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Real-Time Seismic Monitoring in Alberta: Network Expansion, Magnitude Consistency, and Detection Thresholds

Alberta Energy Regulator

AGS ALBERTA GEOLOGICAL SURVEY

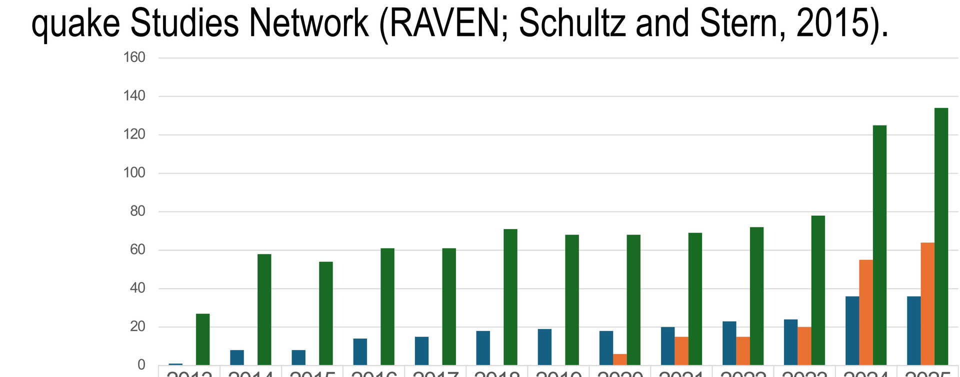
Abstract

Since the early 2010s, Alberta has experienced a significant increase in seismicity linked to industrial activities such as hydraulic fracturing and fluid disposal, prompting expansion of seismic monitoring and regulatory oversight. This study summarizes Alberta's real-time seismic monitoring framework, led by the Alberta Geological Survey (AGS) through the Regional Alberta Observatory for Earthquake Studies Network (RAVEN, RV); complemented by the industry-operated stations under the Scientific Induced Seismicity Monitoring Network (SCISMN, I0) and other regional networks totaling 134 stations by 2025. Using the 2025 earthquake catalogue, we assess consistency between AGS and industry magnitudes, finding strong agreement with minor differences due to network geometry and methodology. Magnitude of completeness estimates show detection thresholds in key industrial regions are below regulatory response levels, confirming sufficient monitoring capacity for reliable detection and characterization of induced seismicity.

Introduction

Alberta has historically been considered a seismically quiescent region of Canada (Stern et al., 2013), but over the past decade earthquake activity has increased significantly, largely linked to industrial operations such as hydraulic fracturing and fluid disposal. Notable clusters have occurred near Fox Creek (Schultz et al., 2015a), Red Deer (Wang et al., 2020), Peace River (Schultz et al., 2023), and south of Grande Prairie (Reyes Canales et al., 2026).

Seismic monitoring was sparse prior to 2006, with only two public stations. Expansion began through collaboration between the Alberta Geological Survey (AGS) and academic institutions, with a major step in 2013 marked by deployment of the first real-time AGS station. Additional expansion led to development of the Regional Alberta Observatory for Earthquake Studies Network (RAVEN; Schultz and Stern, 2015).



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
RV Stations	1	8	8	14	15	18	19	18	20	23	24	36	36
I0 Stations	0	0	0	0	0	0	0	6	15	15	20	55	64
Total Stations	27	58	54	61	61	71	68	68	69	72	78	125	134

Figure 1: Temporal evolution of Alberta's seismic station coverage between 2013 and 2025.

In response to rising seismicity, including events exceeding local magnitude 4.0, the Alberta Energy Regulator introduced Subsurface Orders and Directive 065, requiring real-time monitoring, data submission (SCISMN, I0; Schultz et al., 2020), and mitigation strategies. Together, these efforts have expanded the provincial coverage to 134 stations (Figure 1), significantly improving the detection and characterization of induced seismicity in Alberta.

Seismic Data and Analysis

Data Overview

The AGS uses the Antelope software package from Boulder Real-Time Technologies (BRTT) to acquire, process, and catalogue seismic data, collecting approximately 17 GB of waveform data per day from nearly 125 three-component seismic stations.

