TRACING THE ST. NICHOLAS THRUST AND CAMERON'S LINE THROUGH THE BRONX, NYC

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Introduction

The pelitic rocks of New York City (NYC) consist of three lithologically distinct amphibolite-grade rock sequences (Sauk, Tippecanoe, and Taconic Sequences) formerly deposited as temporally correlative lithotopes within a lower Paleozoic convergent-margin regime. Now metamorphic rocks, these disparate sequences were formerly combined into a single formation, the Manhattan Schist, which overlies and was thought to be **entirely younger** than the Cambro-Ordovician Sauk Sequence carbonates (Inwood Marble formation). As such, the entire Manhattan formation was, in sequence terms, thought to belong to the middle Ordovician Tippecanoe Sequence. In NYC, minor parts of the Manhattan Formation (Om in Figure 1) are indeed interlayered with Sauk carbonates and maintain their Tippecanoe designation. Yet, detailed mapping and recognition of ductile faults within the Manhattan Formation has allowed the new interpretation (Merguerian 1983a, 1983b, 1985, 1996; Merguerian and Baskerville 1987; Merguerian and Sanders 1991, 1993a, 1993b, 1996) that the bulk of the Manhattan (Units Ꞓ-Om and Ꞓ-Oh in Figure 1) is entirely allochthonous, occurring structurally above both the Sauk and Tippecanoe sequences. As such, the main mass of the Manhattan (Ꞓ-Om and Ꞓ-Oh) should be properly grouped with the Taconic Sequence.

In The Bronx, the three "Manhattan" pelitic sequences are separated by ductile faults -- the Saint Nicholas thrust **(SNT)** and Cameron's Line **(CL**) and cut by late ductile shears that have produced retrograde metamorphic textures. Over the past three years, as a continuing project with Hofstra geology majors, we have examined the bedrock exposures of two public parks in The Bronx that contain the St. Nicholas thrust (SNT) and Cameron's Line (CL). The SNT and CL are exposed as steeply oriented, highly laminated, migmatized, complexly folded- and annealed zones of commingled mylonitic rocks. Last year (Merguerian and Sanders, 1998), we reported on an exposure of the SNT exposed in a new construction site on the grounds of the New York Botanical Garden. In this abstract and accompanying presentation, we report our preliminary findings from Boro Hall and Crotona Parks, which straddle the Cross Bronx Expressway (Figure 2). Thus far, in Boro Hall Park, we have identified the Sauk-Tippecanoe unconformity and have mapped the trace of the SNT. In Crotona Park, we have traced the SNT southward from Boro Hall Park and have identified a lithologic change from allochthonous (Taconian) Manhattan rocks (Ꞓ-Om) to the west from allochthonous (Taconian) Hartland rocks (Ꞓ-Oh) to the east. Although not accurately mapped at this time, we have a reconnaissance map showing the position of Cameron's Line. Based on these joint investigations, our placement of the Sauk-Tippecanoe unconformity, the SNT, and CL differ significantly with published maps of the region (Baskerville, 1992).

