Modelling dynamic fault slip and seismic wavefield for production-induced seismicity in Groningen

Ruan, J.; Ghose, R.; Mulder, W.A.

Publication date
2021

Document Version
Final published version

Citation (APA)
Ruan, J., Ghose, R., & Mulder, W. A. (2021). *Modelling dynamic fault slip and seismic wavefield for production-induced seismicity in Groningen*. Poster session presented at Nederlands Aardwetenschappelijk Congres 2021.

TU Delft

DeepNL

NWO

Modelling dynamic fault slip and seismic wavefield for production-induced seismicity in Groningen

Jingming Ruan; Ranajit Ghose; Wim Mulder

Delft University of Technology, Netherlands

Introduction

Induced seismicity from a gas-producing region such as Groningen is caused by reservoir depletion and subsequent compaction of the reservoir due to long-term gas production. However, because of the complexity of the source process and the uncertainty regarding the underground structure and composition, it is difficult to quantify the effects of gas production. In order to properly evaluate the stress state due to production, it is necessary to simulate accurately the physical processes in the source region.

Objectives

In order to investigate the seismogenic potential of pre-existing fault(s) that can be reactivated due to fluid depletion, we use finite-element modelling using Defmod (Meng, 2017) for production-induced earthquake simulation, considering different model settings. With quasi-static loading and dynamic fault slip, this will allow us to quantify the effects of fluid production and fault setting on the induced seismicity.

Quasi-static poroelastic loading

By applying quasi-static poroelastic loading representing reservoir depletion, the stress and strain fields are derived from the displacement field. In poroelastic loading, the pressure variation causes changes in both shear and normal stresses. The equilibrium of the fault is then evaluated assuming either rate-and-state or slip-weakening behaviour for friction. Following figures show the results derived from Defmod, representing the case of a uniform depletion (Buijzer et al., 2019). Our results confirm that for a uniformly depleted reservoir, the fault becomes more unstable with increasing depletion and the initiation of fault reactivation occurs when the depletion exceeds a threshold, the value of which is in agreement with Buijzer et al. (2019).

