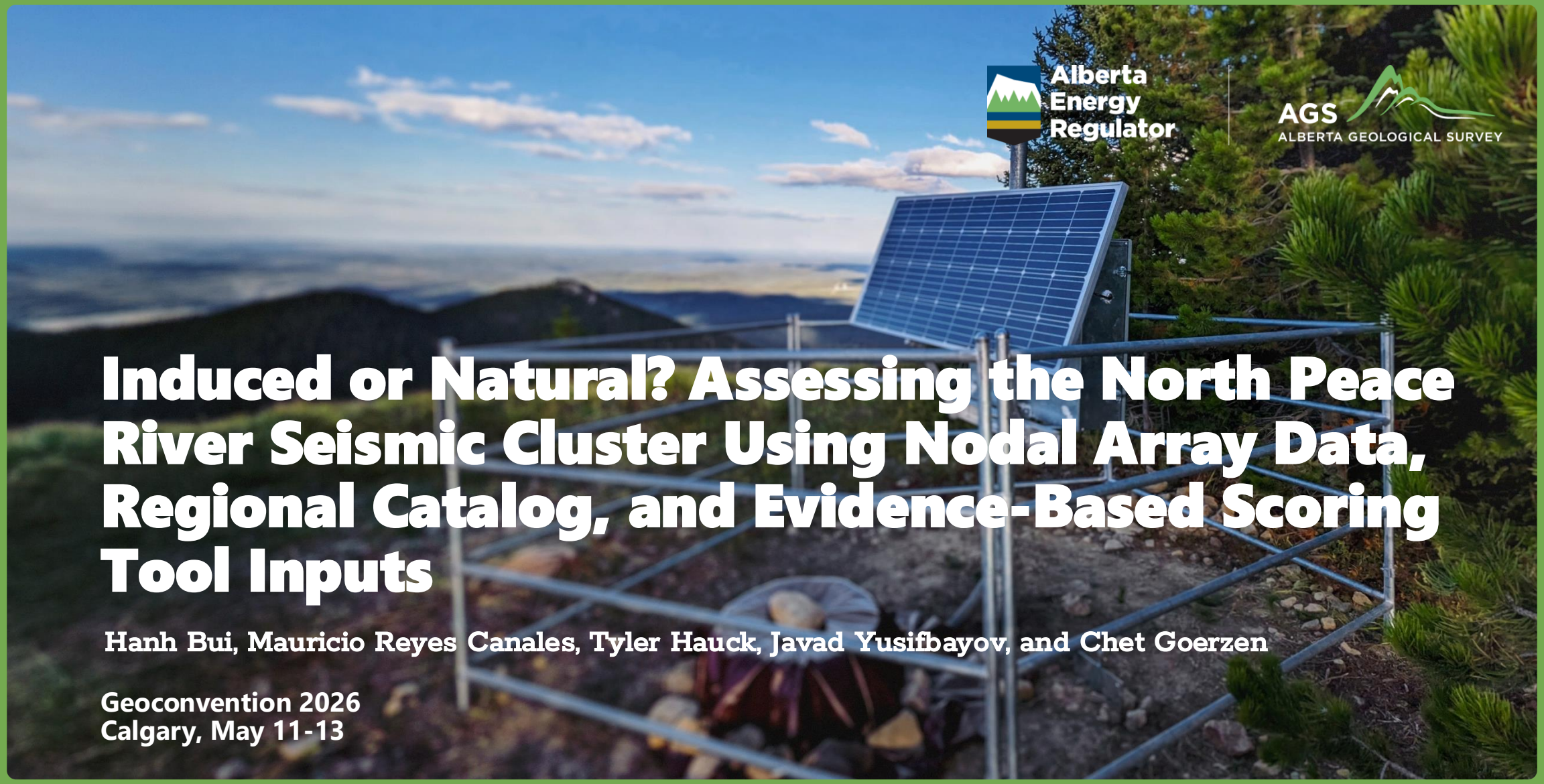


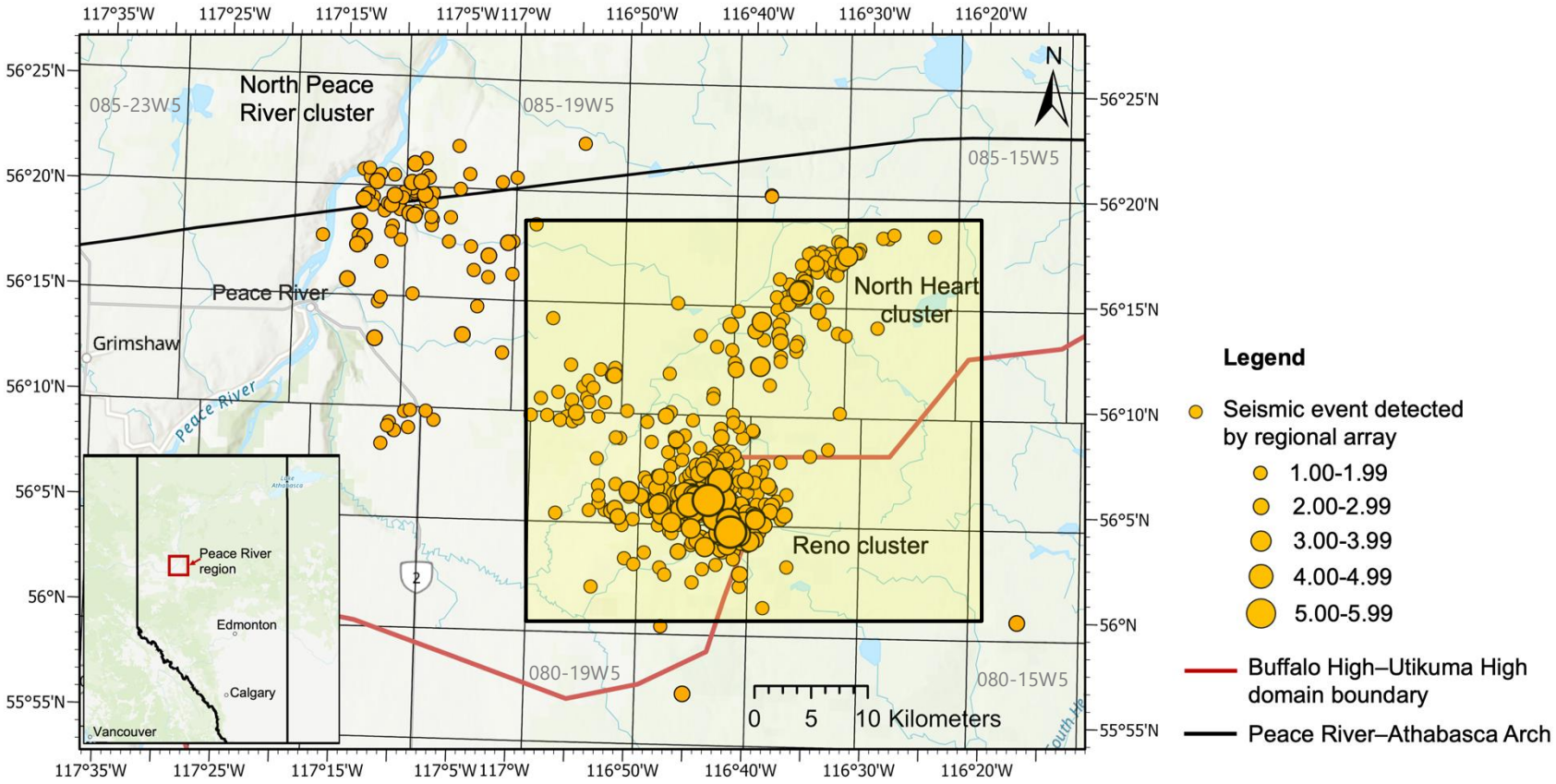
Induced or Natural? Assessing the North Peace River Seismic Cluster Using Nodal Array Data, Regional Catalog, and Evidence-Based Scoring Tool Inputs

Hanh Bui, Mauricio Reyes Canales, Tyler Hauck, Javad Yusifbayov, and Chet Goerzen

Geoconvention 2026
Calgary, May 11-13

Introduction: Seismicity in the Peace River Region

- **Three seismic clusters** identified in the Peace River region by the regional seismic network (RAVEN)
- **Reno and North Heart clusters**
  - Linked to nearby disposal activities in the Leduc Fm.



