geoconvention
Calgary • Canada • May 11-13 2026

Annual seismic hazard maps for the Montney Play, British Columbia: Insights from seismicity and fluid injection patterns

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Summary

The development of unconventional hydrocarbon resources in the Montney Play, British Columbia, has led to recent increases in induced seismicity and raised concerns about the potential induced seismic hazard. To better understand how induced seismic hazard relates to observed seismicity and operational activity, we hindcast annual seismic hazard maps for the Montney Play from 2014 to 2025 using a Monte Carlo-based probabilistic seismic hazard analysis (PSHA) framework. These annual hazard maps enable us to make spatial and temporal comparisons with seismicity metrics, such as earthquake density and cumulative seismic moment maps, and operational metrics, such as total volume of fluid injected maps.

We found that the hazard patterns and earthquake density exhibit strong, consistent spatiotemporal correlation. The cumulative seismic moment and injected fluid volumes, on the other hand, display more complex and nuanced relationships: elevated injection volumes coincide with high hazard in some years but not others. The 12-year-long record demonstrates that induced seismic hazard in the Montney Play is dynamic and spatially heterogeneous, requiring integrated approaches to better understand the driving forces, including seismicity metrics, operational practices, and geological conditions.

Data and Methods

1. **Monte Carlo-based Probability Seismic Hazard Analysis (PSHA)**
   We used a unified earthquake catalog on the local magnitude scale published by the British Columbia Energy Regulator (BCER) and the Geological Survey of Canada (GSC). We converted the local magnitude scale to the moment magnitude scale using the relations provided by Nanometrics for earthquakes recorded around the Montney Play (Nanometrics, 2023). We follow the workflow by Reyes Canales et al. (2022) and the references therein to perform probabilistic seismic hazard analysis (PSHA). We used the ground motion prediction equation (GMPE) developed by Atkinson (2015) to estimate the peak ground acceleration (PGA, in gravitational acceleration units; 1 g = 9.81 m/s^2).

2. **Calculation of earthquake density, cumulative seismic moment, and total volume of fluid injected**
   We calculated the annual earthquake density metrics on a 10 km x 10 km grid. The earthquake density is defined as the number of earthquakes above a minimum magnitude considered in a grid cell. The annual cumulative seismic moment is also calculated for the

same 10 km x 10 km grid. The seismic moment is obtained using the standard relation of Hanks and Kanamori (1979) from the derived moment magnitude of each earthquake. The annual total volume of injected fluid is calculated from data obtained from the commercial database management tool geoSCOUT, aggregated on the same 10 km x 10 km grid cell. Data for 2025 remain under embargo and were excluded from the injection-related analysis.

Results

The changing patterns in the seismicity and operational metrics are reflected in the changing hazard levels across the Montney Play. The most prominent relationship is between the earthquake density and the hazard level. Figure 1 shows such a case in the 2018 Dawson Creek cluster: when more earthquakes occurred, they were usually followed by a higher seismic hazard. The 2018 Dawson Creek cluster is also a good example of a situation where the elevated hazard level was accompanied by a large cumulative seismic moment; i.e., more energy was released, resulting in a higher corresponding seismic hazard. All elevated levels of hazard and seismicity metrics were also accompanied by elevated injection volumes from nearby hydraulic fracturing operations, providing evidence that higher injection volumes may trigger earthquakes and increase seismic hazard (Ellsworth, 2013).

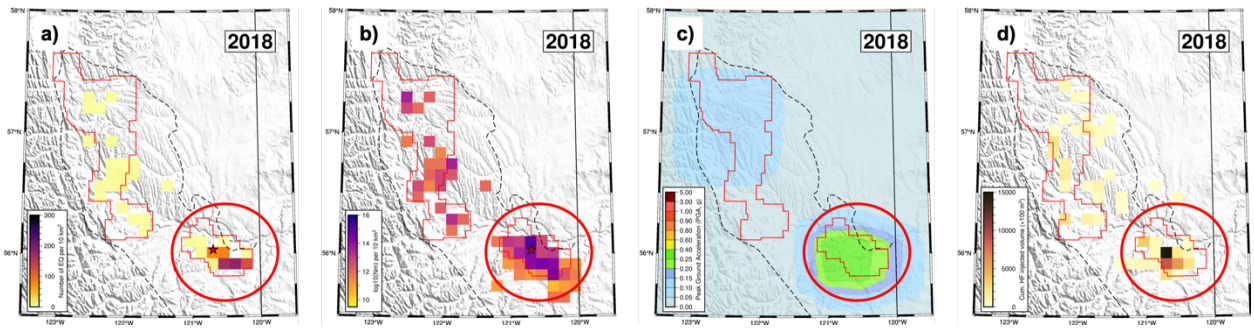


Figure 1. a) Earthquake density map, b) cumulative seismic moment map, c) peak ground acceleration (PGA) hazard map, d) total volume of fluid injected map, all for the year 2018. The dashed black line shows the extent of the Montney Play; the red solid lines show the two monitoring areas: North Peace Ground Monitoring and Mitigation Area in the west, and Kiskatinaw Seismic Monitoring and Mitigation Area in the southeast. The red circle shows the Dawson Creek cluster for this study.