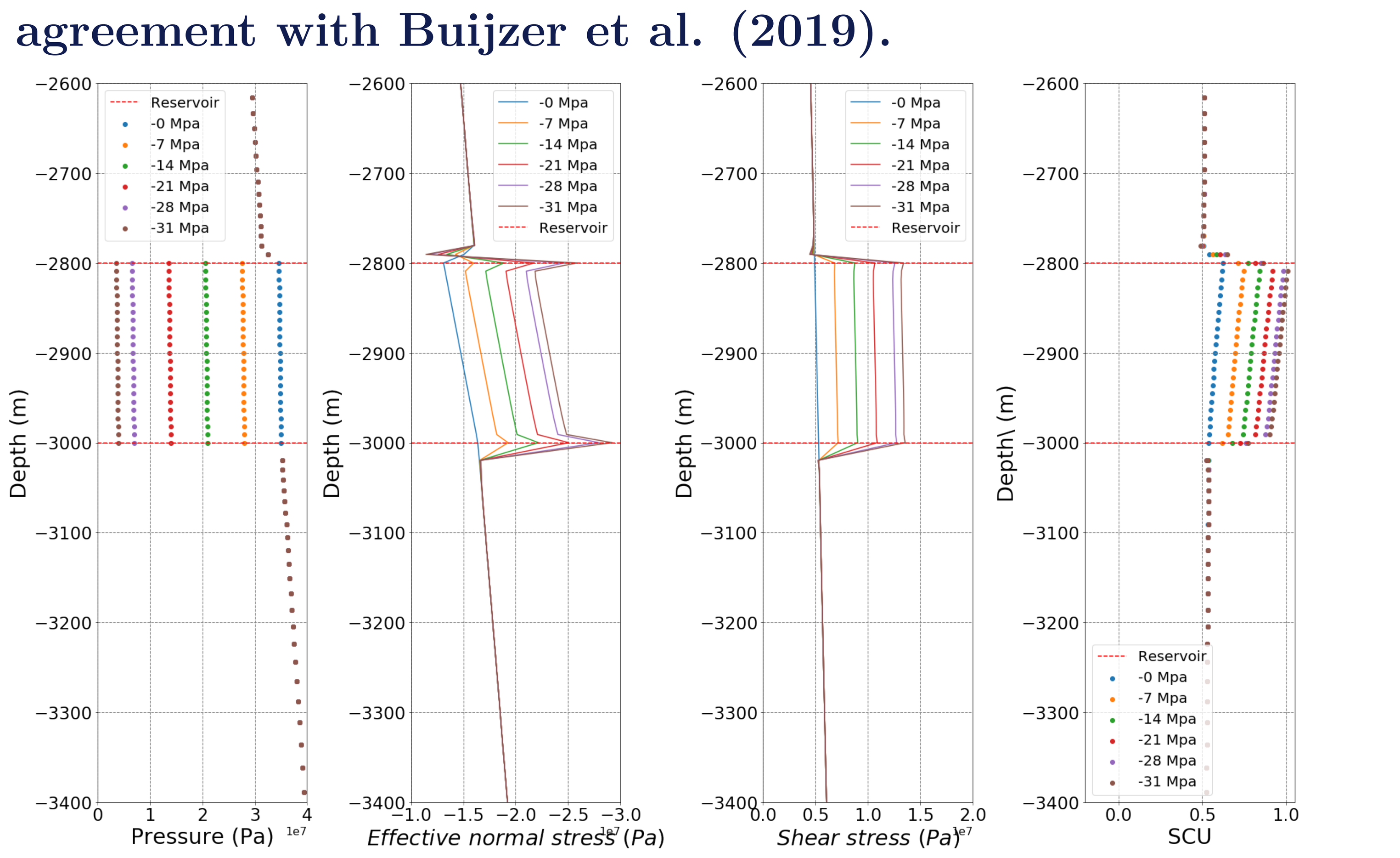

Figure 1:Simulated pressure, stresses and Shear Capacity Utilisation (SCU).

Dynamic fault slip

Fault reactivation depends highly on both the initial stress and the loading rate. When the critical state is reached (shear stress exceeding friction), the fault reactivation occurs. Based on the rupture process, fault slip can be seismic or aseismic. For a seismic slip, the fault experiences acceleration and deceleration. Fault reactivation is simulated by using a dynamic solver to investigate the rupture propagation and arrest of dynamic faulting.

Wavefield simulation

The propagation of seismic waves due to dynamic fault slip and its near-field observation are simulated. The following figure shows the dynamic fault slip and the seismograms (particle velocity) observed at two receivers located on the top surface of the model (the first receiver at the epicenter and the second one at 1800 m distance from the first receiver). In the next stage, seismic wavefield will be computed for single and intersecting faults, and then related to actual field observations.