Seismic event locations in the Peace River region detected by RAVEN (Alberta earthquake dashboard, AGS, 2026) with major tectonic features (AGS, 2021)

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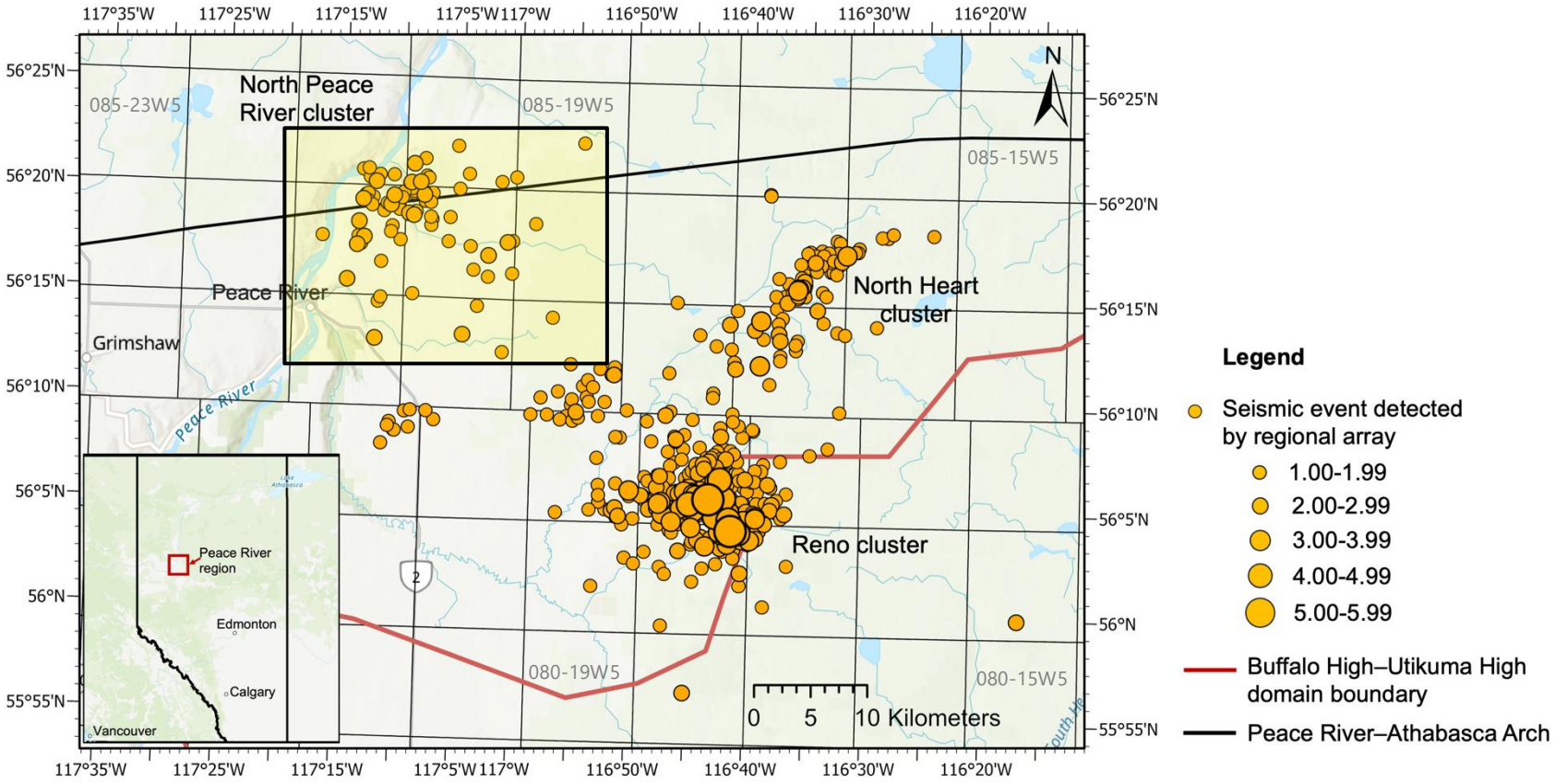
- **North Peace River cluster**
  - Oldest cluster (activity documented as early as 1998, NRCan)
  - ~130 events (local magnitudes $M_L \geq 1$)
  - Initially assumed as predominantly natural
  - Origin requires further assessment



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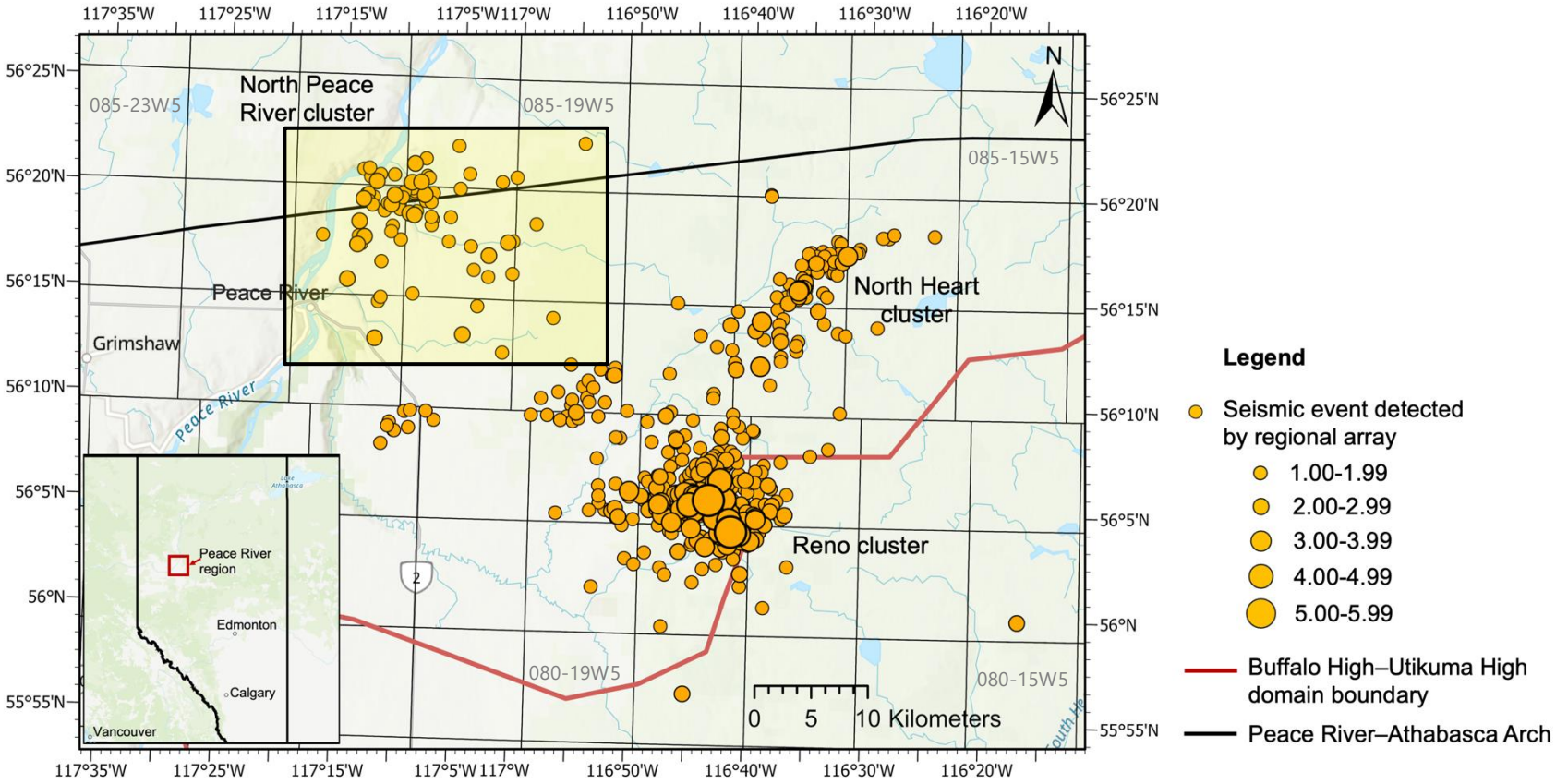
Assessing the cluster using:

- (1) Local nodal array data
- (2) Regional seismic catalog and injection histories
- (3) Inputs derived from an evidence-based scoring tool (questionnaire)



Seismic event locations in the Peace River region detected by RAVEN (Alberta earthquake dashboard, AGS, 2026) with major tectonic features (AGS, 2021)

(1) Local Nodal Array Data

- 3 deployment rounds (~3 months)
- ~200 GB of 3-component seismic data
- Detected and located events within ~15 km of disposal wells not observed by the regional array

