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Determination of Local Magnitude for Induced Earthquakes in the Western Canada Sedimentary Basin: An Update

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Summary

Reliable determination of local magnitude (M_L) is crucial for monitoring of induced seismicity. Natural Resources Canada (NRCAN) uses the original definition of the Richter scale, which was determined for southern California in 1935. Since the magnitude values provided by NRCAN are routinely used by regulatory agencies in Alberta and British Columbia to ensure proper assessment and mitigation of seismic hazard caused by induced seismicity, modification to the Richter magnitude formula to better reflect the local attenuation characteristics of the Western Canada Sedimentary Basin (WCSB) is critical. Using the 2014-2016 comprehensive earthquake catalogue reported by Visser et al. (2017), Babaie Mahani and Kao (2018; BMK18) provided a calibration of the distance correction factors used in the determination of M_L for WCSB. With the recent deployment of additional seismographic stations in the WCSB region, more data (especially at close epicentral distances) became available (Visser et al. 2020). In this study, we present an update on the BMK18 M_L determination using a comprehensive dataset of earthquakes for the period of 2014-2018 (inclusive). We compare our results with those determined by BMK18 and Yenier (2017; Y17). Moreover, we calculate M_L for events located by the Encana seismographic network using the updated model, the original formula of BMK18, and the formula of Y17. A detailed comparison of all the results is conducted to demonstrate the performance of each model.

Method and Results

The Richter (1935) local magnitude scale is defined as $M_L = \log(A) - \log(A_0) + S$, where A is the recorded amplitude, in mm, on a Wood-Anderson (WA) seismometer, A_0 is the distance correction term for the recorded amplitude, and S is a correction term for each station that accounts for any systematic amplitude difference such as local site effect. A_0 at each distance is obtained by defining the zero magnitude (ignoring the S term) at a distance of 100 km (A = 0.001 mm). We obtained A_0 for WCSB through regression of WA amplitudes, as compiled by Visser et al. (2020), with $\log(A) + 3.0 = GS + ATT + M_L - S$ in which GS is the model for geometrical spreading and ATT is the model for anelastic attenuation. Using the bilinear form for GS as obtained by BMK18, the following model for distance correction in WCSB was obtained: $0.671 \times \log(R/100) + 0.003 \times (R - 100) + 3.0$ for $R \leq 85$ km and $-0.881 \times \log(R/100) + 0.003 \times (R - 100) + 3.0$ for $R > 85$ km (R = hypocentral distance; Figure 1). We also obtain the S term for 56 seismographic stations in the WCSB region. The new formula has the same form as the original one proposed in BMK18, but the parameter values are slightly different.

Conclusions

Using a comprehensive earthquake dataset for the period 2014-2018 (inclusive), we provided an update on the distance correction model in the M_L calculation of local earthquakes in the

WCSB. A total of 33995 vertical WA amplitudes from 3575 earthquakes recorded at 56 seismographic stations were used in the regression. Our revised formula can better characterize the attenuation effect associated with the unique geological and tectonic configuration of the WCSB. As a result, it provides higher consistency between magnitude values calculated at individual stations and the final event magnitude over a wide hypocentral distance range from 2 to 600 km, and therefore is a reasonable alternative to the original Richter formula for regulatory purposes in northeastern BC and western Alberta.

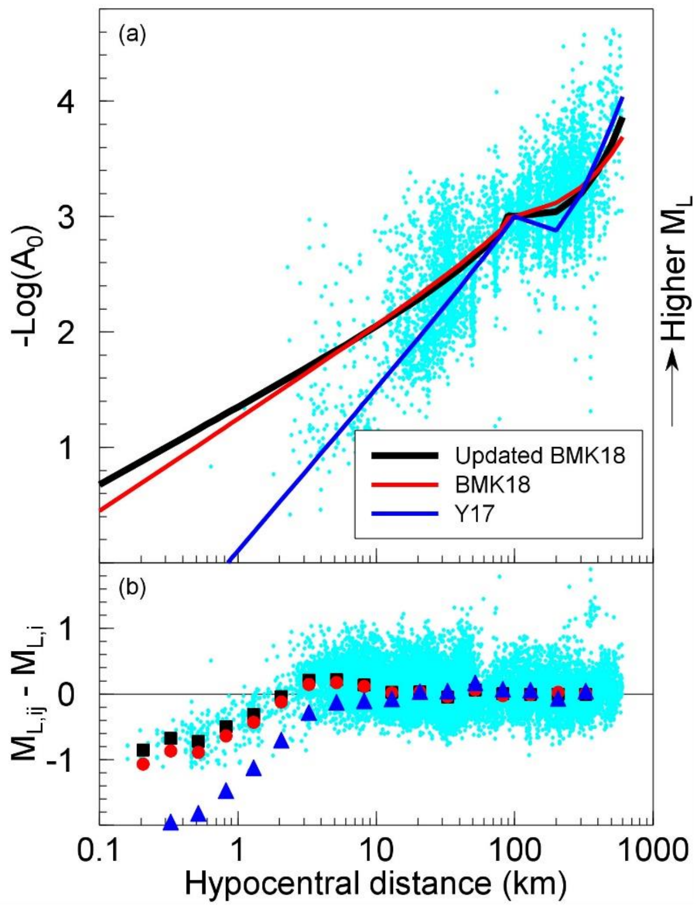

Figure 1. (a) Distance correction term, -log (A_0) versus hypocentral distance from Y17, BMK18, and this study (updated BMK18). Depicted data (cyan dots) are the normalized WA amplitudes. (b) Individual data points (cyan dots) used in this study and the mean difference between the magnitude values calculated at individual stations ($M_{L,ij}$) and the event's final local magnitudes ($M_{L,i}$) in equally log-spaced distance bins using -log(A_0) from Y17, BMK18, and the updated BMK18.

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