Duvernay

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Summary

Development of a resource play such as the Duvernay Formation is subject to intrinsic risks. These may include incurring additional costs due to induced seismicity, or risks associated with lithologic heterogeneity or unexpected thermal maturity (e.g., dry gas vs. condensate). Proximity to basement-rooted faults is a known risk indicator for induced seismicity, but it may also be influenced by the depositional environment and/or the past or present thermal state of a reservoir, especially if the basinal fluid circulation patterns are fault-controlled. In the case of the Duvernay Formation, off-reef depositional systems include contourite deposition, turbidity/mass flow and in-situ biological carbonate precipitation. Transcurrent faulting caused by deep-seated strike-slip faults may have played a role in the development of these systems. Joint interpretation is enabled by combining microseismic data with seismic-reflection data and displaying the data in depth. A geological picture is constructed by visualizing microseismic hypocentres in a chair plot that includes reflection surfaces and depth slices. This type of visualization can be used to determine best practices for the future location and design of horizontal treatment wells.

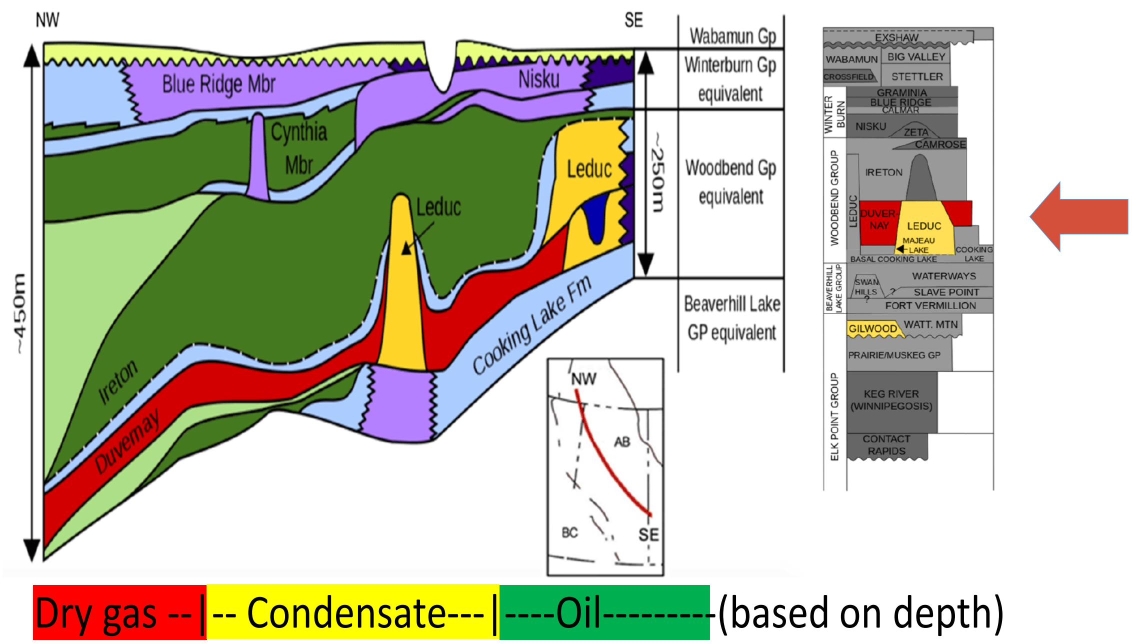

Figure 1. Schematic cross section modified from Preston et al. (2016). The Duvernay Formation (highlighted in red) is stratigraphically equivalent to the Leduc Formation. Generalized, depth-dependent thermal maturity zones are depicted along the base of the cross section.

Overview

The Duvernay Formation is an organic rich calcareous shale (Knapp, 2017) deposited contemporaneously with reef complexes of the Leduc Formation. It represents an important unconventional resource play in western Canada (Preston et al., 2016). Our study area is located West of Fox Creek, within an area that straddles a transition in thermal maturity from oil to condensate (or natural gas liquids, NGL) to dry gas (Preston et al., 2016). Figure 1 shows a stratigraphic table along with a schematic cross section.