Nodal Array Deployment and Data Processing

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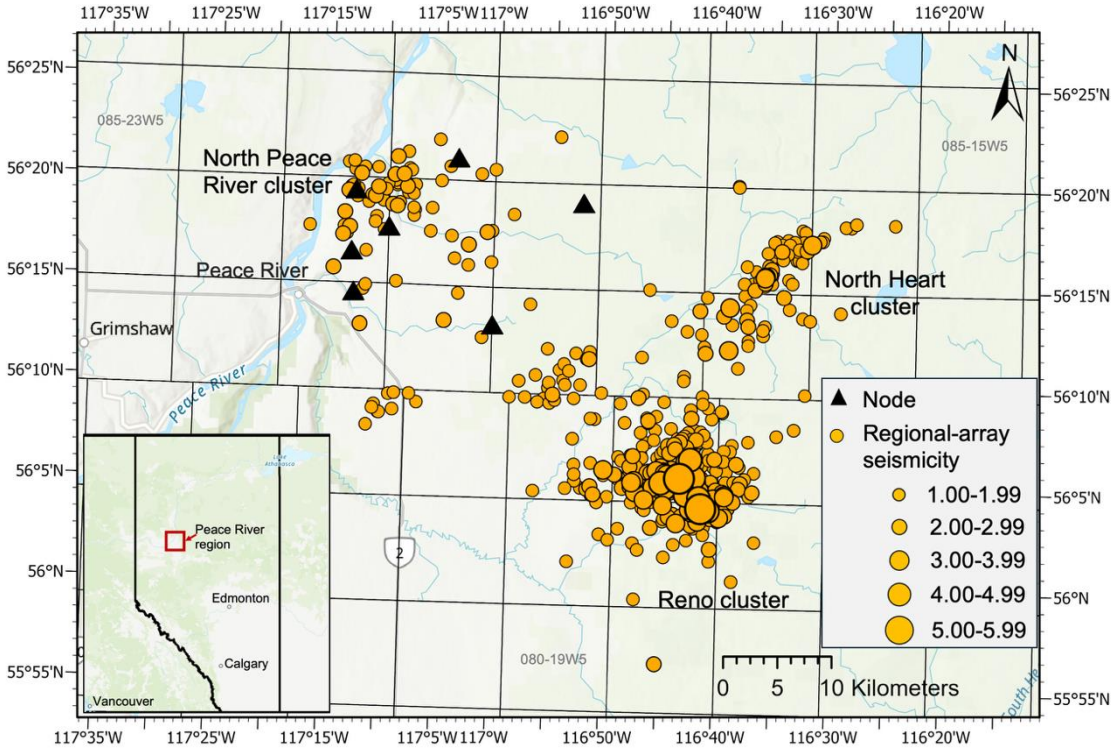
Node locations and regional-array seismicity



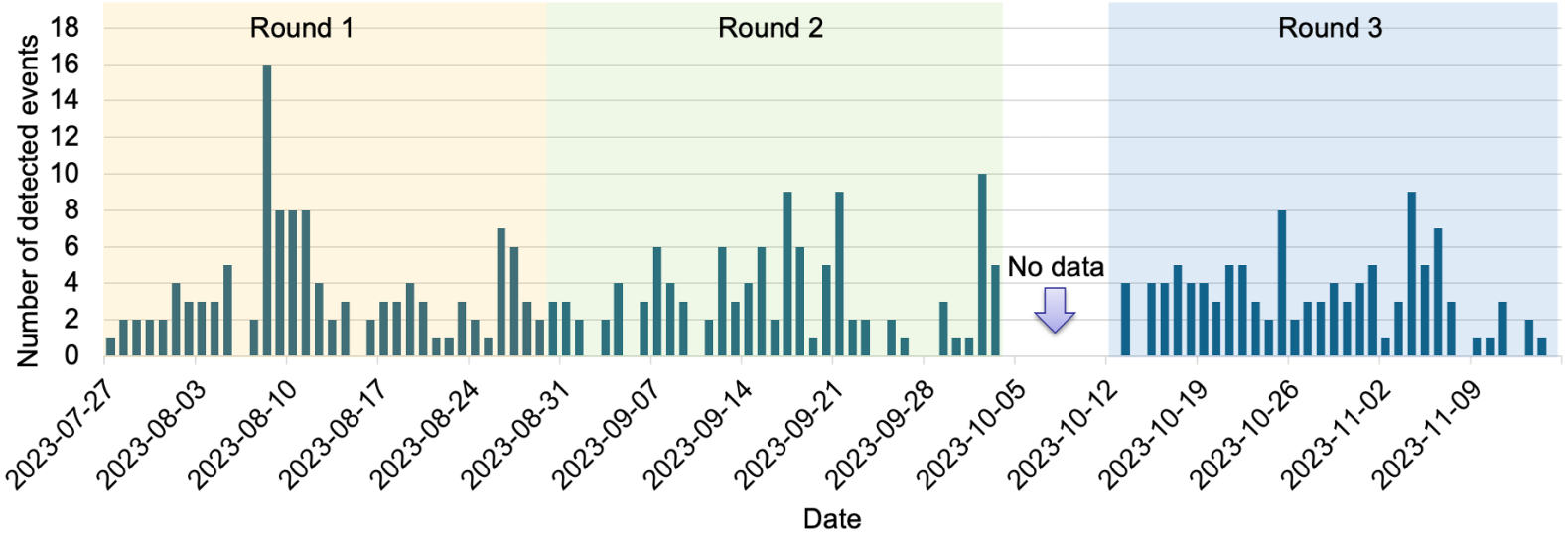
Node deployment

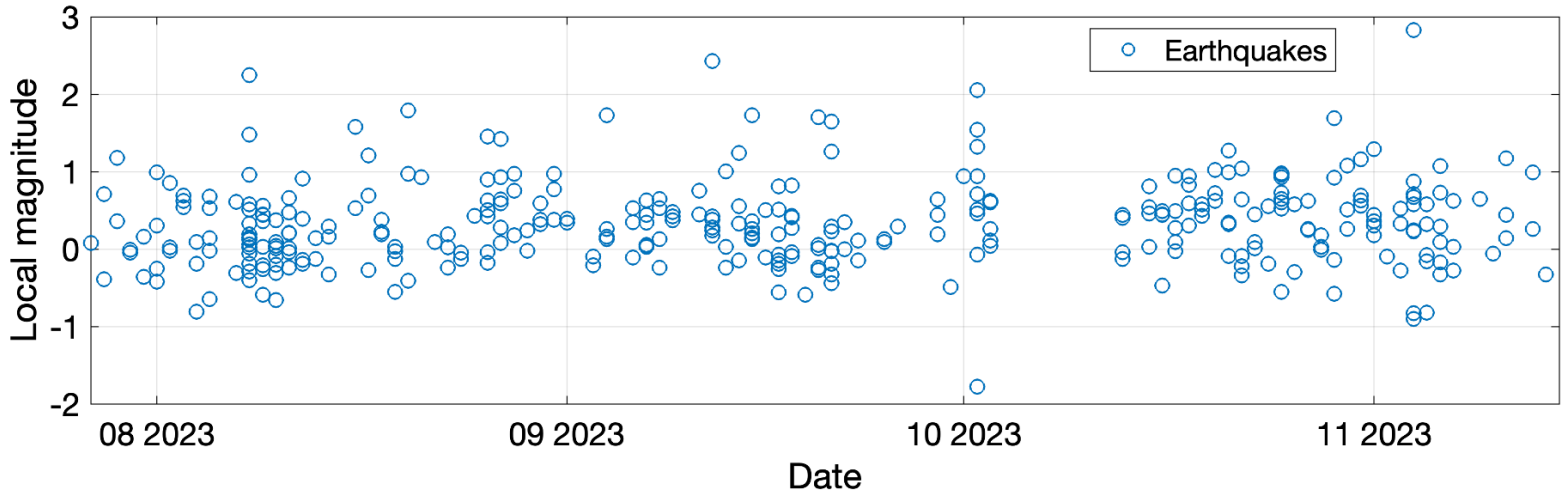
Data collection

(1) Preprocessing ➔ (2) Event Detection ➔ (3) Event Location ➔ (4) Local Magnitude Calculation ➔ (5) Source Characterization

