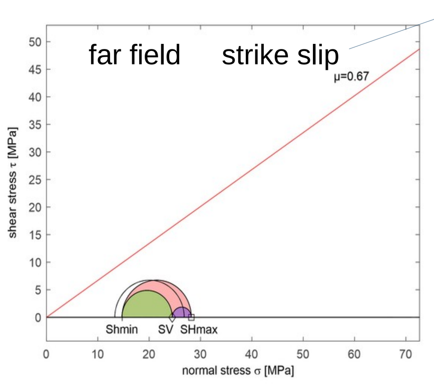
Failure potential

From the stress modelling, the DMF value (distance of Mohr circle to failure) can be derived, which takes into account the pore pressure change caused by flooding. This shows that especially the area between 1100 and 1300 m below the drifts has an increased reactivation potential.

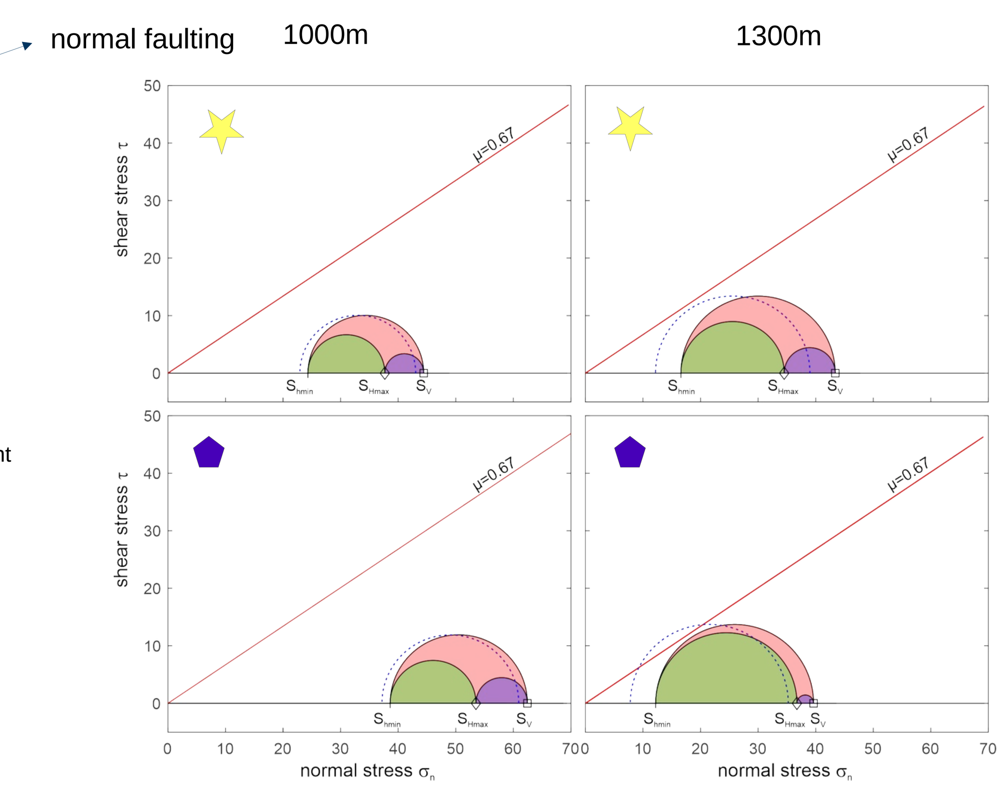
In Mohr's circles, the transition from regional strike to the normal fault regime can be seen in the area of the mine. Below the deepest adits in the area of the pillars, failure occurs when the pore water pressure increases.



DMF values in 1300m depth level and vertical sections



Mohr Circles for the far field and different positions marked in the DMF plot



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Kruszewski, M., Montegrossi, G., Backers, T., & Saenger, E. H. (2021). In Situ Stress State of the Ruhr Region (Germany) and Its Implications for Permeability Anisotropy. *Rock Mechanics and Rock Engineering*, *54*(12), 6649-6663.

Kruszewski, M., Klee, G., Niederhuber, T., & Heidbach, O. (2022). In situ stress database of the greater Ruhr region (Germany) derived from hydrofracturing tests and borehole logs. *Earth System Science Data Discussions*, 1-33.

Floodrisk Partners:

Thanks to:

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