Determining the spatio-temporal patterns of intraplate earthquakes in the Western Quebec Seismic Zone using clustering analysis

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About the WQSZ

The **Western Quebec Seismic Zone** (WQSZ) has a significant number of earthquakes for an intraplate region – the mechanism for which are unclear. However, spatial patterns in the WQSZ may offer insight into their origin. **What pattern do you see?**

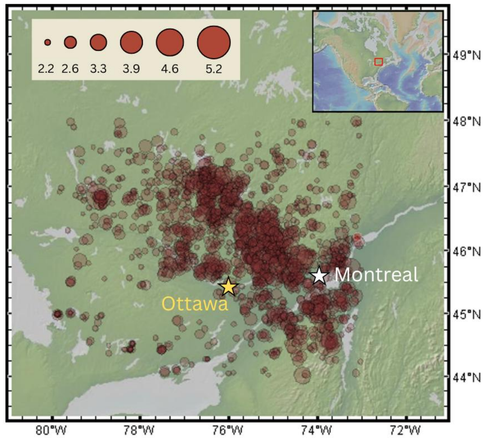


Figure 1. *Spatial distribution of earthquakes within the WQSZ region from January 1st, 1985, to December 31st, 2024 (n = 2245) with magnitude analysis. Marker size is proportional to earthquake magnitude. Ottawa is Canada's capital while Montreal is Canada's second largest city.*

DBSCAN

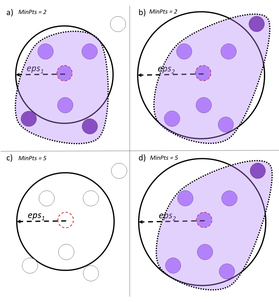


Figure 2. *Examples of DBSCAN clustering when using different combinations of eps (radius) and minPts (minimum points).*

Density-Based Spatial Clustering of Applications with Noise **(DBSCAN)** is a clustering algorithm that could identify spatial patterns within the WQSZ to help with our understanding of tectonic mechanisms.

Research question:
Can we identify geological features that relate to seismicity in the WQSZ via DBSCAN?

Spatio-temporal Analysis

Which cluster scenario were you?

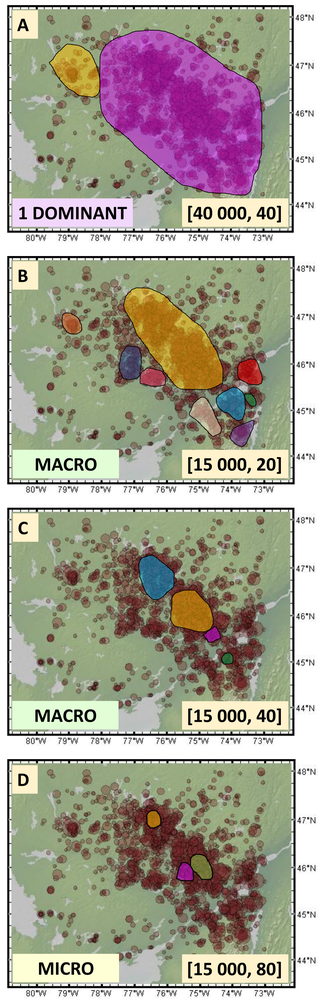


Figure 3. *Spatial patterns of the WQSZ obtained from DBSCAN showing 4 different cluster scenarios.*

Changing the DBSCAN parameters of *eps* and *minPts* can generate **a range of cluster scenarios** which we summarize into four main categories: **1 dominant cluster**, **macro**, **micro**, and **noise**.

