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MONITORING OF INDUCED SEISMICITY IN NORTHEAST BRITISH COLUMBIA, CANADA

Alireza BABAIE MAHANI
Director, Mahan Geophysical Consulting Inc., Victoria, Canada
ali.mahani@mahangeo.com

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During the past decade, fluid injection for the purpose of hydraulic fracturing (HF) and wastewater disposal (WWD) have caused a sharp increase in seismicity rate in the central and eastern United States and Western Canada. Although most of the wells drilled for HF and WWD do not cause felt earthquakes, shallow depth of these events and proximity to populated areas and infrastructure raises significant concern regarding the seismic hazard from larger induced events and motivates close monitoring of oil and gas activities. The BC Seismic Research Consortium (BCSRC) was established in 2012 with collaboration among Geoscience BC, BC Oil and Gas Commission, Natural Resources Canada, and Canadian Association of Petroleum Producers. The aim of BCSRC is to monitor oil and gas activities in the northeast British Columbia (NE BC) and the seismicity associated with HF and WWD operations. Here, I present an overview of the major works performed by BCSRC in filling the knowledge gaps regarding induced seismicity processes in NE BC.

Before 2012, the Canadian National Seismic Network operated only two seismograph stations in NE BC (Figure 1). The large magnitude of completeness (~3; Babaie Mahani et al., 2016) of this network lacked the sufficient precision to monitor small induced earthquakes in this area. Since then, several stations have been installed in NE BC, which significantly improved event detectability of the regional seismic network. Currently, the regional seismograph network in NE BC includes 18 stations from which data is available for public access via IRIS. Moreover, through collaborations with universities and industry, data from other stations in the region are used for more accurate event detections and research purposes. Enhancement of the regional network in NE BC and the surrounding areas such as western Alberta have decreased the magnitude of completeness by 1-2 order of magnitudes.

An important aspect of the monitoring project is answering the knowledge gaps regarding induced seismicity processes in NE BC with the aim of reducing the potential seismic hazard from these earthquakes. Using a comprehensive earthquake catalogue compiled by Visser et al. (2017), Kao et al. (2018) analyzed the tectonic strain rate in western Canada and its relation with induced seismicity. They found that, in areas with moderate tectonic strain, injection may temporarily increase the local seismic hazard, but over an extended period, widespread injection-induced earthquakes may deplete the available tectonic moment, reducing regional seismic hazard.

Although there have not been any report of damage from induced earthquakes in NE BC, several moderate earthquakes have occurred in the area. Babaie Mahani et al. (2017) associated more than 600 earthquakes with moment magnitude range of 1.0 to 4.6 to HF operations in the northern Montney Play of NE BC (Figure 2). Large ground-motion amplitudes have been observed at short distances (< 5 km) from some induced events, despite small-to-moderate magnitudes, because of their shallow depths. For example, peak ground acceleration of > 0.1 g often occurs from events with magnitude of ~3 (e.g. Babaie Mahani and Kao, 2018a).

Traffic light protocols have been proposed in various parts of the world to monitor injection operations. In western Alberta, for example, the occurrence of an earthquake with local magnitude (M_L) of 2 would result in the Amber light and detail mitigation strategies to control the seismic activity. In both Alberta and British Columbia, an M_L 4 earthquake would result in the suspension of operations. Therefore, accurate determination of M_L for induced earthquakes is a vital task for the regional seismograph network. Besides the economical impact of M_L overestimation for the oil and gas industry, underestimation of M_L can also have significant impact with regard to public safety. Babaie Mahani and Kao (2018b) considered the constituents of Richter (1935) relation for calculation of M_L, which is the basis for magnitude determination by Natural Resources Canada in the Western Canada Sedimentary Basin (WCSB). They provided a new correction term for routine M_L calculation that better accounts for the attenuation of direct and refracted waves from events within WCSB.

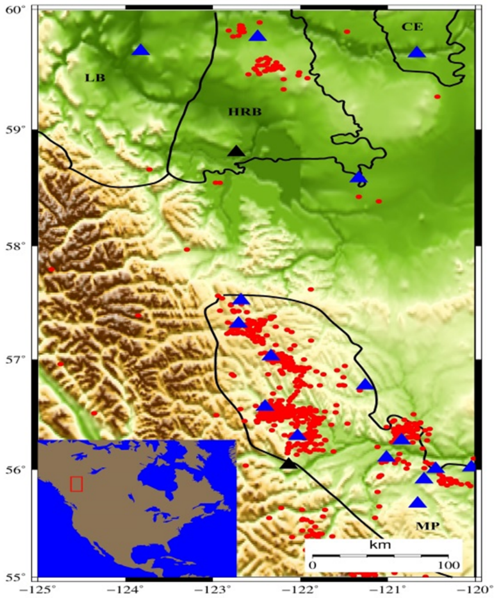

Figure 1. Map of northeast British Columbia. Black triangles are the two stations in the area before 2012. Blue triangles are the stations that were installed by the BC Seismic Research Consortium since 2013. Seismicity (dots) is from Babaie Mahani et al. (2016). Boundaries of the shale gas plays are marked with solid lines; MP: Montney Play, LB: Liard Basin, HRB: Horn River Basin, CE: Cordova Embayment.

REFERENCES

Babaie Mahani, A. and Kao, H. (2018b). Accurate determination of local magnitude for earthquakes in the Western Canada sedimentary basin. *Seismological Research Letters, 90*(1)*, 203-211.*

Babaie Mahani, A., and Kao, H. (2018a). Ground motion from m 1.5 to 3.8 induced earthquakes at hypocentral distance < 45 km in the montney play of Northeast British Columbia, Canada. *Seismological Research Letters, 89*(1), 22-34.

Babaie Mahani, A., Schultz, R., Kao, H., Walker, D., Johnson, J., and Salas, C. (2017). Fluid injection and seismic activity in the Northern montney play, British Columbia, Canada, with special reference to the 17 August 2015 Mw 4.6 induced earthquake. *Bulletin of Seismological Society of America, 107*(2), 542-552.

Babaie Mahani, A., Kao, H., Walker, D., Johnson, J., and Salas, C. (2016). performance evaluation of the regional seismograph network in Northeast British Columbia, Canada, for monitoring of induced seismicity. *Seismological Research Letters, 87*(3), 648-660.

Kao, H., Hyndman, R.D., Jiang, Y., Visser, R., Smith, B., Babaie Mahani, A., Leonard, L., Ghofrani, H., and He, J. (2018). Induced Seismicity in Western Canada Linked to Tectonic Strain Rate: Implications for Regional Seismic Hazard. *Geophysical Research Letters, 45*(20), 11, 104-11, 115.

Richter, C.F. (1935). An instrumental earthquake magnitude scale. *Bulletin of Seismological Society of America, 25*(1), 1-31.

Visser, R., Smith, B., Kao, H., Babaie Mahani, A., Hutchinson, J., and McKay, J.E. (2017). A comprehensive earthquake catalogue for Northeastern British Columbia and Western Alberta, 2014-2016. *Geological Survey of Canada open file,* 8335, 28.