Event Detection Results of Nodal Array Data

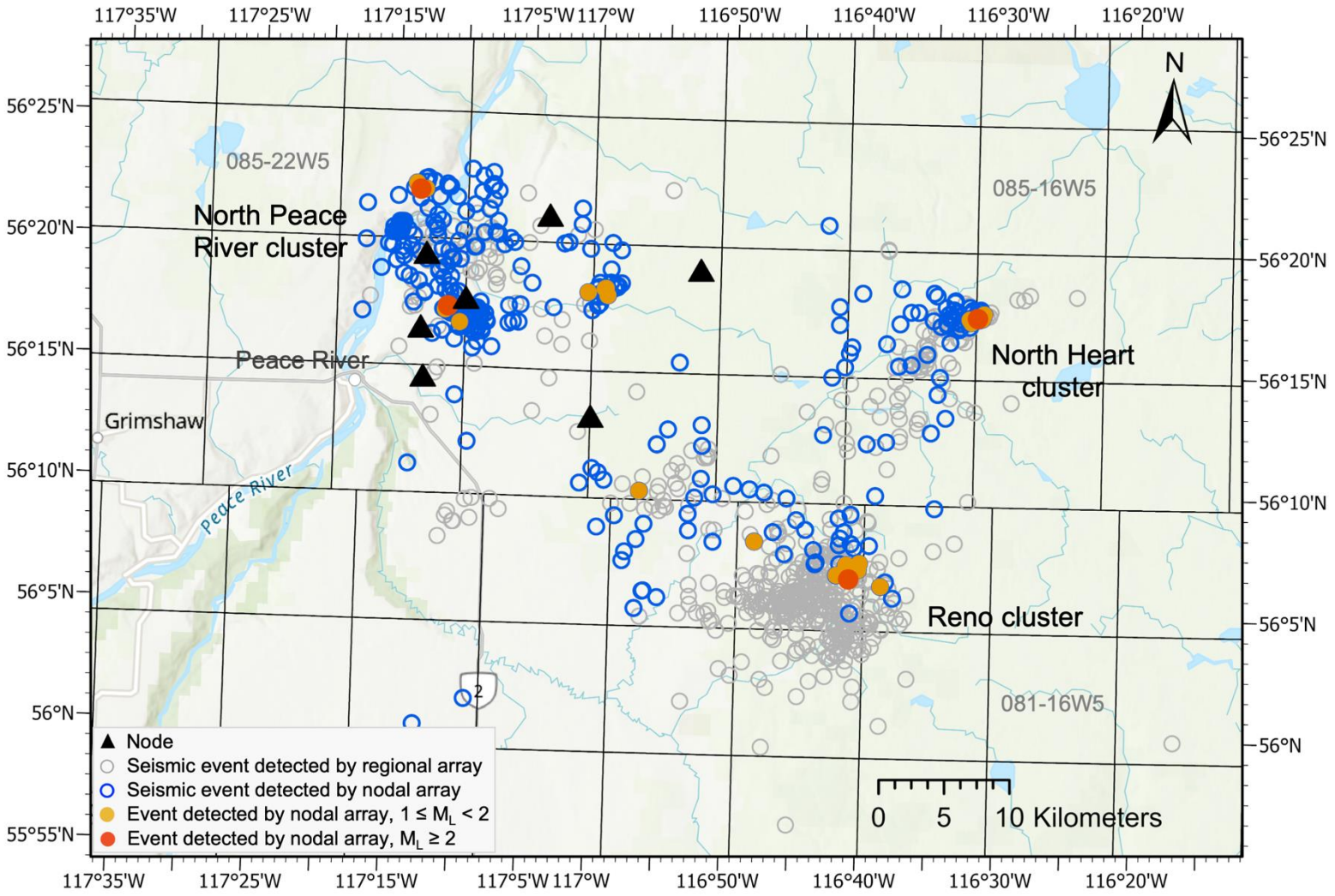
- STA/LTA event detection
- Events detected when recorded by at least 3 nodes
- 340 seismic events detected
- Largest event: M_L 2.83





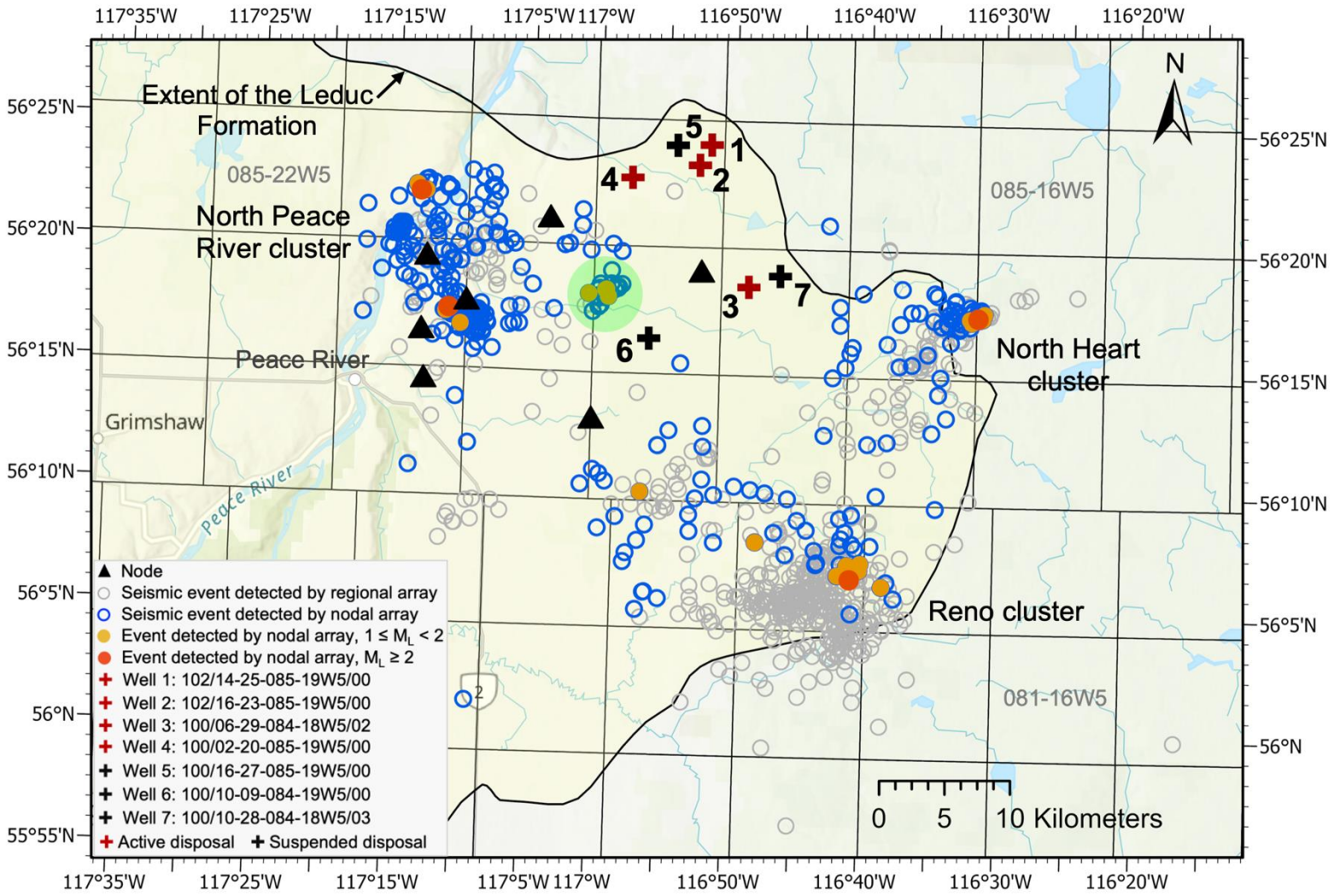
Event Location Results of Nodal Array Data

- Events located using NonLinLoc (Lomax et al., 2000, 2014)
- Event locations from the nodal array data align well with the regional-array seismicity
- Observe consistent spatial pattern: three main clusters



Event Location Results of Nodal Array Data

- Previously undetected local cluster near (56.3°N, 117°W), Section 084, Township 19, Range W5
- Within 15 km of disposal wells in the Leduc Formation (approximately 1.6–1.8 km TVD)
- Demonstrates the improved local resolution of event locations achieved using the nodal array



