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Understanding Geomechanical and Stress Effects of SAGD Production Using 4D-3C Seismic Data

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Summary

This study examines the geomechanical changes associated with a SAGD project that is part of the extensive Athabasca oil sands trend and produces from the lower Cretaceous McMurray Formation at depths of 180 to 250 meters. The reservoir is of excellent quality, with porosities averaging between 33-35% and permeabilities ranging from 4-8 darcies. SAGD developments are considered unconventional plays due to the low grade (6-9° API), high viscosity oil (1-8 million cP) that is being produced by an in-situ method known as Steam Assisted Gravity Drainage, or SAGD. In SAGD, steam is injected into the reservoir along a horizontal well to heat the immobile bitumen. As the bitumen is heated, its viscosity is lowered to the point that it can flow under gravity down to a lower horizontal well where it is produced.

SAGD production involves the injection of large volumes of high-pressured steam into the reservoir. This fluid injection, along with the transition of bitumen from a quasi-solid to a liquid and the unconsolidated nature of the reservoir, results in significant changes in both the geomechanical properties and the in situ stress state of the reservoir. These changes are important because of their impact on permeability. This study will show that these changes can be detected and interpreted using 4D-3C seismic data.

Two multicomponent time-lapse seismic surveys were acquired over a 2.5 km^2 area. The baseline survey was shot in 2002 before steam injection began. The monitor survey was shot in 2011, after about 4 years of injection. Two seismic-based methods will be used to visualize in situ stress and geomechanical changes: the Gray et al method (Gray et al, 2012) and shear-wave splitting observations. The Gray et al method (2012) uses seismic velocities and densities determined through joint inversion to calculate values of Young's modulus and Poisson's ratio. By making several assumptions, these moduli can be used to calculate horizontal stress magnitudes using Hooke's Law and Linear Slip Theory. Variation in geomechanical and stress properties between the two surveys is indicative of production effects in the reservoir.

Shear-wave splitting analysis is another useful tool to visualize stress changes in the subsurface. Shear-wave splitting occurs when either vertical fractures or high differential stress causes the shear wave to split into two polarizations: a fast shear and a slow shear. The fast shear polarizes in the direction of maximum horizontal stress and the slow shear polarizes in the direction of minimum horizontal stress. The azimuth of the fast and slow shears will indicate the orientation of maximum horizontal stress and minimum horizontal stress, respectively, while the difference in travel time will give a sense of the magnitude of the differential stress. Although the origin is unclear, shear-wave

splitting has been observed previously in the very compliant heavy oil sands of Alberta (e.g. Wikel et al, 2012, Whale et al, 2009, and Cary et al., 2010). This is the first study, however, to interpret changes in splitting parameters in relation to SAGD steam injection and production.

References

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