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Stratigraphic controls on the distribution of poroelastic properties in the Late Cretaceous Cardium Formation, Alberta

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Summary

Over the past decade, the application of horizontal completions and multistage hydraulic fracture treatments (“HFT”) has proven to be an effective strategy to stimulate oil and natural gas production from low permeability and heterogeneous reservoirs. Despite this success, HFT is controversial due to a perceived lack of objective scientific study of the potential impacts of the technology. One particular issue of growing public concern is the potential link between HFT operations and induced or triggered seismicity. This concern is greatest where high-consequence infrastructure is located close to oil and gas operations employing HFT.

Since 2008, hundreds of horizontal wells have undergone multistage HFT to stimulate light oil production from the Late Cretaceous (Turonian - Coniacian) Cardium Formation in the West Pembina area. To date, there have been no recorded seismic events associated with these operations. Drilling and completion strategies continue to evolve in the West Pembina tight oil play; the risk associated with different treatment parameters, however, is currently unknown. This research aims to better understand the geologic properties that control the propagation of seismic waves throughout the Cardium Formation. Core and petrophysical data will be studied in the context of a high-frequency allostratigraphic framework to determine how depositional facies govern the vertical and lateral distribution of poroelastic properties throughout the formation. The results of this research will be incorporated into a companion project that will use simulation to predict the operational thresholds for triggered seismicity.

Introduction

The Cardium Formation is a prolific hydrocarbon reservoir in the Western Canada Foreland Basin that emerged recently as a significant source of unconventional light oil (Clarkson and Pedersen, 2011). Advances in technology have enabled production from the low-permeability margins of the Pembina field through the application of horizontal completions and multistage hydraulic fracturing (Ghaderi et al., 2013). These techniques, which involve the injection of large volumes of high-pressure fluid through isolated perforated intervals in the wellbore, typically induce very low magnitude microseisms (**M**<0) (Davies et al., 2013). Recent large and unplanned seismic events associated with HFT operations, such as the 2011 **M**3.6 to 3.8 sequence generated in the Horn River Basin (B.C. Oil and Gas Commission, 2012), have raised concerns about the potential to trigger damaging ground motions.

The fact that seismicity results from fluid injection, as well as fluid extraction, has been well-established for many years; quantification of the risks associated with this process, however, is unresolved (Shapiro and Dinske, 2009). Causes are largely attributed to changes in pore pressure and effective stress, and are thought to be governed by elastic moduli (poroelastic properties) of the reservoir formation (Baranova et al., 1999). Although the basic mechanisms are understood, current knowledge of the physics of induced seismicity processes is insufficient to predict the likelihood or magnitude of induced or triggered events. One of the barriers to development of a predictive model of induced seismicity processes is the lack of well-characterized local models of poroelasticity in seismically-monitored reservoirs undergoing dynamic changes in pore pressure.

The goal of this project is to address the dynamic poroelasticity of the tight Cardium Formation in the West Pembina area. It is hypothesized that the local stratigraphy will control the distribution of poroelastic properties, and therefore, affect seismic wave propagation. The main objectives for this project are to a) identify depositional facies and stratigraphic bounding discontinuities, b) develop a high-resolution allostratigraphic framework to identify coeval depositional units, c) determine zonal constraints for predicting the distribution of poroelastic properties, and d) construct a 3D predictive model of poroelastic properties within the project area.

Method

Sedimentary rocks can possess significant anisotropy in their poroelastic properties due to changes in lithological composition and sedimentary facies (Abousleiman et al., 2010). This implies that depositional processes and stratigraphic preservation impose first-order controls on the distribution of poroelastic properties. The stratal architecture of the Cardium Formation has been described in two competing models, leading to uncertainty in the geomechanical stratigraphy in the West Pembina area. Plint et al. (1986) documented a tabular geometry based on regional correlations, whereas recent local correlations characterize the Cardium as laterally-discontinuous imbricated shoreface deposits (Fraser, 2012; Pedersen et al., 2013). Building on the work of Fraser (2012), detailed core descriptions will be completed to identify depositional facies and bounding discontinuities; these will be correlated to corresponding geophysical well log characteristics as the first stage of developing a high-resolution allostratigraphic framework throughout the study area, with the goal of confirming the stratal geometry. This framework will be used to define zonal subdivisions for petrophysical analyses, including estimation of poroelastic properties. Predictive facies mapping — constrained by allomember correlations — will guide the construction of a 3D model of poroelastic properties in the Cardium Formation of the study area.

Conclusions

This research represents the first step toward development of a robust tool to predict the likelihood and magnitude of induced seismicity in an area of active oil production operations. The poroelastic model, and the subsequent simulation study, aims to estimate boundary conditions under which industrial operations might trigger hazardous ground motions. At this moment, no such events have been observed but the petroleum industry will benefit from understanding safe operating limits that will minimize the risk of damage to surface infrastructure. In a larger sense, Canada as a whole will benefit from a balanced approach to ensure public safety while preserving economic growth through development of the oil-rich Cardium reservoir.

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