3D Seismic interpretation of the ToC2ME seismic volume: implications for localization of induced microseismicity in the Fox Creek area

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Summary

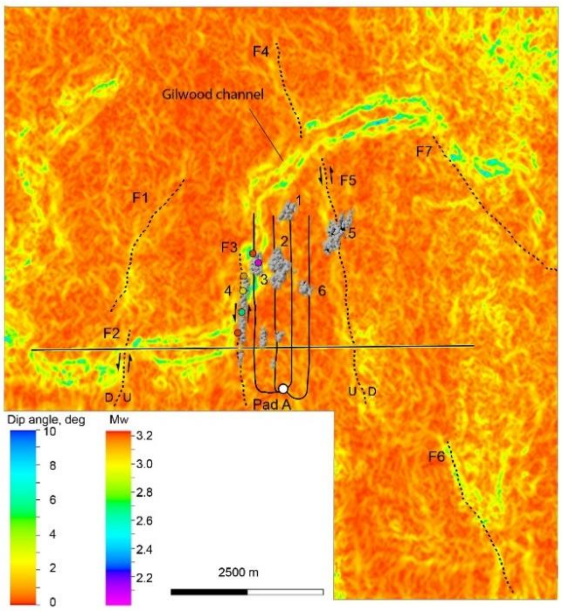
Identifying lateral facies changes, natural fracture systems, and faults helps constraining factors that affect fluid circulation and pore pressure build-up in Devonian sedimentary succession stimulated by hydraulic fracturing in the Fox Creek area. In this study, we analyze seismic amplitude and attributes of the ToC2ME seismic volume to identify faults, fractures, and lateral facies changes that may help to explain fluid circulation and localization of induced microseismic events of cluster 4 (Eaton et al., 2018). The events of cluster 4 are aligned for ~1.3 km from N to S (Fig. 1) at ≥ 200 m west from injection wells, with hypocenters located up to 400 m above the Duvernay Fm. Well log correlation, core description and outcrop observation of analog stratigraphic units are used to support seismic interpretation.

Results, Observations, Conclusions

Analysis of amplitude volume and seismic attributes (variance, RMS, instantaneous frequency, spectral decomposition, dip angle) allowed us to map a series of sub-longitudinal high-angle strike-slip normal faults (F1-F7) that bound relative highs of the top surface of the Gilwood and Swan Hills Fms (Fig. 1). These faults displace a channel structure in the Gilwood Fm (Weir et al., 2018; 2019). A sub-vertical, N-S, left-lateral strike-slip fault F3 is aligned with epicenters of cluster 4 events. However, faults F1-F7 can be traced only to the top of the Duvernay Fm or basal layers of the Ireton Fm, while most of the hypocenters of cluster 4 events, including felt events (Mw>2.5), are located in the Ireton and Wabamun Fms (Fig. 2a).

The Lower Ireton Fm contains a zone of chaotic seismic pattern (Fig. 2a) located in the SW part of the seismic volume that is characterized by positive amplitude, high values of chaos and dip angle attributes, low frequency values (Fig. 2b) and positive phase that is contrasting with its lateral analogs characterized by well-defined layered structure. This zone is interpreted as a carbonate-rich facies of the Lower Ireton Fm with relatively higher bed thickness and/or fracture density that is laterally replacing thin-layered alternation of shales and carbonate rocks. A southward decrease of shale content and increase of carbonates in the Lower Ireton across the structure is supported by well log data. The eastern border of the inferred carbonate-rich facies in the Lower Ireton (~ 2 km in diameter) is located above the fault F3. Similar structures have been described in the Mount Hawk Fm, an outcrop analog of the Lower Ireton Fm (Patterson, 1955).

The core samples of Lower and Middle Duvernay shales from well E are characterized by the presence “beef” calcite-filled bedding-parallel and sub-vertical granular-calcite filled veins. These veins and bedding are displaced by low-angle calcite veins inclined at ~30° to the bedding located above the fault breccia zone. The inclined veins and rotational calcite pressure shadows indicate the occurrence of shearing related to horizontal shortening under high horizontal stress.



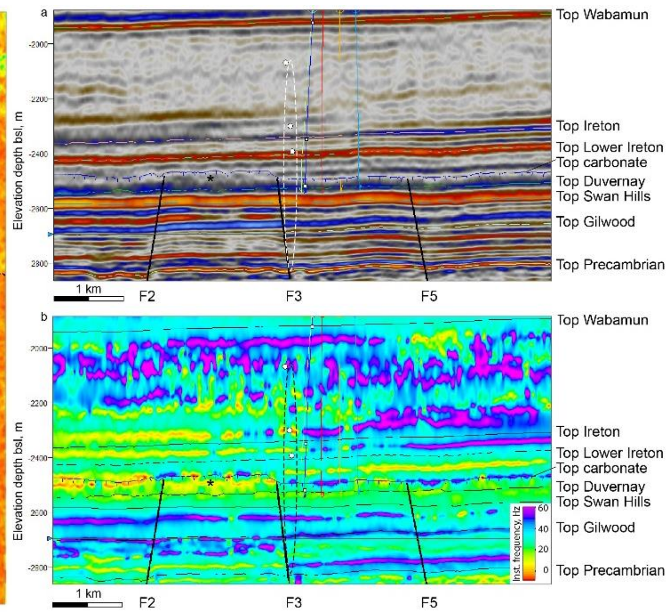


Fig. 1 Dip angle attribute, time slice -2052 ms, ToC2ME seismic volume. F1-F7, faults; colored circles show epicenters of events with Mw > 2.5 of clusters 3 and 4; grey circles delineate other seismic events (Eaton et al., 2018). Pad A, treatment wells.

Fig. 2 The W-E line across the ToC2ME amplitude cube (a) and instantaneous frequency attribute (b). Mean elevation datum asl is 910 m. F2-F4, faults; blue horizon with ticks delineates top of inferred carbonate-rich facies in the Lower Ireton Fm; white circles show hypocenters of events with Mw > 2.5, dashed oval - area of other microseismic events of cluster 4 (Eaton et al., 2018). See Fig. 1 for line location.

The model of bedding-plane interfacial slip occurring during hydraulic fracturing (Soltanzadeh et al., 2015) or interaction between hydraulic and natural fractures may help to explain a westward fluid propagation away from injection wells, then upward along fault F3 and associated vertical fractures or dolomitized zone at the eastern margin of the Lower Ireton high-carbonate facies, where events of cluster 4 occur.

Further 3D coupled reservoir geomechanical modeling is planned to test the impact of the Lower Ireton lateral facies changes on perturbation of fluid flow, pore pressure and horizontal stresses to estimate risk of shear reactivation of fault F3 and associated fracture zones.

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