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Flood-induced seismicity in the Ruhr area – a geomechanics perspective

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The Ruhr area is characterised by centuries of intensive coal mining. After the closure of the last mines, their controlled flooding began. The Floodrisk project investigates ground uplift, stress changes due to pore pressure changes and the reactivation potential of faults to explain induced seismicity. A particular focus is on monitoring and investigating in detail the relationship between mine water level rise, tectonic stress and induced seismicity in the Haus Aden catchment. Since 2014, mine water levels measured at the pumping stations of the central drainage system have been available for this region. This includes data from the post-mining phase through to flooding.

Highest seismicity during mining was observed in the area of the former "Bergwerk Ost". Ruhr University of Bochum has installed a network of 30 short-period seismic stations spaced between 0.5 and 3.5 km apart. The stations cover an area of about 160 km². They allow continuous monitoring of seismicity. By using the method of relative localization in combination with the dense network, it was possible to improve the precision of the measurements to a lateral resolution of less than 100 m. This detailed localisation of earthquakes made it possible to study the spatial and temporal evolution of earthquake clusters due to rising mine water levels.

The main underground waterways are the former adits which are surrounded by safety pillars of the mine. Since the permeability of the rock is rather low, the rising mine water affects the surroundings of the adits first and the mined-out sections. Over 2200 induced events have been localized since the start of flooding, showing spatial clustering. However, the majority of events occurs about 300 m below the main pillars between the longwall mining panels.

The geomechanical investigations are based on a compilation of the regional stress state in the eastern Ruhr area. We re-evaluated hydraulic fracturing tests that had been carried out to minimize rock bursts. The results were compared with stress orientations from independent sources (stresses in deep boreholes and earthquake source mechanisms). The new map of the spatial distribution of stress orientations shows a rather homogeneous stress pattern with very few locations where stress orientations deviate significantly from the average of N 154°E.

The second focus of the geomechanical approach is a 3D numerical model of stress concentration due to stress arching effects: Based on the geometry of the pillars, shafts and longwall panels, a generic FE numerical model was developed for a section of the Heinrich Robert mine using the collected stress data for model calibration. Increased vertical stresses within and below the pillars were observed as a result of stress arching. As the horizontal stress changes below the mining level are small, this results in increasing differential stresses which, with rising mine water, may lead to the observed events 300 m below the mining level.