However, there are cases where elevated injection volumes are not followed by elevated seismic hazard. Figure 2 shows such a case in the 2023 Dawson Creek cluster. The total volume of fluid injected is slightly higher, and slightly more earthquakes were observed in the same year, but this did not manifest in an elevated level of seismic hazard. This case showed that geological processes and stress conditions might help explain why some areas are higher in seismic hazard than others. Overall, the interplay between earthquake occurrence, cumulative seismic moment release, and fluid injection patterns around the Montney Play underscores the complexity of seismic hazard associated with induced seismicity.

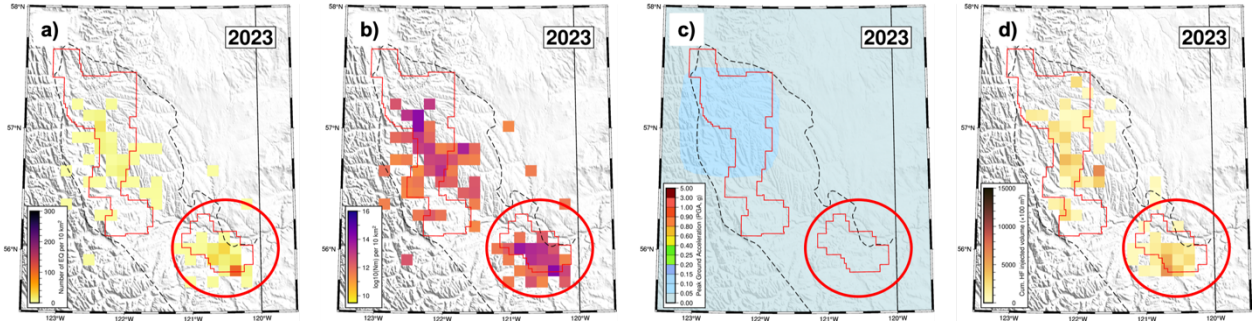


Figure 2. a) Earthquake density map, b) cumulative seismic moment map, c) peak ground acceleration (PGA) hazard map, d) total volume of fluid injected map, all for the year 2023. The dashed black line shows the extent of the Montney Play; the red solid lines show the two monitoring areas: North Peace Ground Monitoring and Mitigation Area in the west, and Kiskatinaw Seismic Monitoring and Mitigation Area in the southeast. The red circle shows the Dawson Creek cluster for this study.

Conclusions

We hindcast the annual probabilistic seismic hazard maps for the Montney Play from 2014 to 2025 and compared them with earthquake density, cumulative seismic moment, and fluid injection volumes. The results show year-to-year variability, with earthquake density providing the clearest relationship with seismic hazard. The cumulative seismic moment also explained the corresponding seismic hazard, provided that the interpretation is combined with the information of Gutenberg-Richter (GR) a- and b-values. The injected fluid volumes exhibit a more complex, nuanced relationship with the corresponding seismic hazard. Overall, these findings emphasize the need to integrate multiple metrics and site-specific geological information to better understand the driving forces behind induced seismic hazard in hydrocarbon-producing basins, such as the Montney Play.

Acknowledgements

The authors would like to thank the sponsors of the Consortium for Distributed and Passive Sensing (C-DaPS) for financial support.

References

Atkinson, G. M. (2015). Ground-Motion Prediction Equation for Small-to-Moderate Events at Short Hypocentral Distances, with Application to Induced-Seismicity Hazards. *Bulletin of the Seismological Society of America, 105*(2A), 981-992. https://doi.org/10.1785/0120140142.

Ellsworth, W. L. (2013). Injection-Induced Earthquakes. *Science, 341*(6142), 1225942. https://doi.org/10.1126/science.1225942.

Hanks, T. C., & Kanamori, H. (1979). A moment magnitude scale. *Journal of Geophysical Research: Solid Earth, 84*(B5), 2348-2350.

Nanometrics. (2023). Integration of Ground Motions into Induced Seismicity Risk Management in the Kiskatinaw Area, Northeast B.C. *BC Oil and Gas Research and Innovation Society (ER-Seismic-2022-01).*

Reyes Canales, M., Yusifbayov, J., & van der Baan, M. (2022). Evolution of Short-Term Seismic Hazard in Alberta, Canada, From Induced and Natural Earthquakes: 2011-2020. *Journal of Geophysical Research: Solid Earth, 127*(2), e2021JB022822. https://doi.org/10.1029/2021JB022822.