Analysis Workflow

1. Data Collection

Continuous waveform data are acquired via the SeedLink protocol from EarthScope for public networks, or directly from vendors for privately operated I0 stations.

2. Automatic Event Detection

Automatic phase detection uses a standard multi-frequency STA/LTA method (Allen, 1978) to identify potential seismic arrivals. Orbassoc then groups phase picks into candidate events using a spatial grid search, triggering automatic alerts to AGS staff.

3. Manual Phase Picking

Events and waveform data are reviewed, and those recorded at three or more stations are refined by manual P- and S-wave picking on unfiltered data, within 1.5° of the hypocentre. A 1–10 Hz bandpass filter is applied if needed, or unreliable picks are removed.

4. Location Calculation

Event locations are computed using dbloc2 with 1D velocity models refined for various seismic clusters using GENLOC (Pavlis et al., 2004), optimised by minimising sdobs, the standard error of observations.

5. Magnitude Calculation

Local magnitude (M_L) is derived from Wood–Anderson (WA) equivalent amplitudes after instrument correction and convolution with a standard WA response (2080 magnification, 0.8 damping). S-wave peak amplitudes are measured on both horizontal components, with the higher value used per station, and a regional distance correction (Yenier, 2017) applied. The final magnitude is the median of station values.

6. Event Catalogue

Events are uploaded to the seismic dashboard on a weekly basis, or sooner if a notable event occurs.