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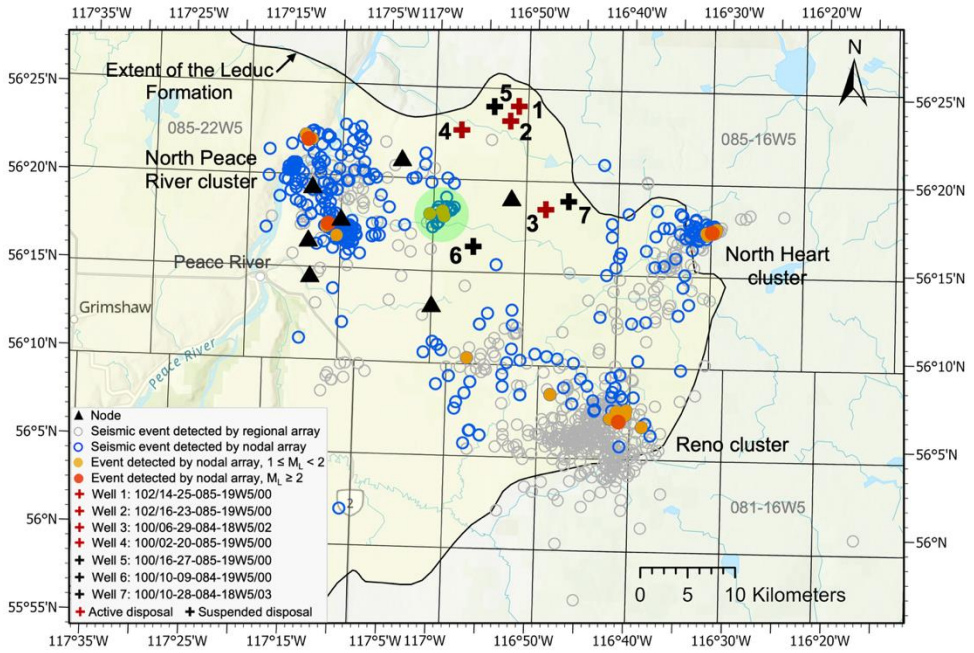
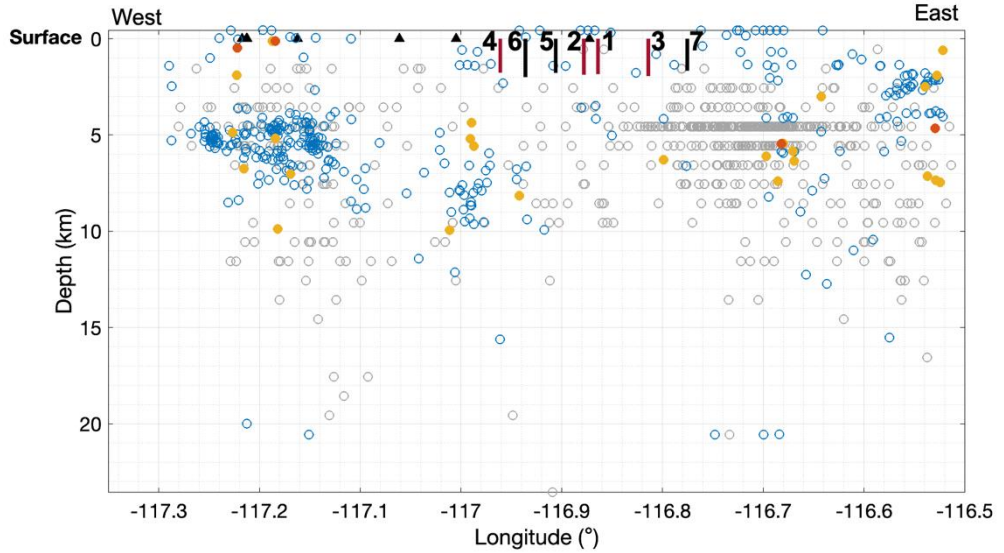
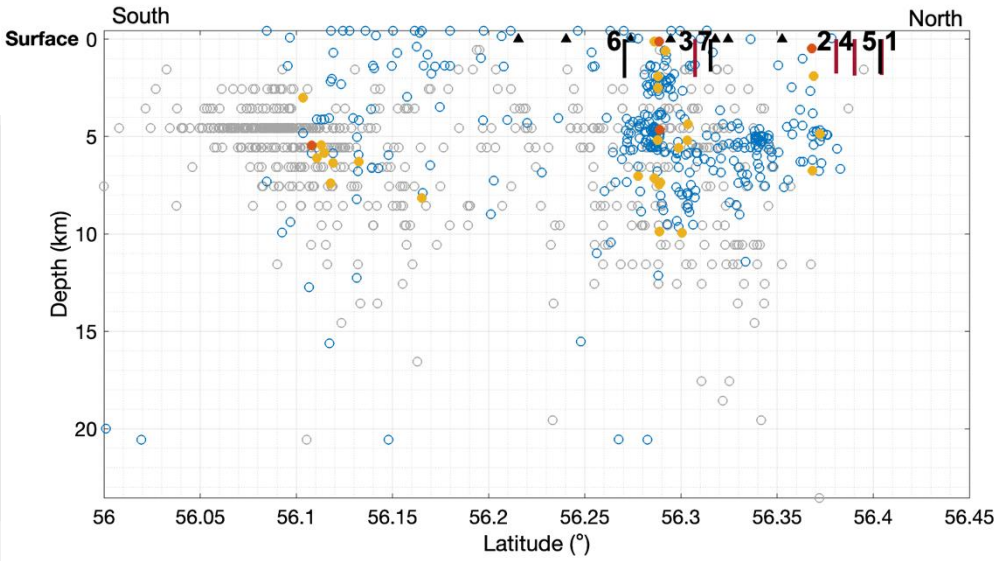
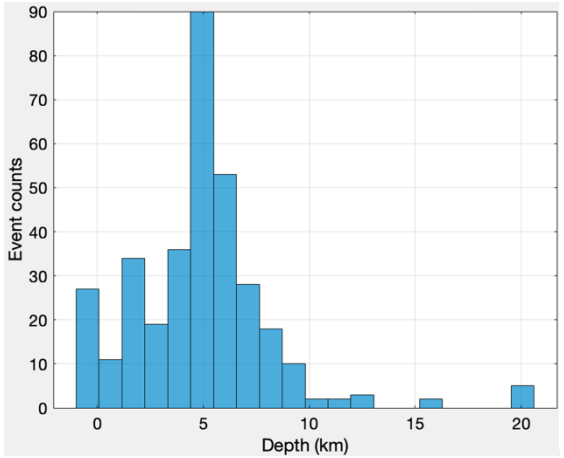




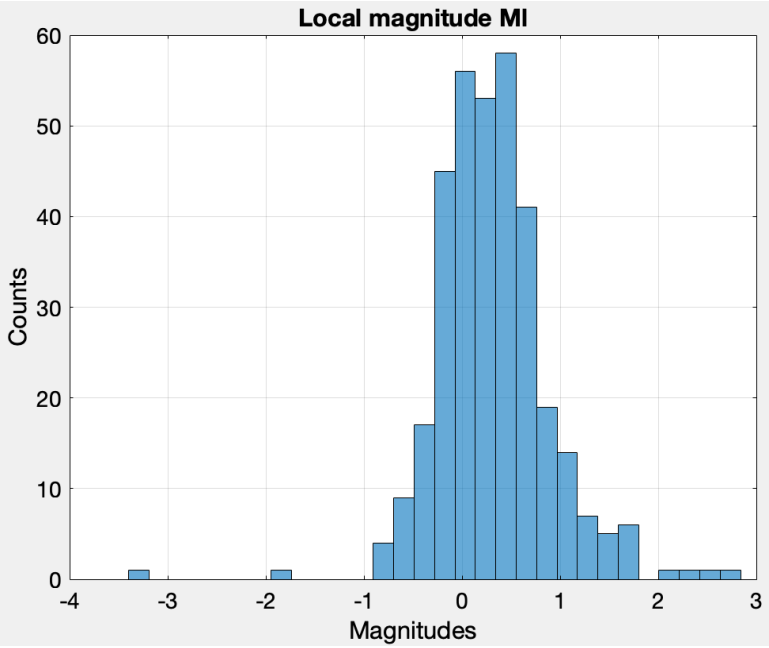




- Event depths primarily between 4–6 km below the surface, suggesting the occurrence in the Precambrian basement

