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Regional-scale geomechanical impact assessment of underground coal gasification by coupled 3D thermo-mechanical modeling

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Underground coal gasification (UCG) has the potential to increase the world-wide coal reserves by utilization of coal deposits not mineable by conventional methods. The UCG process involves combusting coal in situ to produce a high-calorific synthesis gas, which can be applied for electricity generation or chemical feedstock production. Apart from its high economic potentials, UCG may induce site-specific environmental impacts such as fault reactivation, induced seismicity and ground subsidence, potentially inducing groundwater pollution. Changes overburden hydraulic conductivity resulting from thermo-mechanical effects may introduce migration pathways for UCG contaminants. Due to the financial efforts associated with UCG field trials, numerical modeling has been an important methodology to study coupled processes considering UCG performance. Almost all previous UCG studies applied 1D or 2D models for that purpose, that do not allow to predict the performance of a commercial-scale UCG operation. Considering our previous findings, demonstrating that far-field models can be run at a higher computational efficiency by using temperature-independent thermo-mechanical parameters, representative coupled simulations based on complex 3D regional-scale models were employed in the present study. For that purpose, a coupled thermo-mechanical 3D model has been developed to investigate the environmental impacts of UCG based on a regional-scale of the Polish Wieczorek mine located in the Upper Silesian Coal Basin. The model size is 10 km $\times$ 10 km $\times$ 5 km with ten dipping lithological layers, a double fault and 25 UCG reactors. Six different numerical simulation scenarios were investigated, considering the transpressive stress regime present in that part of the Upper Silesian Coal Basin. Our simulation results demonstrate that the minimum distance between the UCG reactors is about the six-fold of the coal seam thickness to avoid hydraulic communication between the single UCG reactors. Fault reactivation resulting from fault shear and normal displacements is discussed under consideration of potentially induced seismicity. Here, the coupled simulation results indicate that seismic hazard during UCG operation remains negligible with a seismic moment magnitude of $M_W < 3$.