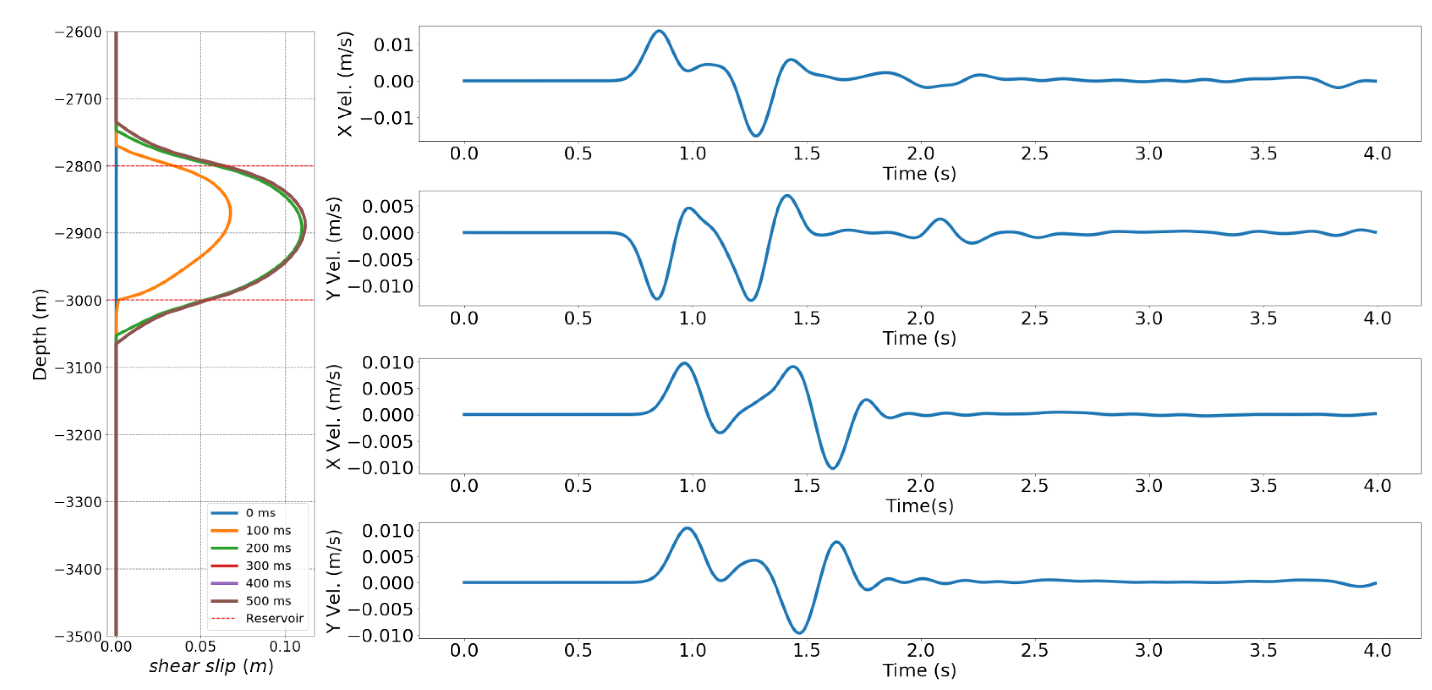

Figure 2:Estimated fault slip since rupture initiation and the seismograms at two receivers.

Fault intersection

The effect of fault intersection is crucial in simulating realistic fault slip, as faults often exist as inter-connected systems of multiple fault segments. For seismic observation, intersecting faults are needed to account for non-double couple component of the seismic moment tensor. The following figure shows two intersecting faults, constrained in our simulation using split nodes.

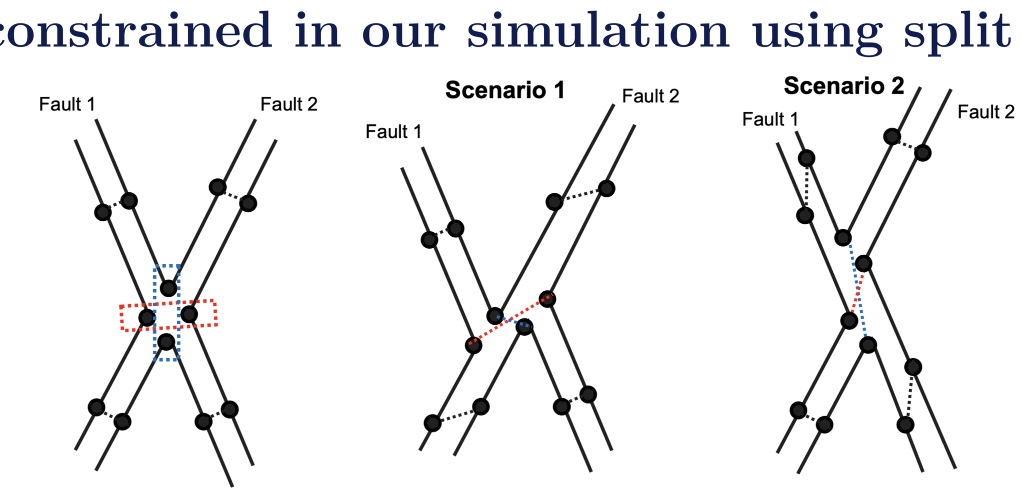

Figure 3:Intersecting faults simulated using split nodes.

Results so far

In the Groningen field, the change of pressure in the reservoir induces a stress state which brings a pre-existing fault close to failure. Our on-going physics-based simulation will help understanding the underground processes, as well as relating the observed seismic wavefield at the surface to the processes occurring at the source region of the production-induced seismicity.

Future work

By using detailed, realistic models which represent underground structure and stress scenarios of the Groningen gas field, we plan to simulate accurate, dynamic fault slip and the observed seismic wavefield. This understanding will be crucial in linking observed seismicity to stress and displacement changes in the reservoir.

Reference

Meng, Chunfang. "Benchmarking Defmod, an open source FEM code for modeling episodic fault rupture." Computers & Geosciences 100 (2017): 10-26.

Buijze, L., et al. "Nucleation and arrest of dynamic rupture induced by reservoir depletion." Journal of Geophysical Research: Solid Earth 124.4 (2019): 3620-3645.