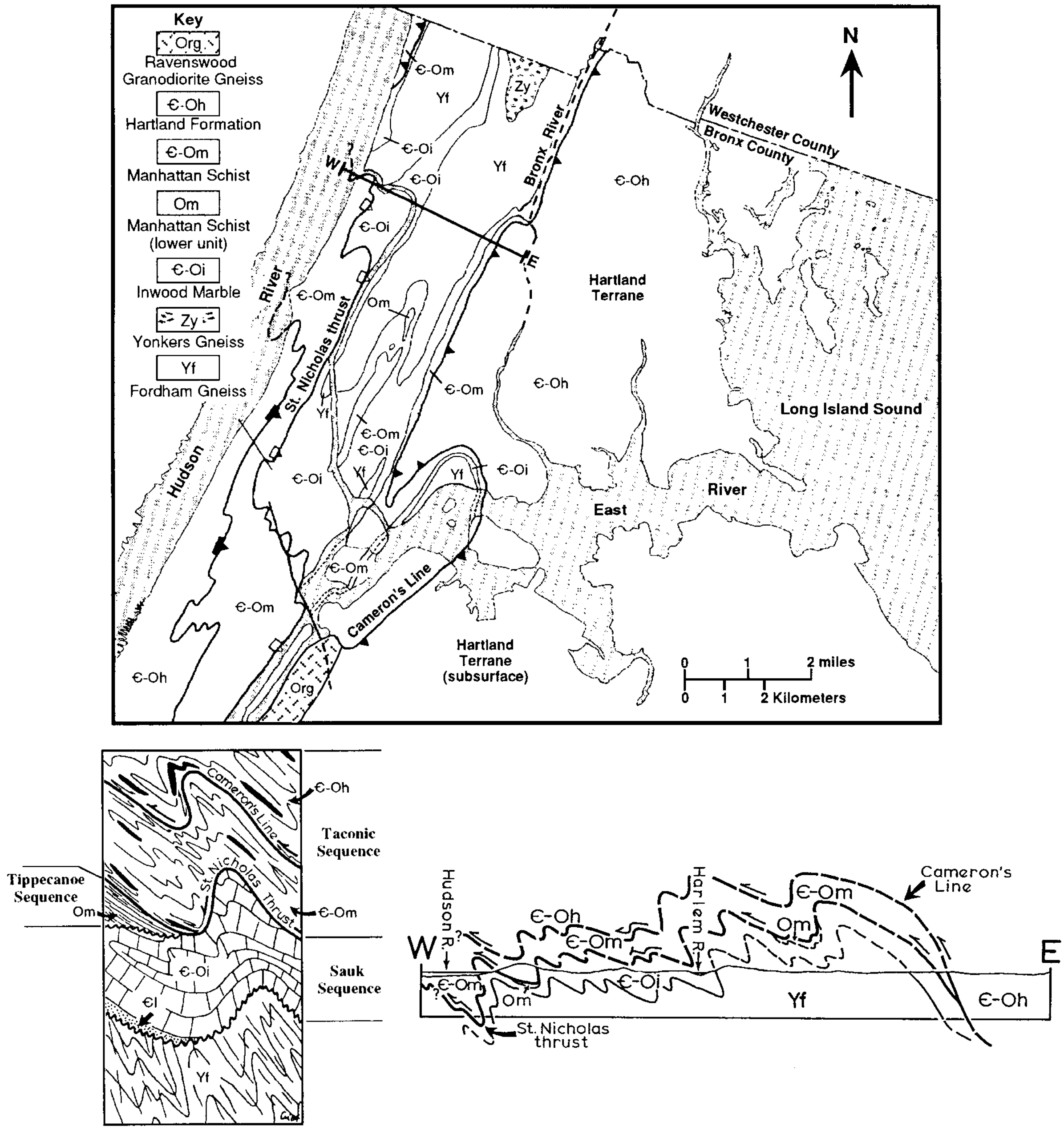

Figure 1 - Geologic map of the south end of the Manhattan Prong showing Cameron's Line, the Saint Nicholas thrust, and bounding metamorphic rock units (as described in text). Inset shows the tectonostratigraphic units of New York City as subdivided into the Sauk, Tippecanoe, and Taconic sequences. Geologic section (keyed to line of section W-E) shows folded Taconian thrusts.