Local Magnitude Calculation of Nodal Array Data

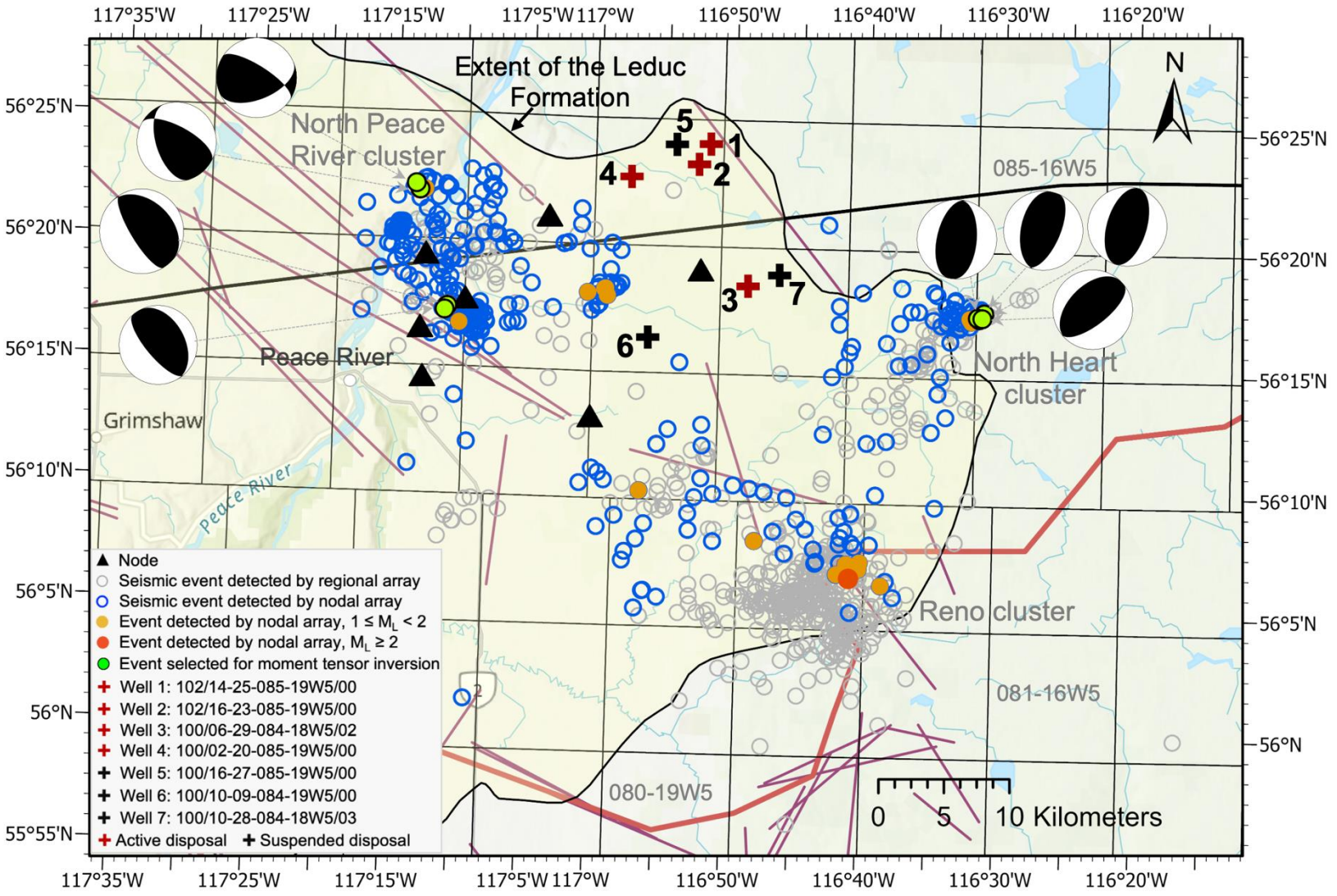
- Local magnitudes calculated using Yenier et al. (2017)
- 29 events with $M_L \geq 1$, 13 of these were not detected by the regional seismic array
- The nodal and regional array magnitudes are comparable



Event Date	Event Time	Nodal array data	Regional array data	Difference
2023-08-08	03:09:16.421	2.25	1.95	0.3
2023-08-16	05:19:29.489	1.58	1.86	0.28
2023-08-20	02:04:23.489	1.79	1.79	0
2023-09-04	20:30:05.904	1.73	1.97	0.24
2023-09-20	19:34:35.618	1.70	missed	
2023-09-21	15:57:05.775	1.65	missed	
2023-10-02	10:20:36.596	2.05	2.44	0.39
2023-10-02	10:25:27.103	1.54	1.82	0.28
2023-11-04	07:23:40.257	2.83	2.83	0

Source Mechanisms of Selected Nodal Array Events

- Moment tensor inversions of events with $M_L \geq 1.5$
- Amplitude-based method (Eyre and Van der Baan, 2017)
- Predominantly reverse faulting
- Possible nodal plane solutions broadly align with the mapped lineaments (Mei, 2006)



Lineament

Peace River–Athabasca Arch

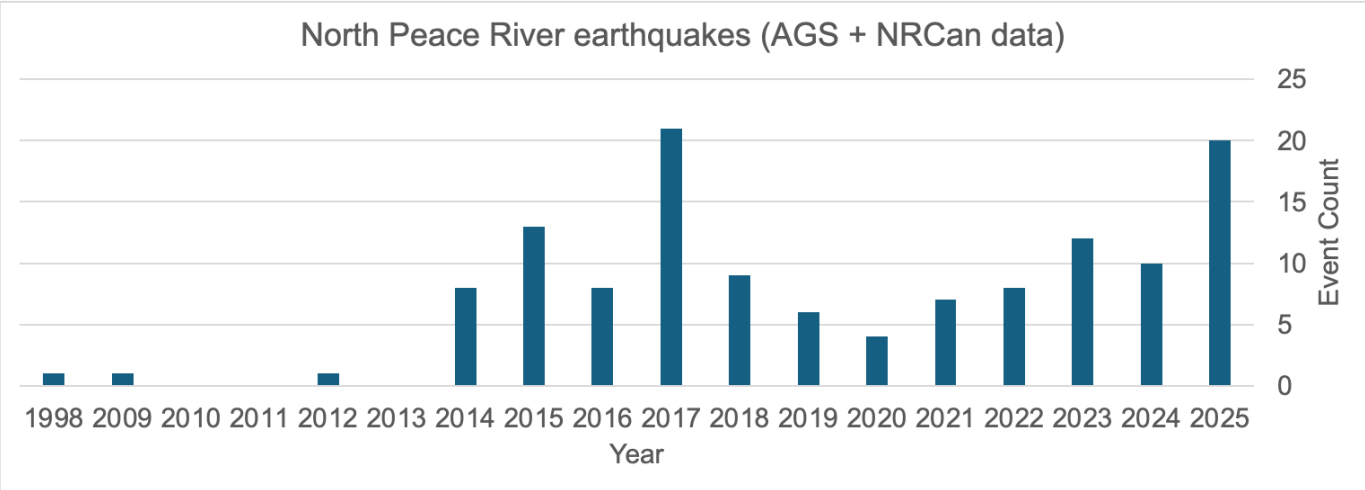
Buffalo High–Utikuma High domain boundary

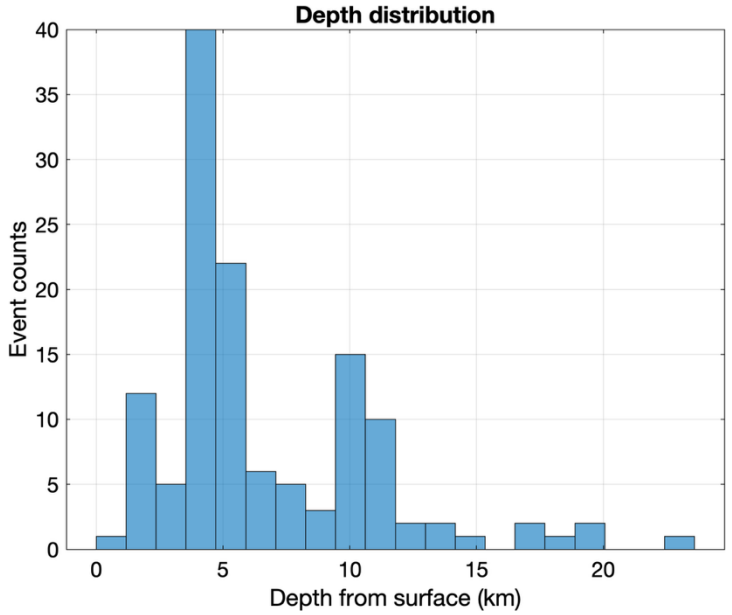
(2) Regional Array Data and Injection Histories

- Combine NRCan catalog and AGS regional catalog
- Leduc disposal wells
- Strong correlation between seismic rates and wastewater disposal into the Leduc Formation

Regional Seismic Catalog

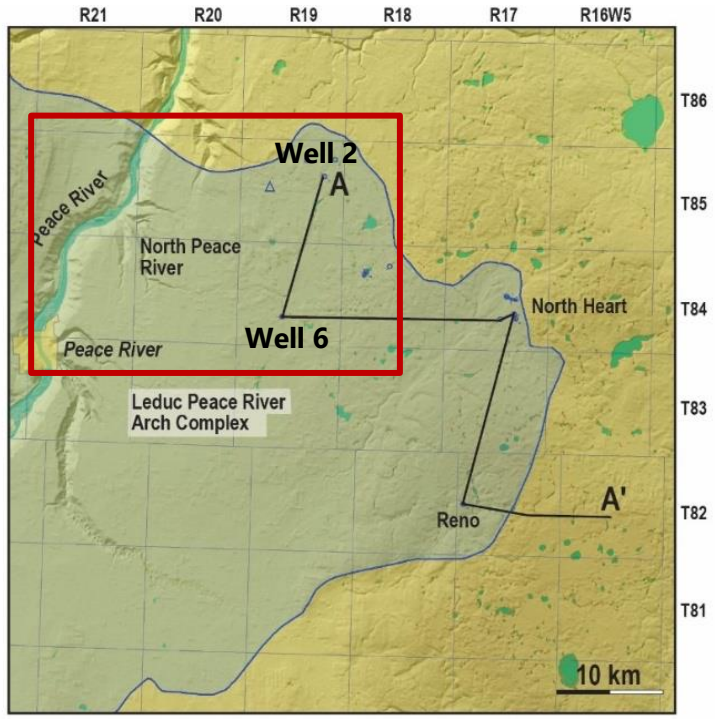
- Limited monitoring prior to 2014 (pre-RAVEN)
- Combined NRCan and AGS regional catalogs (~130 events)

