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Calcite U-Pb Geochronology of the Montreal Fault Network Record the Protracted Brittle Deformation of the Laurentian Passive Margin (Southern Quebec, Canada)

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The St. Lawrence Lowland platform, upon which the Island of Montreal sits, is crosscut by a complex network of brittle faults with highly variable orientations whose origin and timing remain poorly constrained. Understanding the tectonic evolution of these fault systems carries both scientific and practical significance: they pose real challenges for urban infrastructure development, and their origin is likely linked to the post-rift evolution of the North American passive margin.

To address these questions, we applied U-Pb geochronology of syn-kinematic calcite cements, integrated with three-dimensional subsurface modeling and detailed field structural analysis. Brittle faults in the Montreal area are dominantly normal faults cutting the St. Lawrence platform in two main orientations (E-W and NW-SE), with subordinate N-S and NE-SW sets. The main fault zones display complex anastomosing architectures locally coeval with emplacement of mafic dykes associated with the Cretaceous Mont Royal intrusion, suggesting a genetic link between magmatic fluid infiltration and fault development.

U-Pb calcite ages, generated at the Geotop laboratories (UQAM), span from ca. 150 Ma to near-recent. A pronounced peak at 110–120 Ma coincides with emplacement of the Mont Royal intrusive complex and the broader New England-Quebec magmatic province (90–110 Ma), and is coeval with rifting and opening of both the Equatorial and North Atlantic branches of the Atlantic Ocean. These ages are significantly younger than initial Atlantic rifting, long considered the primary driver of faulting in this region, demonstrating that the brittle deformation record here is far more protracted and complex than previously recognized.

We propose that the passage of the North American plate over the Great Meteor hotspot triggered crustal weakening, enabling magmatic fluid infiltration and fault nucleation within the St. Lawrence platform. Subsequent reactivation phases likely reflect far-field intraplate stresses from Atlantic plate reorganization, coupled with episodic fluid migration within the sedimentary basin. This study demonstrates the power of fault-hosted calcite U-Pb dating as a tool for recovering the multi-stage fluid and deformation history of ancient passive margins, with broad implications for understanding intraplate seismicity and long-lived tectonic reactivation.