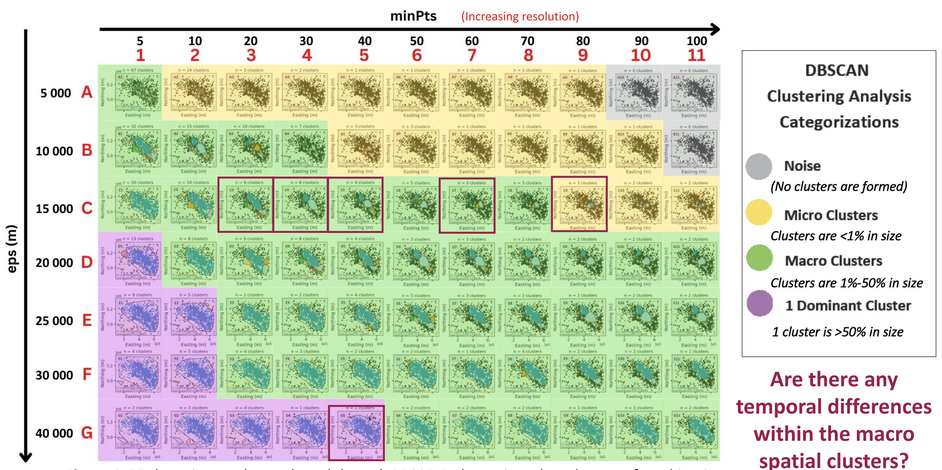


Figure 4. *77 clustering results conducted through DBSCAN when using a broad range of combinations of eps and minPts. Each clustering result is categorized into one of 4 groups depending on the size of the clusters with respect to the entire region.*

Are there any temporal differences within the macro spatial clusters?

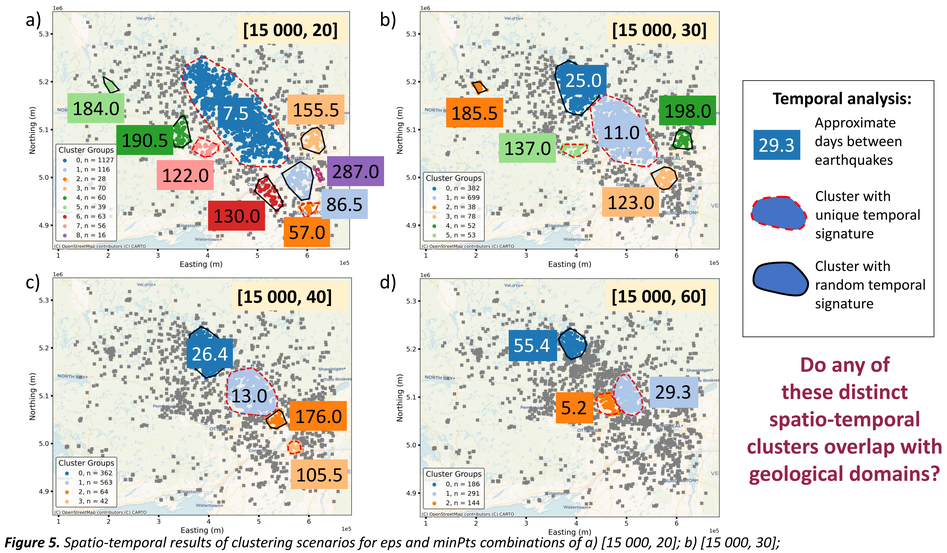


Figure 5. *Spatio-temporal results of clustering scenarios for eps and minPts combinations of a) [15 000, 20]; b) [15 000, 30]; c) [15 000, 40]; d) [15 000, 60]; Clusters with a red dashed border indicate clusters with a statistically unique temporal signature.*

Temporal analysis:

29.3 Approximate days between earthquakes

Cluster with unique temporal signature

Cluster with random temporal signature

Do any of these distinct spatio-temporal clusters overlap with geological domains?

Discussion: Geological Context

Figure 6 shows that spatial clusters derived from spatio-temporal analysis **align with distinct geological boundaries** in the WQSZ. **But which is correct?**

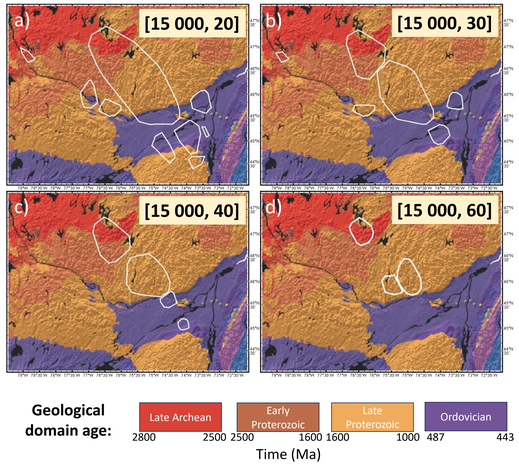


Figure 6. *Geological context of DBSCAN clustering results overlaid on regional bedrock geology.*

Summary

- **Spatial patterns of intraplate earthquakes** within WQSZ may offer insight into ***why*** earthquakes occur.
- Although **DBSCAN provides a range of cluster scenarios** for the WQSZ, it is difficult to determine which is correct without additional information.
- Future work will **further analyze the geological data and DBSCAN clusters together** to determine the possible mechanisms influencing seismicity.

More Information

Abstract

References

Earthquake Early Warning System in Quebec