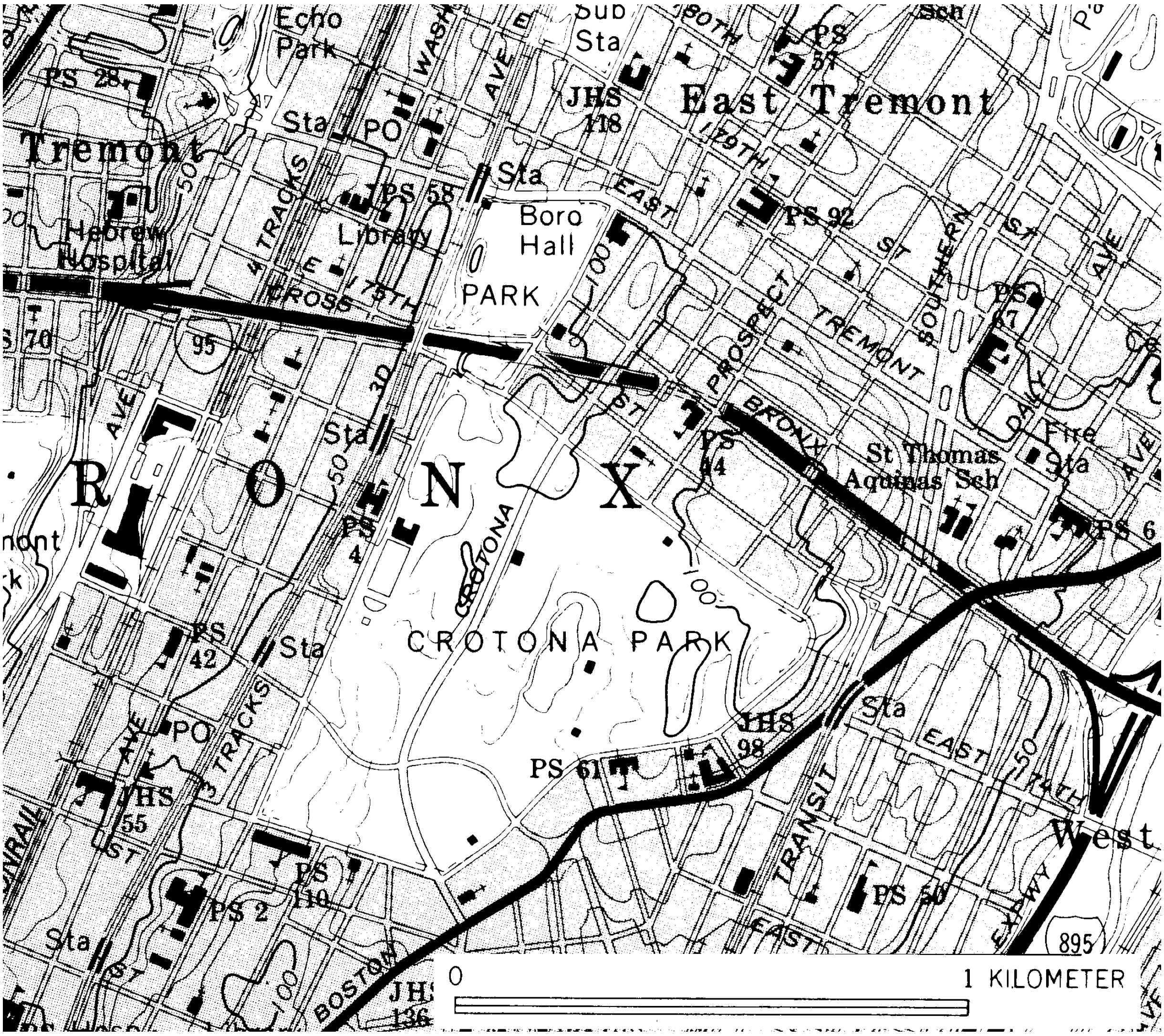

Figure 2 - Index map of the central Bronx showing the position of Boro Hall and Crotona Parks. Base map from the USGS Central Park 7-1/2 minute quadrangle.

The Manhattan Formation

Based on two decades of detailed mapping, CM divides the schist of Manhattan Island and The Bronx into three, lithologically distinct, structually imbricated, lithostratigraphic units of kyanite- to sillimanite metamorphic grade. (See Figure 1.) The structurally lowest unit (Om), crops out in northern Manhattan and the west Bronx, including Boro Hall Park and the New York Botanical Garden. This unit is composed of brown- to rusty-weathering, fine- to medium-textured, typically massive, biotite-plagioclase-quartz-muscovite-garnet-kyanite-sillimanite-garnet schist containing interlayers centimeters- to meters thick of biotite±hornblende+plagioclase+
quartz granofels and calcite+diopside+plagioclase+mica marble. *(NOTE - Minerals are listed in order of decreasing relative abundance).* This lower unit is found interlayered with the

underlying Inwood at three localities (1) at the NW corner and western edge of Boro Hall Park, (2) at the northern end of Inwood Hill Park in Manhattan, and (3) along the Grand Concourse and the I-95 overpass in The Bronx. Near the schist-Inwood contact, the schistose rocks include layers of calcite marble (probably metamorphosed Balmville, the basal limestone of the Tippecanoe Sequence). Because Unit Om is interpreted as being autochthonous (depositionally above the Inwood Marble), we assign it a middle Ordovician age and consider it to be a part of the Tippecanoe Sequence.

The lower “Tippecanoe” schist unit and the Inwood Marble are structurally overlain by the middle schist unit (Ꞓ-Om = Taconic Sequence), a vast structural sheet which forms the bulk of the "schist" exposed on the Island of Manhattan and throughout the west Bronx (including Boro Hall and Crotona Parks). The middle schist unit consists of rusty- to sometimes maroon-weathering, medium- to coarse-textured, massive biotite+quartz+plagioclase+muscovite+garnet+kyanite±sillimanite gneiss and, to a lesser degree, schist. The middle unit is characterized by kyanite±sillimanite+quartz+magnetite layers and lenses up to 10 cm thick, cm- to m-scale layers of blackish amphibolite, and local quartzose granofels. Lithologically identical to the Waramaug and Hoosac formations of Cambrian to Ordovician age in New England (Hatch and Stanley 1973; Hall 1976; Merguerian 1983a, 1985), these “Taconian” rocks are inferred to represent metamorphosed Cambrian to Ordovician sedimentary- and minor volcanic rocks formed in the transitional slope- and rise environment of the Early Paleozoic continental margin of ancestral North America.

