UNIVERSITÉ DE NEUCHÂTEL

CHYN
Centre d'hydrogéologie
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MSc in Hydrogeology and Geothermics
MSc Thesis Summary, **2017-2018**

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Mechanical Explanation and Modelling of Induced Seismicity in Southern Kansas, USA

In recent years, Southern Kansas has become an area of interest for the study of induced seismicity. In 2014, one of the largest earthquakes (M_W 4.9) recorded in Kansas shook the Sumner County near Conway Spring. The series of events related to this mainshock is commonly referred as the Milan sequence. Brine disposal wells in the deep Cambrian Arbuckle Group are suspected to have reactivated a deep unmapped fault in the underlying Precambrian basement. The depth and geological complexity of this injection reservoir makes the understanding of the seismic triggering process challenging. The purpose of this study is to explore the influence of the injected brines on the fluid reservoir along the fault and to propose a hydromechanical interpretation that links the reservoir pressure evolution to the spatiotemporal distribution of the Milan sequence.

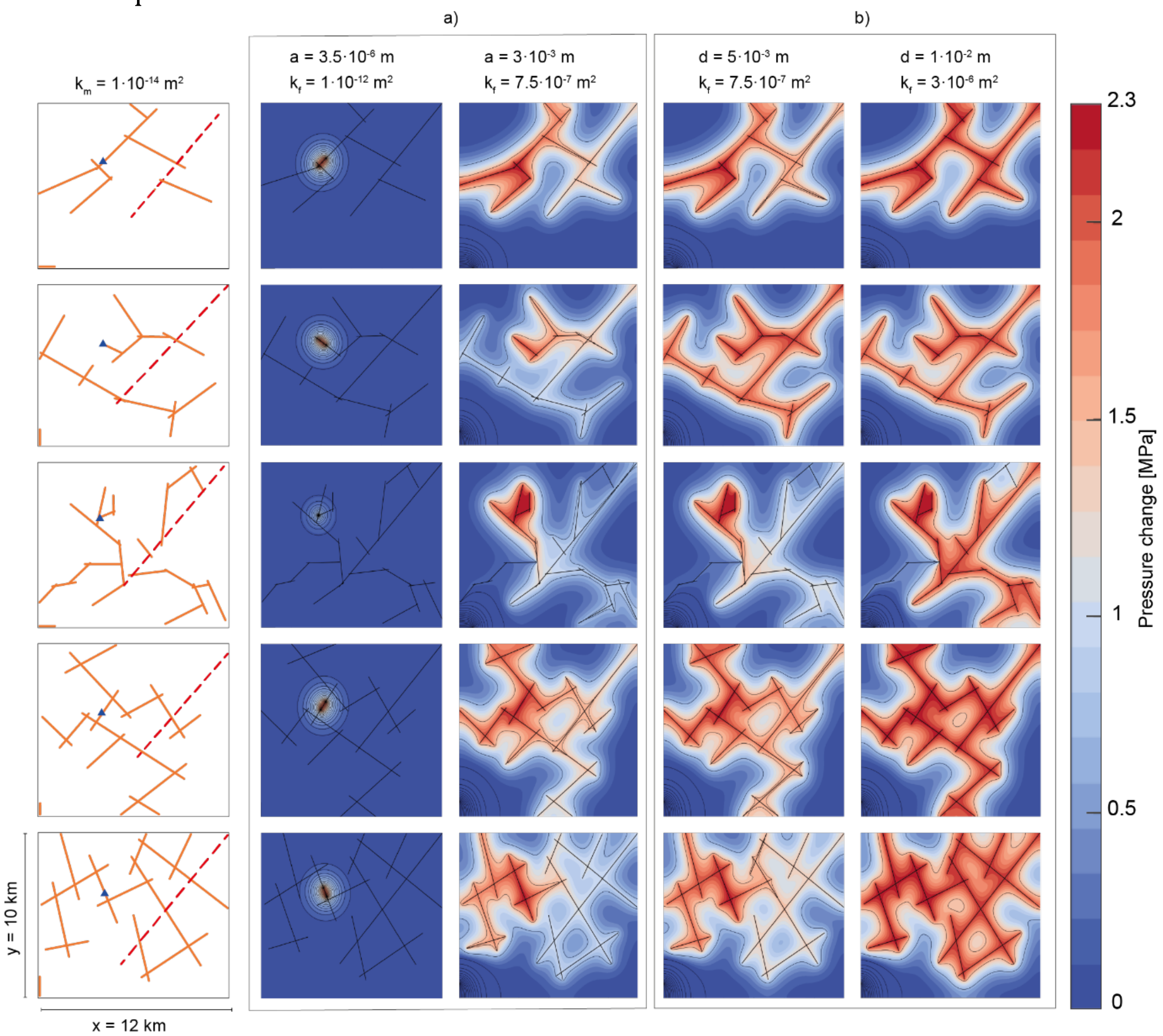

Figure: Advancement of the pressure front after 180 days of brine injection into the Arbuckle Group with different permeability for planar fractures in a) and circular conduits in b). The first column shows the different simulated domains. Each domain investigates a different fracture network configuration displayed in orange. They all represent a surface of 120 km² (12km x 10km) within the Arbuckle Group characterized by a matrix permeability of 10^{-14} m². The blue triangle marks the injection point and the red dashed-line, the fault that originated the Milan sequence (Milan fault).

The numerical approach aims to quantify the pore pressure changes induced by fluid injections and to investigate the influence of the fractured and karstic nature of the Arbuckle Group. Simulations of the pressure diffusion are performed using THERMAID, which is a fractured reservoir framework implemented in MATLAB developed at the CHYN. Those results are then compared with the fluid pressure required to trigger a slip calculated with the Mohr-Coulomb friction criterion for two depths: in the injection reservoir and for the mainshock depth.

The presence of a high-permeability pathway acting as principal mean of hydraulic connection between the injection site and the Milan fault has a great impact on the pore pressure change induced along the fault. Simulations of the pore pressure changes after an injection period of 180 days show that the reservoir pressure can increase up to 16 MPa along the fault. The Mohr-Coulomb analysis demonstrates that this fluid pressure is not enough to trigger a slip in the Arbuckle Group. However, considering the hydrostatic equilibrium with the Precambrian fractured reservoir, the modeled pressure change is sufficient to trigger a frictional slip in the deep basement, at the mainshock depth. From both numerical and analytical approaches, a hydromechanical explanation of the seismic triggering process is reconstructed in respect with the spatiotemporal distribution of the Milan sequence.

This study highlights the influence of conductive networks on pore pressure changes, which are induced by the disposal operations and can lead to the triggering of earthquakes. On one hand, further studies need to be realized to better understand the geology of the Arbuckle Group in Southern Kansas. For instance, the karstic nature of this reservoir is known but not characterized and, as evidenced by the numerical modelling, it impacts the pressure diffusion process. On the other hand, additional investigations should be conducted to link other seismic sequences to high fluid pressure changes influenced by the presence of high-permeability pathways in the injection reservoir.