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Geotechnical Centrifuge Modeling of CO_2 EOR in CHOPS Reservoirs

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Summary

Deliberate massive sand influx used to increase oil recovery from shallow heavy oil resources ultimately results in low oil recovery (e.g. Dusseault, 2007). This means 85-95% of oil would remain unrecovered during the co-production of oil and sand process, which is referred to as Cold Heavy Oil Production with Sand (CHOPS). In recognition that sand production during CHOPS creates high-permeability and heterogeneous channel-like structures among multiple wells (Rangriz Shokri and Babadagli 2017; Sawatzky et al. 2002; Solanki and Metwally, 1995; Tremblay et al., 1999; Wong, 2003), the application of enhanced oil recovery techniques such as cyclic solvent injection (CSI) with different solvents requires careful planning and management to achieve optimal efficiency in terms of costs, energy use, and environmental impacts (e.g. Soh et al. 2018; Rangriz Shokri and Babadagli 2014).

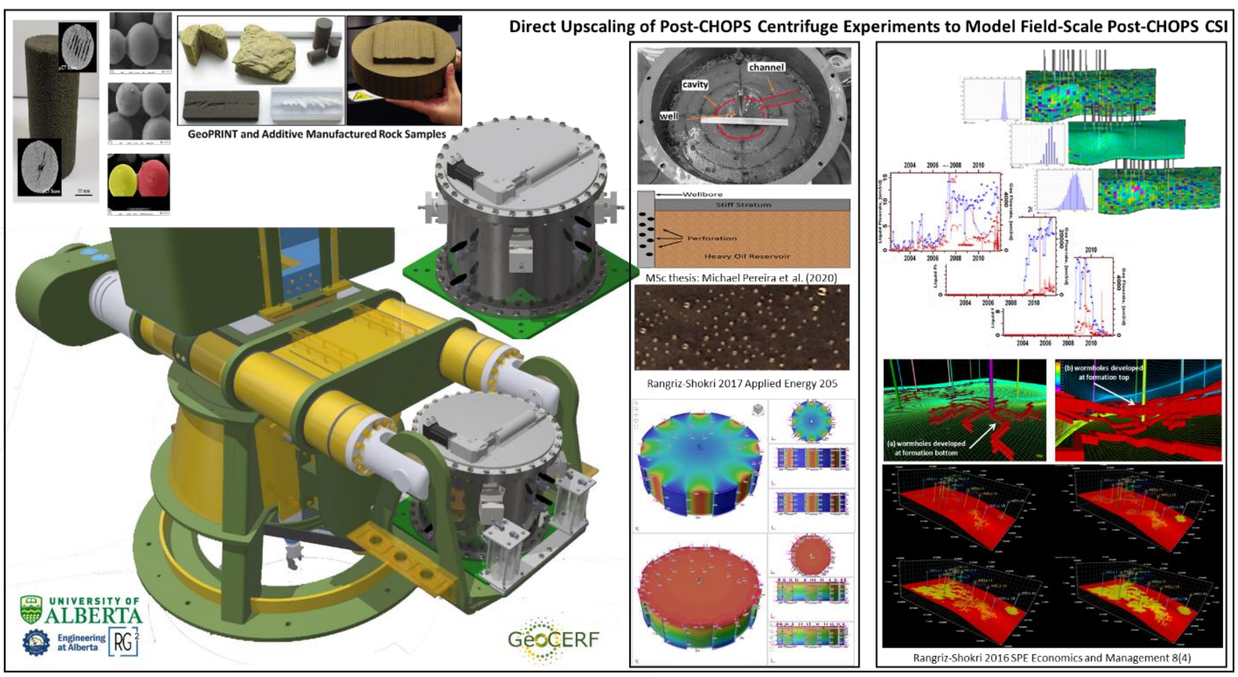

Figure 1: Physical modeling of post-CHOPS CO2 EOR

Expanding the learnings from Layeghpour (2021) and Pereira (2021) into this work, we present the application of a 2-meter beam geotechnical centrifuge for scaled physical modeling of multiphase flow (i.e. live heavy oil) in a 3D printed rock specimen (Gomez et al. 2017; Hodder et al. 2018) under different triaxial stress states. We employed the geotechnical centrifuge (e.g.

Pereira 2021; Vaziri et al. 2003; Simone 1999) and additive manufacturing technology to better understand the dominant driving mechanisms during CHOPS (single phase) and CO_2-based cyclic solvent injection in post-CHOPS (multi-phase).

Within our newly designed multi-phase centrifuge cell, we included a vertical loading system to represent the weight of the rock and earth above the CHOPS formation. Anisotropy in horizontal stresses were applied using an 8-arm horizontal loading system. We incorporated the high-permeability channels (i.e. wormholes) near the perforations of a scaled wellbore inside the 3D printed unconsolidated sandstone rock (with actual sand grains). To establish residual water saturation, we first saturated the CHOPS sample with water, followed by dead oil and live oil; live oil was prepared by dissolving CO_2 into the dead oil sample from a CHOPS well in Alberta. The test was completed by spinning the CHOPS physical model at approximately 120 revolutions per minute; that's equivalent to 30 times the gravitational acceleration. As the 500 kg setup was spun, we opened the wellbore and initiated the multi-phase fluid and sand production. We collected the produced fluids and the collapsed sand grains.

The results of our scaled physical experiments provide a better understanding of the dominant driving mechanisms of CSI at reservoir conditions with respect to fluid displacement processes, wormhole collapse, and sand production. Our new experimental tool can be used to explore the multi-phase flow in deformed porous media in other geoenergy applications including CO_2/H_2 storage and safe disposal of radioactive waste.

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