Magnitude Consistency and Detection Thresholds

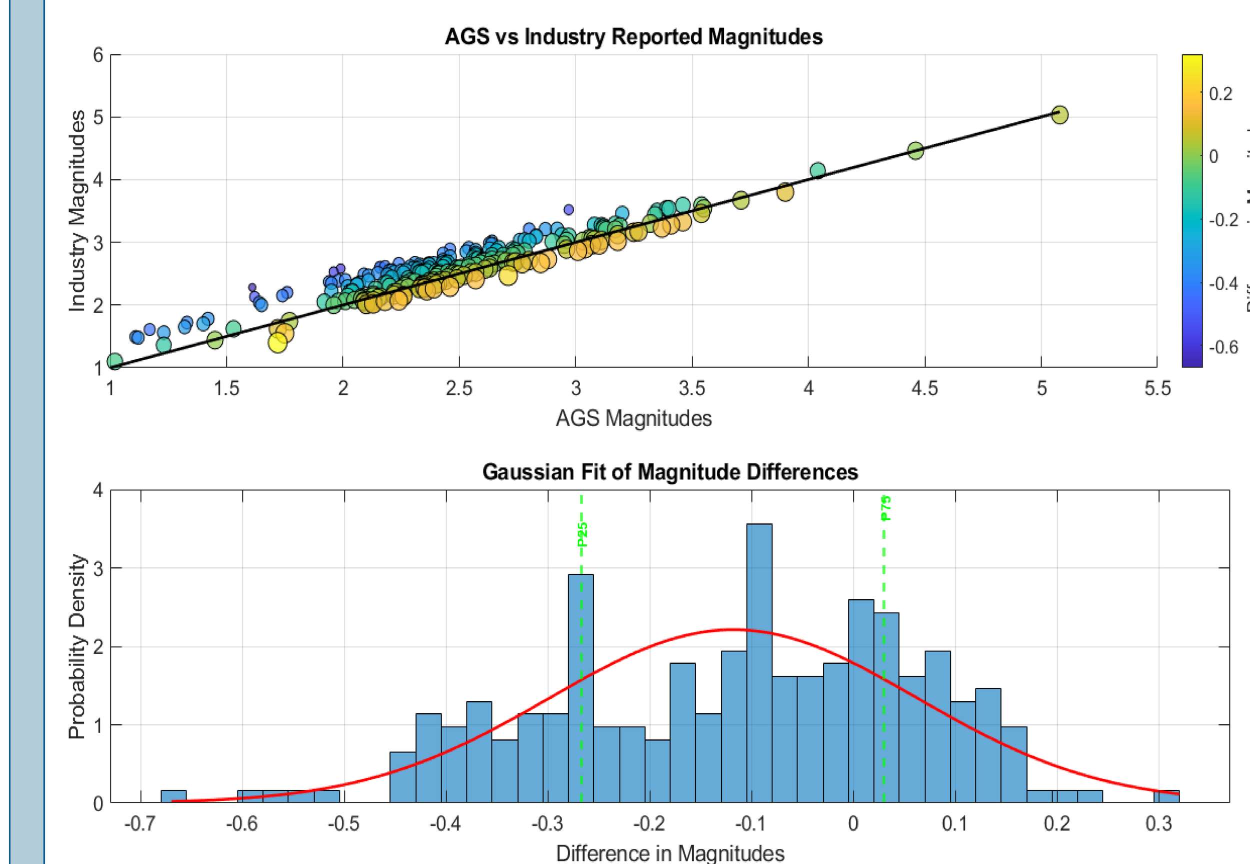


Figure 2: (a) Comparison of magnitudes reported by industry and those detected by the Alberta Geological Survey, where a black line represents a 1:1 ratio and (b) the Gaussian distribution of the residuals.

The operators report induced seismic events to the AER, including event location and magnitude, for all events exceeding the applicable yellow-light threshold. These events were compared with the AGS catalogue to assess magnitude consistency. Operator-reported induced seismic events were compared with the AGS catalogue to assess magnitude consistency. Based on 2025 data, results show strong overall agreement, with most magnitude differences within ±0.5 M_L (Figure 2). The interquartile range (−0.27 to 0.03 M_L) indicates a slight tendency for AGS magnitudes to be marginally lower on average.

This bias is primarily attributed to differences in station coverage and processing approaches: AGS benefits from multiple dense local stations on the I0 network, while operators typically rely on stations near their well pads and the regional RV network. Additional contributors include differences in velocity models, amplitude picking methods, and signal-to-noise thresholds. A small fraction of outliers (~2%) exceeding 0.5 M_L likely reflect alternative magnitude correction procedures used, such as Hutton and Boore, 1987.

Annual detection threshold analyses are conducted by the AGS to evaluate network performance and its ability to detect events exceeding yellow-light thresholds under current regulatory frameworks. Detection sensitivity is quantified using the magnitude of completeness (M_c), defined as the minimum magnitude above which all events in a region are reliably detected (Rydelek and Sacks, 1989). Given the spatially and temporally variable nature of seismicity in Alberta, a numerical approach (Schultz et al., 2015b) was applied, providing a more robust estimate than traditional frequency–magnitude approach (Figure 3).

Results indicate highest detection sensitivity in areas of concentrated industrial activity, including hydraulic fracturing near Fox Creek and Red Deer, wastewater disposal south of Grande Prairie and Peace River, and carbon capture operations near Redwater. In these regions, M_c values are below 1.0 M_L, indicating reliable detection of all yellow-light events.

