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Phase Equilibria and Geochronologic Constraints on Paleozoic Metamorphism, Anatexis, and Melt-Facilitated Exhumation in New York City

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The boroughs of Manhattan and the Bronx in New York City preserve outcrops of metasedimentary bedrock thought to be deposited on the margin of Laurentia and complexly metamorphosed and deformed during the Taconic (520-470 Ma) and Acadian (416-360 Ma) orogenies. Though these units have been mapped as part of major infrastructure development, much of their purported history is based on correlations with potentially equivalent units elsewhere in New England. Their specific petrology and geochronology have gone largely understudied, and thus their tectonometamorphic history is largely unsubstantiated. Here we apply phase equilibria modeling, and monazite U-Pb chemical dating to constrain the Pressure-Temperature-time (P–T–t) histories of kyanite-bearing migmatites in the Manhattan Formation.

This study explores four samples from parks across Manhattan and the Bronx that are garnet-kyanite-biotite-muscovite migmatitic schists. The matrix is dominated by foliated muscovite+biotite+quartz. Kyanite occurs in ~1-2 mm long nodules characterized by oriented kyanite grains with interstitial plagioclase+muscovite+quartz. These nodules are interpreted as recrystallized leucosome from the back-reaction of muscovite-out melting. Sillimanite occurs as both ~0.5-0.7 mm long blades cross-cutting kyanite, and fibrolite needles included in texturally late muscovite. Garnet grains are typically syn- to pre-tectonic, hypidioblastic, and range from ~0.5-1.00 mm in diameter. Garnet grains display bell-shaped Mn-zoning decreasing in concentration from core to rim, while Fe, Mg, and Ca all display reverse zoning.

The synthesis of phase equilibria modeling, the method of intersecting isopleths and petrographic analysis suggest the following P–T path: (1) garnet growth at 550 °C and 6 kbar, (2) muscovite-out melting and kyanite growth at 750 °C and 9 kbar, (3) melt-facilitated nearly-isothermal exhumation to fibrolite stability, and (4) continued exhumation to 700 °C and 6.5 kbar along with sillimanite growth. Preliminary monazite dating retrieved Taconian ages, however anatectic conditions are rarely associated with Taconic orogenesis in the northern Appalachians, and may instead reflect polymetamorphism during the subsequent Acadian orogeny. Continued analysis of monazite inclusions in other phases (e.g. garnet) will better constrain the timing of metamorphism and associated tectonism. Nevertheless, our results suggest that the Manhattan Formation records evidence for Paleozoic crustal thickening, anatexis, and melt-facilitated exhumation.