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Sequential porphyroblast growth during progressive metamorphism revealed by the measurement of FIAs in the Big Thompson region of Colorado Rockies, USA.

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A progression of FIAs (foliation intersection/inflection axes preserved within porphyroblasts) in the foothills of the Colorado Rocky Mountains reveals four periods of garnet and staurolite growth and two growth phases each of cordierite and andalusite. These minerals grew in an overall prograde path, where the growth of garnet was always followed by the formation of staurolite for each FIA. For the last 2 periods of FIA development the growth of staurolite was also followed by the development of andalusite and cordierite. Inclusions of earlier minerals within the younger phases have supported the porphroblastic mineral sequence obtained through FIAs. Thermodynamic modelling in the MnNCKFMASH system reveals that this episodic growth occurred over a similar bulk compositional range and PT path for each FIA in the succession. Multiple phases of growth by same series of reactions in these rocks strongly suggests that PT and X are not the only factors controlling the commencement and cessation of metamorphic reactions. The FIAs preserved by these porphyroblasts reveal that each stage of growth occurred during deformation and that the local partitioning of deformation at the scale of a porphyroblast was the controlling factor on whether or not the reaction took place. In-situ dating of monazite grains preserved within porphyroblasts from each FIA set has revealed that the first period of tectonism occurred around 1759.7$\pm$9.8 Ma, recorded within the porphyroblasts of FIA set 1, where garnet nucleated at 540-550°C and 3.8-4.0 kbars. The intersection of Ca, Mn, and Fe isopleths in garnet cores for 3 samples, containing FIA set 1, set 2 (1759.7$\pm$9.8, 1721.0$\pm$6.4 Ma) and set 3 (1674$\pm$11 Ma), trending NE-SW, E-W and SE-NW respectively, indicate that these rocks never got above 4kbars throughout the Colorado Orogeny. They remained around the same depth until the onset of younger orogeny at 1420$\pm$14 Ma, when the pressure decreased slightly as porphyroblasts formed with inclusion trails preserving FIA set 4 and trending NNE-SSW. A slightly clockwise P-T path occurred for both orogenies.