Method

Our interpreted fault model, consisting of a regional flower structure, is illustrated in Figure 2. Based on a combined interpretation of 3-D seismic data and microseismicity (Weir et al., 2018, Eaton et al. 2018), the inferred transcurrent flower structure system is segmented, is at least several km in width and extends (discontinuously) in a general N-S direction for several 10's of km. Structurally, it is composed of basement-rooted strike-slip faults that bound a secondary set of oblique, antithetic faults. At one particular location, microseismic data show an alignment of microseismic events with the pre-existing Swan Hills reef edge (Figure 3), suggesting that development of the fault system was controlled, in part, by strength contrasts at lithofacies boundaries. To the north, the microseismic event alignment is approximately N-S. This orientation parallels the overall strike direction of the fault system, but it is not aligned to SHmax (Figure 3), which is 43° N in this region (Shen et al., 2019).

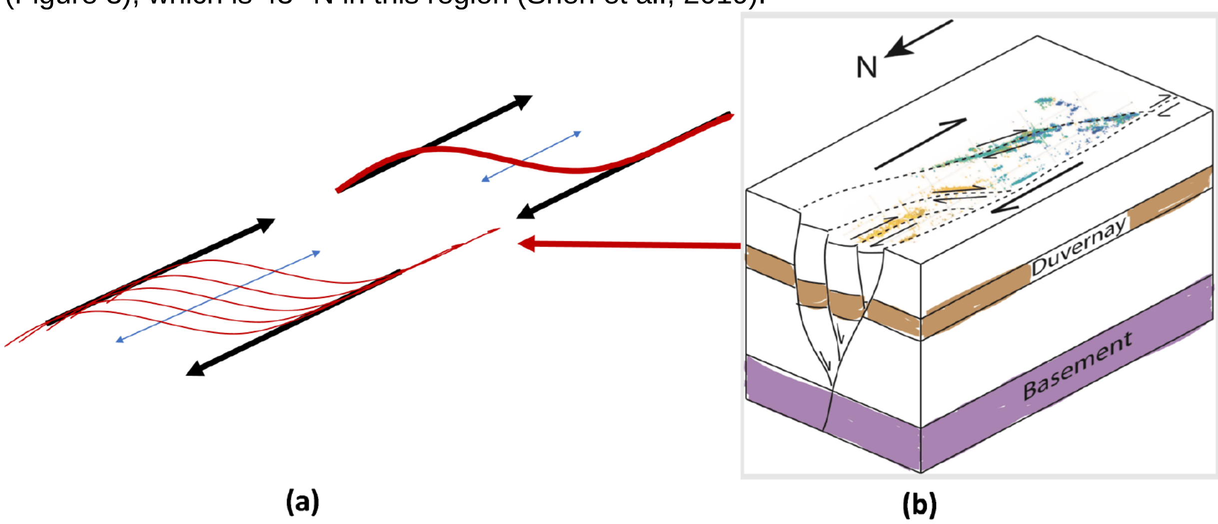

Figure. 2. (a) Schematic diagram of our interpreted transcurrent fault system in the Duvernay. The movement of the strike-slip fault is transferred to oblique slip along a set of secondary faults. (b) Schematic diagram of a basement-rooted flower structure (from Eyre et al., 2019).

These results suggest that the location and geometry of induced seismicity is controlled by pre-existing transcurrent faults that cut through the Duvernay Formation. Although their expression is subtle, many of the associated faults can be mapped in the seismic volume from the basement to several hundred meters above the reservoir. Seismic inversion studies indicate abrupt changes in seismic properties across faults, suggesting that the interpreted fault system influenced the depositional and/or diagenetic environment of the Duvernay Formation (Weir et al., 2018).

From an induced-seismicity risk-management perspective, it is advisable to drill horizontal wells so that they intersect known faults at a high angle, as this approach facilitates mitigation steps during completion such as skipping stages near a fault. There is nearby petrographic and geochemical evidence that deep-rooted faults provide conduits for circulation of hydrothermal fluids from the basement (Al-Aasm, 2002). Such a mechanism could explain localized thermal anomalies that would impact thermal maturity in the Duvernay.

