Reactivated basement faults: Why the events that created North America may still matter for optimal shale development and exploring for hydrothermal dolomites. A case study from the Horn River Basin.

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Summary

A comprehensive dataset around the most seismically active area within the Horn River Basin (northeastern BC) was studied. Through the careful analysis of one inactive fault and it's livelier neighbours, this work provides insights on induced seismicity, fault impact on optimal shale development and fault impact on the Clarke Lake Hydrothermal dolomite field.

Introduction

Seismicity has long been associated with critically stressed faults, which may also enhance reservoir permeability. More recently, seismicity has also been associated with hydraulic fracture stimulation and water disposal wells. The Horn River Basin is one of the first examples of seismicity associated with hydraulic fracturing and still provides one of the best non proprietary datsets to study this phenomenon.

Consistently mapping and predicting which faults will slip is notoriously difficult. Many slipping faults aren't mapped and many mapped faults aren't slipping, even if our understanding of their stress state suggests they might. Recent observations about pore pressure anomalies in the Horn River Basin provide some insights into why a fault may not slip. Production variability, previously attributed to stress anomalies, is revisited in this light along with ideas around optimal development of these shale gas resources.

Seismicity in the Horn River Basin was concentrated around the boundary between the Fort Simpson and Nahanni terranes, which amalgamated during the Paleoproterozic Wopmay orogeny. Paleoproterozoic planes of weakness, created under a compressional regime, were then reactivated under transtension during the Late Devonian/Early Mississippian, likely as conjugate faults to those controlling the Prophet trough. This was a period of intense hydrothermal fluid flow, when many of Western Canada's most important hydrothermally influenced reservoirs were created. Hydrothermal alteration signatures have been identified within the Horn River Basin shales, but the connection between hydrothermal fluids in the shales and nearby hyrothermally controlled gas accumulations is not clear. Most recently these faults were active under a transpressional strike/slip regime, as the stresses from the most recent orogenic collison have relaxed. Recently active faults within the Horn River basin shales are interpreted as the likely conduits that control the diagenetic alteration and hydrocarbon charge in some of British Columbia's most prolific conventional gas accumulations.

Theory and/or Method

Log, core, pressure, temperature and gas composition data was analyzed along with government and 3rd party resources assessments to estimate in-place hydrocarbon volumes in the Devonian Muskwa, Otter Park and Evie shales of the Horn River Basin. Production and completion data was analyzed to estimate well and basin-level recovery factors and recoverable volumes. Published literature was used to understand production anomalies and unusual hydraulic fracture behavior. Kick and loss data was utilized to identify anomalous reservoir permeability and to identify areas at higher risk of induced seismicity and/or depleted reservoir pressure. Using NRCAN's earthquake database and completion data from Canadian Discovery's Frac Database, spatiotemporal methods were applied to understand which wells and pads were associated with induced seismicity and which were not. Seismic interpretation aided in mapping basin structure with a focus on areas of recent seismicity. Magnetic data was used to make inferences about the relationship of these faults to important basement boundaries. Surface topography, river offsets and kinks in established geoedges and field boundaries were used to map faults away from seismic & well control.

Conclusions

Hydraulic fracture induced seismicity and associated faults have provided a unique window into shale reservoir permeability and the complex processes of source rock maturation, fluid migration and diagenesis. Understanding the complex history of recently active faults is imperative to optimally drill, complete and space wells economically and safely in some low permeability reservoirs. It may also be crucial in exploring for undiscovered conventional resources based on new understanding of the pathways controlling hydrocarbon and diagenetic fluid migration.

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