Rapid cooling of HP mafic blocks in the Canadian Grenville Province: Insights from garnet zoning and rutile U-Pb depth profiling

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Geodynamic models applied to the western Canadian Grenville Province predict a protracted period of high-temperature conditions (e.g. T > 700 °C for >70 Myrs) across the orogenic infrastructure during and after the main collisional phase. This is supported by a ~50 Myr range in zircon ages from mid-crustal migmatites and hornblende ^{40}Ar-^{39}Ar cooling ages that are younger by another ~65 Myrs across much of the western Grenville. This type of long-duration high-T thermal history should result in complete diffusional re-equilibration of major-element zoning in most garnet crystals and young ages in U-Pb thermochronometers with amphibolite-facies closure temperatures. However, exploratory thermal-chronological studies of HP mafic blocks within the orogenic core show a number of characteristics consistent with relatively short high-T residence times and rapid cooling. Prograde growth zoning (i.e. decreasing Mn and increasing Mg# from core to rim) is well-preserved in ~4 mm garnet crystals and moderately preserved in many ~1 mm crystals. Given that these samples yield peak T estimates of ~ 800-850 °C, the preservation of growth zoning suggests high-T durations of <10 Myrs (for T_{char} = 750 °C) and <30 Myrs (for T_{char} = 700 °C). Steep Mn enrichment profiles along the garnet margins, associated with resorption and back-diffusion during decompression, also yield short timescales of cooling (~2 Myrs for T_{char} = 743 °C and ~7 Myrs for T_{char} = 663 °C). Finally, depth-profiled rutile crystals commonly show ^{207}Pb/^{206}Pb age progressions from ~1080 Ma in the cores to ~980 Ma along the rims, indicating core-to-rim migration of the intracrystalline diffusional closure front (associated with cooling from ~650 °C to ~500 °C) over this timeframe. The older ages preserved in the rutile cores are commonly within 10 Ma of U-Pb zircon ages for the same samples (1085-1097 Ma), and suggest relatively rapid cooling (>10 °C/Myr) to <650 °C following HP metamorphism. Rapid cooling early in the Ottawan collisional phase suggests syn-convergent exhumation to shallow crustal levels, a process that may have been aided by melting at HP conditions within the high-strain margins of the mafic blocks.