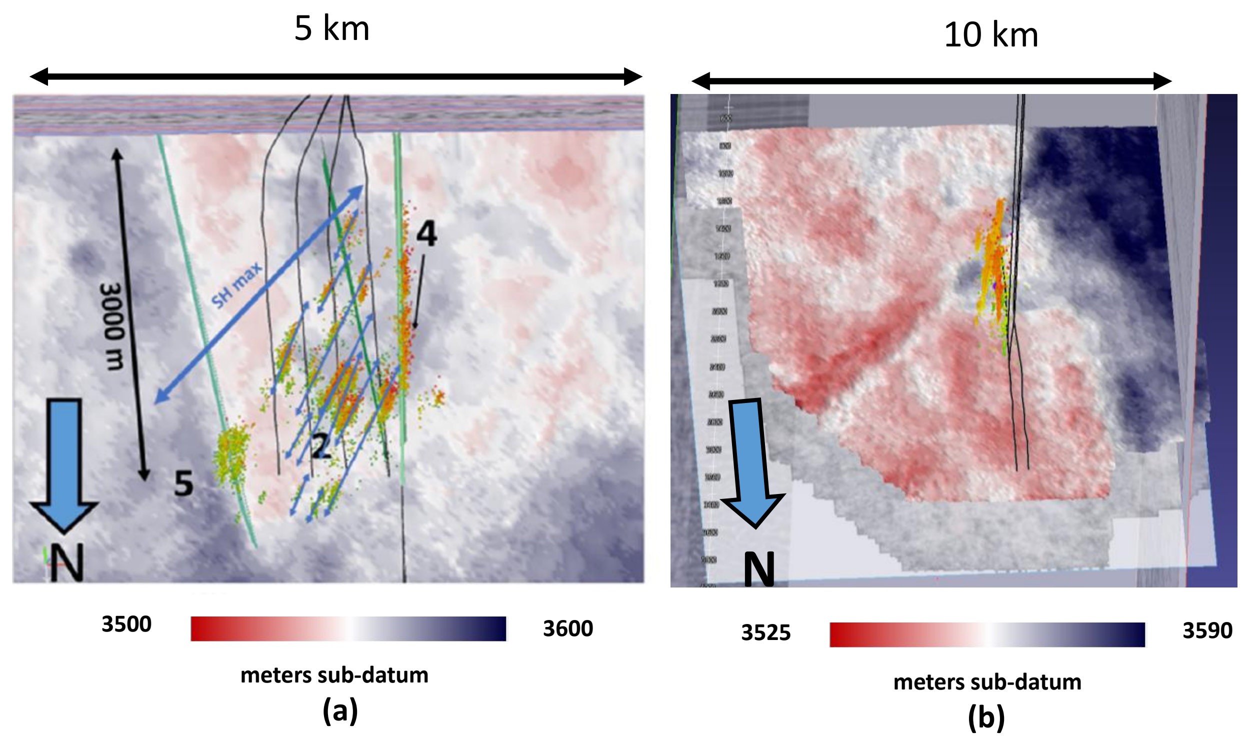

Figure 3. Depth to the top of the Swan Hills Formation, derived from two 3-D seismic data examples. Microseismic events recorded during a Duvernay completion program are plotted as points within the seismic volume. The microseismicity tends to follow pre-existing faults that are NNE trending (a), and N-S trending (b). SHmax is oriented 43° N in this area (Shen et al., 2019).

Conclusions

The interpretation methodology deployed here emphasizes the use of combined microseismic analysis and reflection seismic imaging. The depth-dependent patterns observable in the microseismic catalogue were observed to align along faults identified on the reflection seismic data. The North-South induced earthquake patterns are aligned with pre-existing strike-slip faults, seated within the basement. The 30° N alignment is consistent with a pattern observed in the Swan Hills Formation structure map, interpreted here to be influenced by transcurrent faulting. The Swan Hills Reef front appears to have acted as a barrier to hydraulic fracture stimulation, preventing observable seismicity to the South of the reef front. The deep-seated faulting may create areas of increased heat flow, influencing thermal maturity, hence the local variations in condensate production. The findings here may be used in future treatment well design to mitigate geohazards and optimize completion programs.

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