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Cretaceous joints in southeastern Canada: dating calcite-filled fractures

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To resolve the timing of brittle tectonism is a challenge since the classical chronometers required for analyses are not often in equilibrium with the surrounding material or simply absent. In this study, we propose to couple LA-ICP-MS U-Pb and (U-Th)/He dating with geochemical proxies in vein calcite to tackle this dilemma. We examined intracratonic Middle Ordovician limestone bedrock that overlies Mesoproterozoic crystalline basement, which are cut by NE-trending fault zones that have historic M4-5 earthquakes along their trace. E-W to NE-SW vertical joint sets, the relatively youngest stress recorded in the bedrock, possess 1-7 mm thick calcite veins that seal fractures or coat fracture surfaces. The veins possess intragranular calcite that are lined with fine-grained calcite along the vein margin and can exhibit μm- to mm-scale offset (e.g. displaced fossil fragments in host rock). Calcite d18O and d13C values are analogous to the bulk composition of Middle to Late Ordovician limestones, and suggest vein formation from a source dominated by connate fluids. The calcite contain trails of fluid inclusions commonly along fractures, and 3He/4He analyses indicate a primitive, deep fluid signature (R/Ra: 0.5-2.7). Trace element geochemistry of the calcite is highly variable, generally following the elevated HREE and lower LREE of continental crust trends but individual crystals from a single vein may vary by three orders of magnitude. LA-ICP-MS geochemical traverse across veins show elevated concentrations along (sub)grain boundaries and the vein-host rock contact. Despite abundant helium concentrations, (U-Th)/He dating was unsuccessful yielding highly dispersed dates likely from excess helium derived from the fluid inclusions. However, LA-ICP-MS U-Pb dating on calcite separated from the veins yielded model ages of 110.7 $\pm$ 6.8 Ma (MSWD: 0.53; n: 16) to 81.4 $\pm$ 8.3 Ma (MSWD: 2.6; n: 17). Since all veins are from the same ENE-trend, we regressed all the calcite dates together, yielding an age of 101 $\pm$ 6 Ma (MSWD: 2.3). These veins are $\sim$200 km to the west and slightly younger than the c. 140-120 Ma alkaline igneous rocks which mark the surface trace of the Great Meteor Hotspot. The period of 110-90 Ma has been identified as a time of major plate reorganization that involved tectonic and magmatic events, which may be reflected in our new calcite dates. Nonetheless, LA-ICP-MS U-Pb dating of vein calcite was successful, and coupled with other geochemical information, can yield primary information about the timing and source of fluid flow through joints and fractures, which has direct applications to reducing risk associated with characterizing hydrocarbon reservoirs and deep geological repositories for nuclear waste.