New model for induced seismicity caused by hydrocarbon production in the Western Canada Sedimentary Basin

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Over the past three decades, a significant number of small magnitude earthquakes have occurred in the Western Canada Sedimentary Basin. Many of the epicentres appear to be shallow and are located along the western flank of the basin near areas of oil and gas production. One of the better documented examples is the earthquakes associated with the Strachan Field, in the Alberta foothills southwest of Rocky Mountain House. Earlier studies by Wetmiller documented significant earthquake activity beneath the Devonian carbonate reservoir. Remarkably, no fluids were injected to enhance gas recovery at Strachan. Thus, it was not possible to invoke a lowering of effective stress as the trigger for induced seismicity.

In this study, we confirm the spatial and temporal correlation between gas production and seismic events at Strachan. Segall's poroelastic model is developed to account for the occurrence of earthquakes at a subsurface depth of 4 kilometres beneath the Strachan reservoir. Using this methodology, we show that the earthquake of October 19th, 1996, below the D3-A pool of Strachan field was most probably triggered by gas extraction. The numerical model also implies that gas extraction would cause subsidence and localised changes in in-situ stress magnitudes. Neither prediction can be confirmed at the present time. There is a strong correlation between rates of production and the number of seismic events, but the onset of major seismic activity postdates the commencement of production by approximately five years. Poroelastic modelling can account neatly for the observed delay.

Nearly 70% of the total gas extracted from Strachan was produced during the first 5 years from the D3-A pool. Our model suggests that this high rate of extraction would have caused approximately 12.5 cm of subsidence over the field at the end of this period. The modelled stress changes due to gas extraction point to a regime which favours reverse or thrust faulting. Stress magnitude measurements in the area are compatible with such a stress regime. The proposed mechanism involves volume changes which decrease the vertical stress Sv and increase the larger horizontal stress SHmax. Mean stress increase beneath the reservoir appears to be small, but increasing the deviatoric stresses permits Mohr-Coulomb failure. As a result, the initially high rate and long history of gas extraction appears likely to be the main trigger for the seismicity beneath the Strachan Field.

Production-triggered seismicity has been documented at Fort St. John, where the promoting mechanism is fluid injection. This mechanism and the one proposed here are believed to occur elsewhere the western margin of the basin where deviatoric stresses are naturally high. In particular, production triggered seismicity is suspected to occur around Turner Valley and Brazeau River. To date, with the possible exception of Snipe Lake (magnitude 5.1), all suspected production-triggered earthquakes have been of magnitude 4 or smaller. This is enough to rattle buildings, but is not likely to cause structural damage, so there is no cause for alarm. Production-triggered seismicity appears to be restricted to specific areas and to fields with high production rates. Also, it appears to be largely restricted to the western margin of the basin.

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