# THE QUEENS TUNNEL COMPLEX - A GRANULITE FACIES ORTHOGNEISS TERRANE EXPOSED IN NYC WATER TUNNEL #3

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Between 1996 and 1999, a high-performance TBM has excavated a 7 m wide, 7.7 km long, and 214 m deep tunnel through the subsurface of southwestern Queens. Taking almost twice as long as expected, low penetration rates resulted from unusual rock mass conditions attributable to the high-grade metamorphic history of the rocks. Indeed, evidence from field mapping at 1"=10' and from petrographic-, geochemical-, and geochronologic studies conclusively demonstrate that the TBM penetrated weakly foliated granulites containing broad zones of garnet enrichment (up to 50% garnet in some zones). Based on these studies, Proterozoic Fordham orthogneiss is now recognized to underlie a region where mixed Paleozoic metasedimentary and metaigneous rocks of the Hartland formation were formerly anticipated. Granulite facies metamorphism of predominately mesocratic intrusive rocks resulted in coarse granoblastic textures consisting of interlocking plagioclase, pyroxenes (opx+cpx), and garnet. Early, coarse-grained garnet coexists with opx, with or without cpx and with cpx alone. This early phase of high-pressure granulite metamorphism dehydrated the rock mass and produced a tough fabric that was subsequently annealed under similar P-T conditions. Here, the coarse-grained "old" granulite textures were partially replaced by granular amphibole+garnet with oval garnet reaction rims and then by biotite grade metamorphism associated with late syntectonic pegmatites and a suite of glassy, post-tectonic rhyodacite dikes. Despite the complexity of the protracted metamorphic and intrusive events, the early stage granulite textures were only slightly modified by later tectonism and the relict rock mass textures prevailed. High-pressure granulite facies metamorphism generally produces an anhydrous, isotropic rock mass. In the case of the Queens Tunnel Complex, the primary coarse interlocking rock texture, the lack of a penetrative foliation, and the extraordinary garnet content together proved an impediment to efficient chip production and TBM mining. Such fundamental textural and mineralogical control over TBM tunneling can only be identified by careful pre-bid geological analysis. Detailed, as-built mapping and analysis provide an important geotechnical case history to assist bidders in future tunneling endeavors.

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