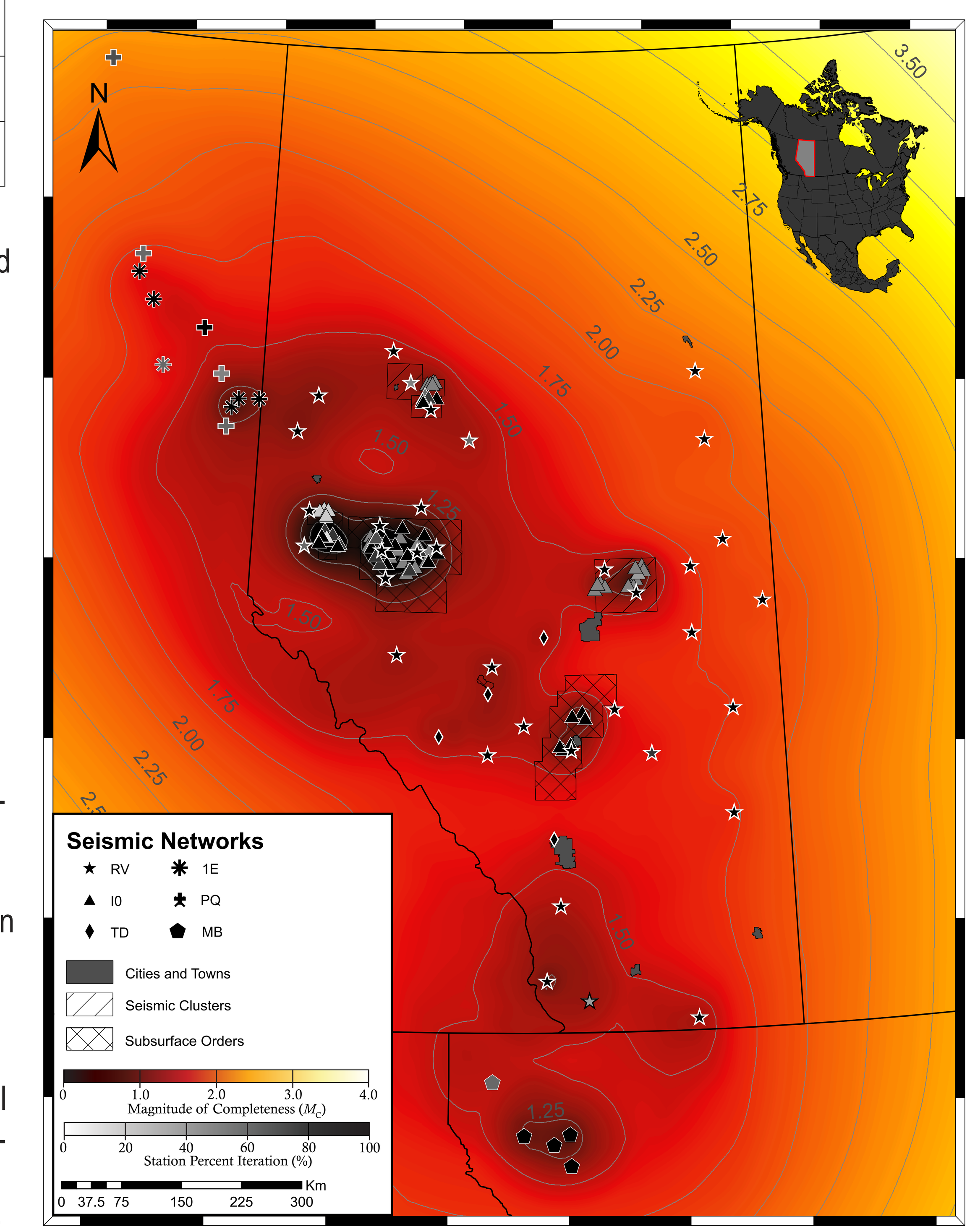


Figure 3: Detection thresholds for Alberta in 2025. Lower values indicate higher detection sensitivity; darker station symbols represent greater station reliability.

Discussion

The AGS publishes two parallel magnitude datasets: AGS-calculated magnitudes and those reported directly by the industry licensees. This dual framework supports regulatory compliance, provides a consistent long-term reference dataset, and ensures industry-reported values are integrated into operational decision-making, including induced seismicity mitigation.

Minimizing discrepancies between AGS-calculated and industry-reported magnitudes improves consistency, interpretability, and reduces ambiguity across licensees and monitoring regions. However, perfect agreement is neither expected nor required, as variations in station coverage, processing workflows, velocity models, and magnitude calibration naturally introduce differences. In this context, Yenier's magnitude correction can be applied to reduce outliers and improve overall consistency. Rather than enforcing strict equivalence, the focus is on ensuring these differences are well-characterized, stable, and transparent over time within acceptable operational tolerances.

Conclusions

The expansion of seismic monitoring infrastructure in Alberta has significantly improved the detection, location, and characterization of natural and induced seismicity. Network expansions led by the Alberta Geological Survey through the Regional Alberta Observatory for Earthquake Studies Network and the Scientific Induced Seismicity Monitoring Network, have enabled more comprehensive real-time surveillance across the province.

This study finds strong consistency between AGS-calculated and industry-reported magnitudes, while highlighting the role of industry stations in lowering detection thresholds. Systematic differences in event magnitudes are expected due to variations in station coverage and processing methods, however remain within acceptable operational limits when properly understood. Magnitude of completeness estimates indicate that current monitoring capacity is sufficient to reliably detect events within regulatory thresholds. Overall, increased network density and improved data integration have strengthened monitoring robustness, supporting regulatory oversight, operational decision-making, and seismic hazard assessment.

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