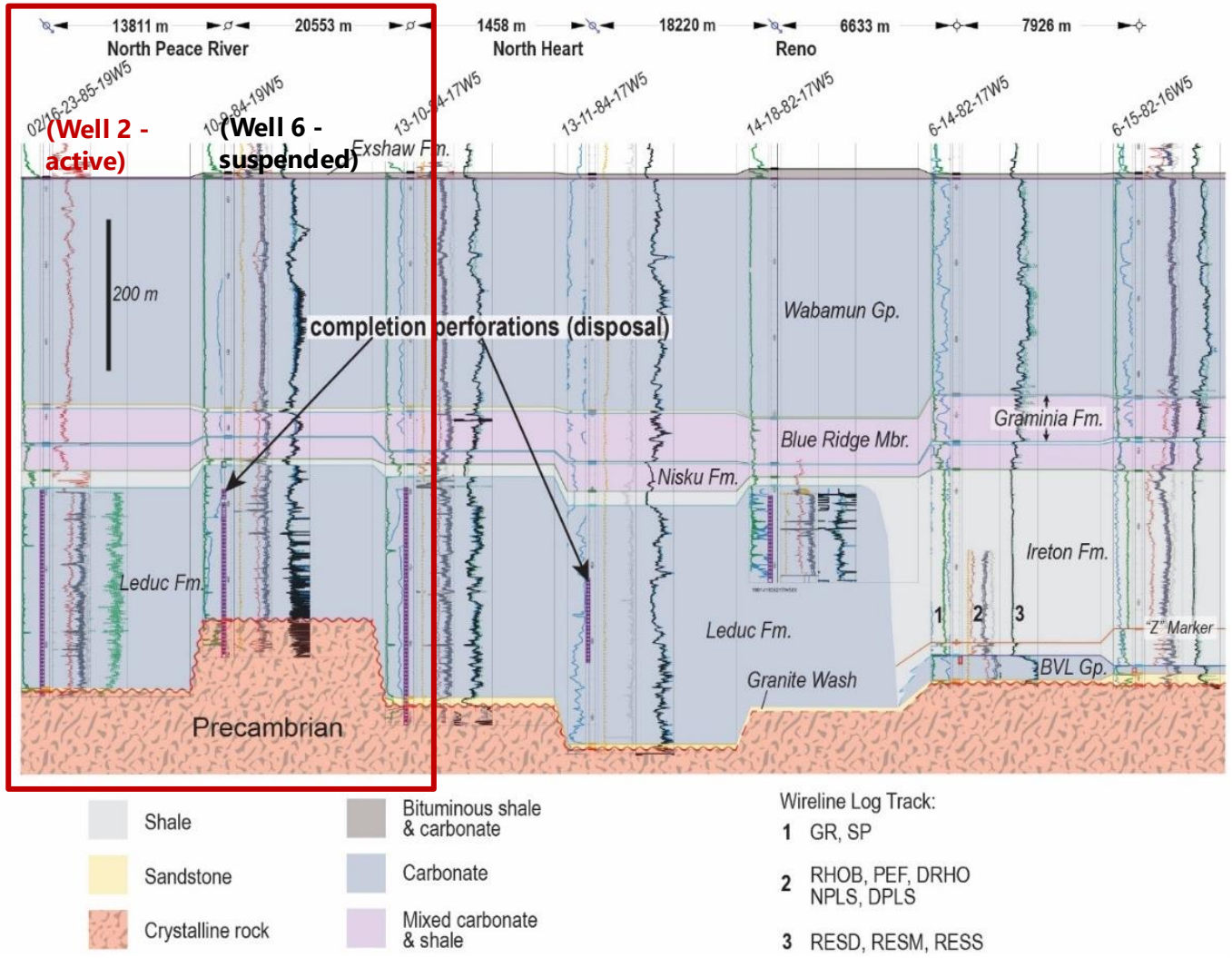




- Depth primarily between 4 and 6 km (Precambrian basement)

Leduc Formation and Disposal Wells



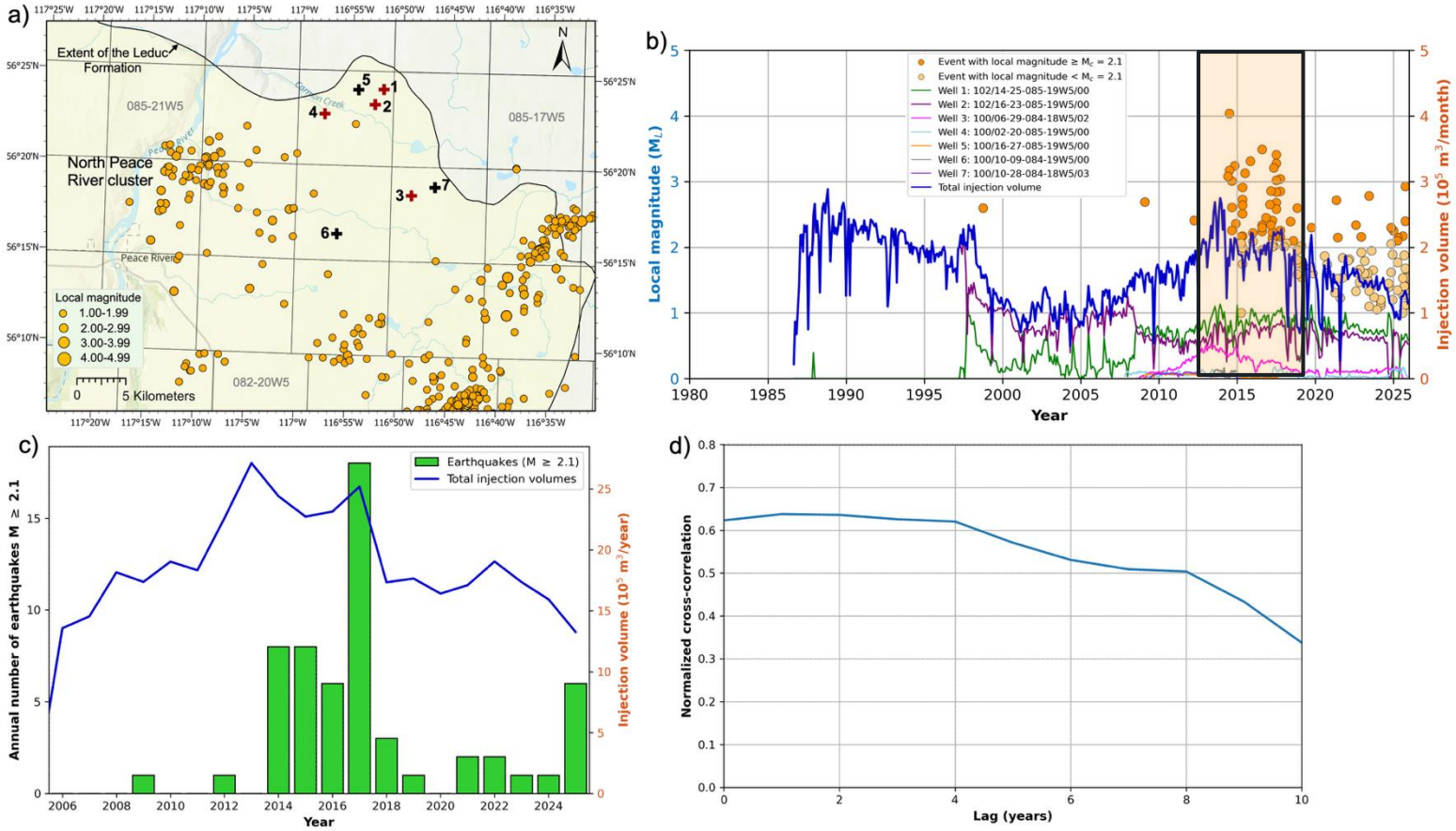


- Location of the seismic cluster areas relative to Leduc Formation buildup complex, which all disposal wells are targeting
- Leduc disposal wells proximal to basement-rooted faults in the Precambrian

Spatiotemporal Association between Seismicity and Injection Histories

- Seismicity more clearly observed after RAVEN station installations in 2014
- Seismic activity likely initiated prior to reliable detection
- Peak seismicity during 2015-2017 coincides with high injection volumes
- Cross correlation of annual seismicity rates and Leduc injection volumes shows coefficient > 0.6 for lags of 0-4 years

➔ Indicates a strong temporal association over multi-year time window

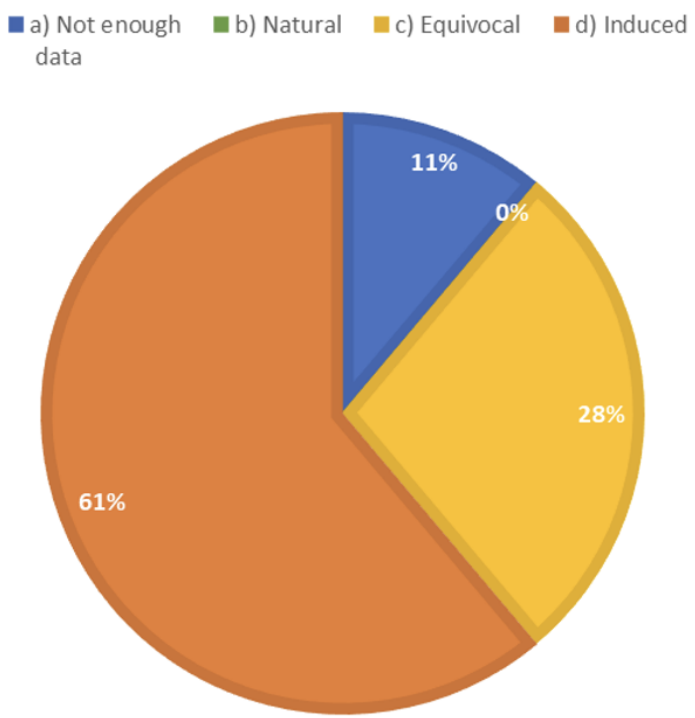


(3) Inputs Derived from an Evidence-based Scoring Tool (Questionnaire)

- The framework provides additional guidance for assessing whether seismicity is natural or induced (Foulger et al., 2023)
- Evaluates sequence onset, spatial and temporal associations, and additional data such as focal mechanisms
- Inputs: regional-array seismicity, local nodal array data, and injection data

Inputs Derived from Evidence-based Scoring Tool

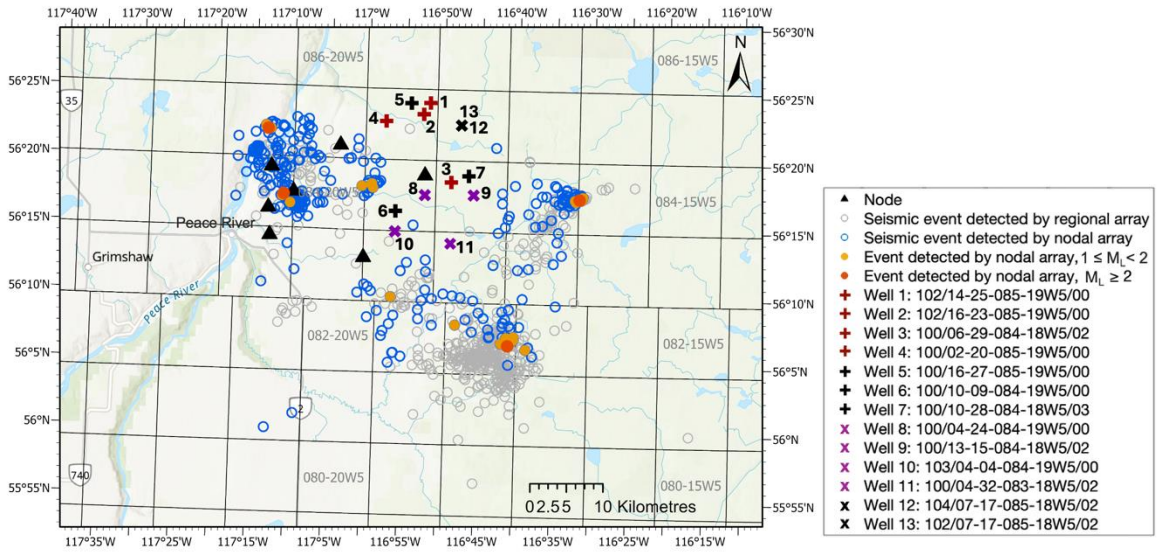
- **Foulger et al. (2023) questionnaire:**
  - Nine questions, four response options:
    (a) insufficient information, (b) evidence supporting a natural origin, (c) inconclusive (equivocal) information, and (d) evidence supporting an induced origin
  - Three key questions accounts for 86% of the points
- **Key questions and results:**
  - Q2 (Epicenter): Spatial collocation with area influenced by industrial activity
    - ➢ Result: c) Equivocal
  - Q3 (Hypocenter): Spatial collocation with volume influenced by industrial activity
    - ➢ Result: d) Evidence supporting induced
  - Q4 (Temporal correlation): Temporal association with industrial activity
    - ➢ Result: d) Evidence supporting induced



Discussions

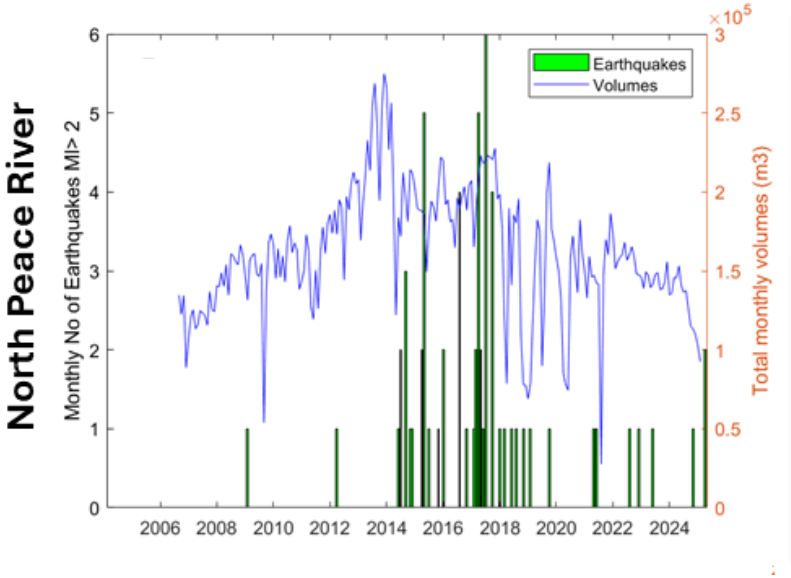
Shallow disposal wells (6 wells, #8-13)

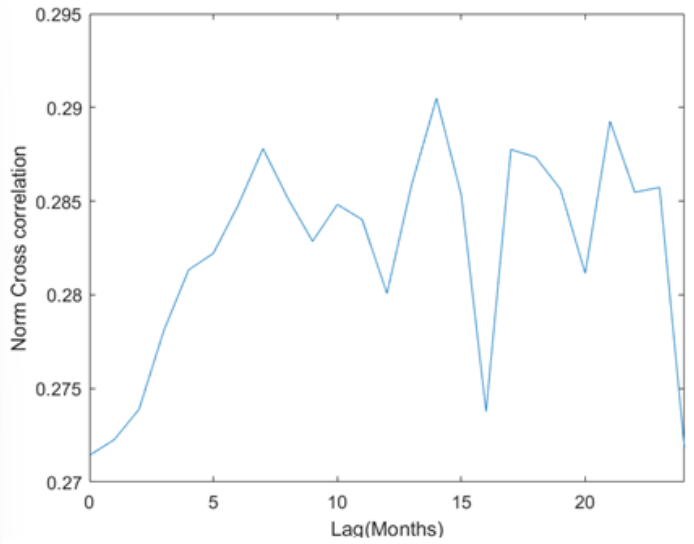
- Shallow formations (e.g., Belloy), ~0.5–0.7 km TVD
- Contribute relatively small injection volumes
- Unlikely to be the primary driver of observed seismicity



Correlation using monthly data

- Monthly correlations between seismicity and injection are less clear
- Earthquake catalogs often miss small events that capture fine-scale variability
- Disposal-induced seismicity commonly shows time lags between operations and seismic responses
- These lags reflect gradual stress redistribution in the reservoir





Conclusions

- **(1) Nodal array data significantly improve local seismic detection and location resolution**, supporting a better understanding of the causes of seismic clusters.
  - Three months of nodal deployment detected 340 events in the Peace River region, with the largest event having M_L 2.83. Among these, 13 events with $M_L \geq 1$ were not detected by the regional seismic network.
  - Event depths are primarily between 4–6 km, suggesting seismicity occurring in the Precambrian basement.
  - Notably, a previously undetected local cluster was identified within ~15 km of disposal wells.
- **(2) Regional catalog data show a strong temporal association** between annual seismicity rates and injection volumes.
- **(3) Inputs derived from an evidence-scoring tool (questionnaire) support an induced interpretation**, with 61% of the points inclined toward induced seismicity origin.

Acknowledgements

The authors would like to thank Shaurat Sayani, Nick Roman, Jason Hendrick, Alex MacNeil, Todd Shipman, Chris Filewich, Kelsey MacCormack, and Andrew Beaton (Alberta Geological Survey and Alberta Energy Regulator) for their constructive and helpful support developing this project.

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Thank you for listening!

For more details on the regional seismic network and earthquake catalog, please visit the **AGS Earthquake Dashboard**

Questions?