The structurally highest, uppermost schist unit (Ꞓ-Oh = Taconic Sequence) is dominantly gray-weathering, fine- to coarse-textured, well-layered muscovite-quartz-biotite-plagioclase-kyanite-garnet schist, gneiss, and granofels with cm- and m-scale layers of greenish amphibolite ± garnet and distinctive quartz+garnet+biotite granofels (coticule). The uppermost schist unit underlies most of the western- and southern third of Manhattan and the eastern half of The Bronx (including exposures in Crotona Park and east along the Cross Bronx Expressway) and is lithologically identical to the Cambrian and Ordovican Hartland Formation of western Connecticut and southeastern New York. On this basis, we correlate them with the Hartland and have extended the name Hartland into New York City. Accordingly, we infer that together they represent metamorphosed deep-oceanic shales, interstratified graywackes, and volcanic rocks formed in deeper water environments adjacent to Early Paleozoic North America.

Although we remain loyal to the concept that **all** of the schistose (pelitic) rocks of NYC occur physically above the Sauk, over the years we have subdivided the Manhattan Formation into three essentially coeval sequences that were formerly deposited in contrasting environments ranging from a continental shelf (Om = Tippecanoe Sequence) seaward across a continental rise (Ꞓ-Om = Taconic Sequence) and onto a former sea floor (Ꞓ-Oh = Taconic Sequence). How to sort all this out depends on how one feels about the term "Manhattan Schist." If one adopts the view that the only appropriate basis for continuing to use "Manhattan Schist" is as implied in the original definition (i.e., schists younger than the Inwood Marble and belonging to the Tippecanoe Sequence), then only Unit Om merits the designation of "Manhattan Schist." By contrast, if one adheres to the view that all the schistose rocks of New York City belong under the term "Manhattan Schist," then continued use of the term "Manhattan" merely serves to perpetuate confusion about the correct ages and structural relationships of the schistose rocks found there. Accordingly, we feel the term "Manhattan Schist" should be discontinued and replaced by three new names: one for the in-situ Tippecanoe-age schists and two others, for the overthrust Taconian schists.

Merguerian (1983a) has renamed the structurally highest unit (Ꞓ-Oh) the Hartland Formation based on its lithostratigraphic equivalence to Hartland rocks found in western Connecticut. These deposits, which may have been formerly separated from one another by distances of hundreds of kilometers during the Ordovician Taconian orogeny, when they were internally folded, metamorphosed, and telescoped together. During this deep-seated event, ductile shear zones developed in a former continentward-facing subduction complex wherein these former shelf-, rise-, and deep-water facies were subducted, metamorphosed, and juxtaposed. Field- and petrographic evidence suggest that they were sheared again under retrograde metamorphic conditions.

In summary, the three distinctive mappable units of the "Manhattan Schist" represent essentially coeval foreland-basin-fill- (Om), transitional slope/rise- (Ꞓ-Om), and deep-water (Ꞓ-Oh) lithotopes that were juxtaposed when the ancestral North American shelf edge was telescoped in response to closure of the proto-Atlantic (Iapetus) ocean during the Taconic orogeny. (See geologic section in Figure 1.) Regional correlation suggests, then, that the higher structural slices of the Manhattan Schist are older, or possibly overlap in age with the lower unit (Om). All three of the “Manhattan Schists” are exposed in Boro Hall and Crotona Parks in The Bronx as described below.

Boro Hall Park

Starting in mid 1998, along with former Hofstra geology majors Kathleen Currington and Steven Roth, CM embarked on a mapping project in Boro Hall Park. Boro Hall Park in The Bronx is surrounded by East Tremont Avenue on the north, Third Avenue on the west, Arthur Avenue on the east and E. 175th Street on the south, (which also serves as the westbound service road for the Cross Bronx Expressway [I-95]). Merguerian and Baskerville (1987) and Baskerville (1992) placed Cameron’s Line through the center of the park and placed the Saint Nicholas thrust to the west. Our mapping indicates that the Hartland formation lies entirely to the east of the park and that Saint Nicholas thrust trends roughly through the center (Figure 3).

Within the park are fourteen natural exposures that we have mapped, sampled, and photographed. We’ve mapped two distinctly different rock formations on either side of the park. Rocks of the Taconic Sequence (Manhattan Formation Unit Ꞓ-Om; Stops 9, 10, 11, and 12) occur on the eastern side of the park and the Tippecanoe sequence (Manhattan Formation Unit Om; Stops 1 through 7, 13, and 14) occurs on the western side. The Taconic rocks, which crop out along the SE portion of the park, consist of sheared maroon weathering biotite-quartz-plagioclase-muscovite-garnet gneiss and lesser schist with abundant “nubby” weathering aluminosilicate nodules. These mylonitic rocks are cut by syntectonic granitoids. By contrast, in the NW corner and W edge of Boro Hall Park, the Tippecanoe sequence consists of sheared biotite-quartz-garnet gneiss interlayered with biotite-diopside-tremolite-staurolite calc-schist and granoblastic- to weakly foliated bitotite-calcite marble layers and lenses up to 2 m thick.

Because of the profound ductility contrast between the pelitic- and calcareous units, boudinage and intraformational shearing is locally developed.

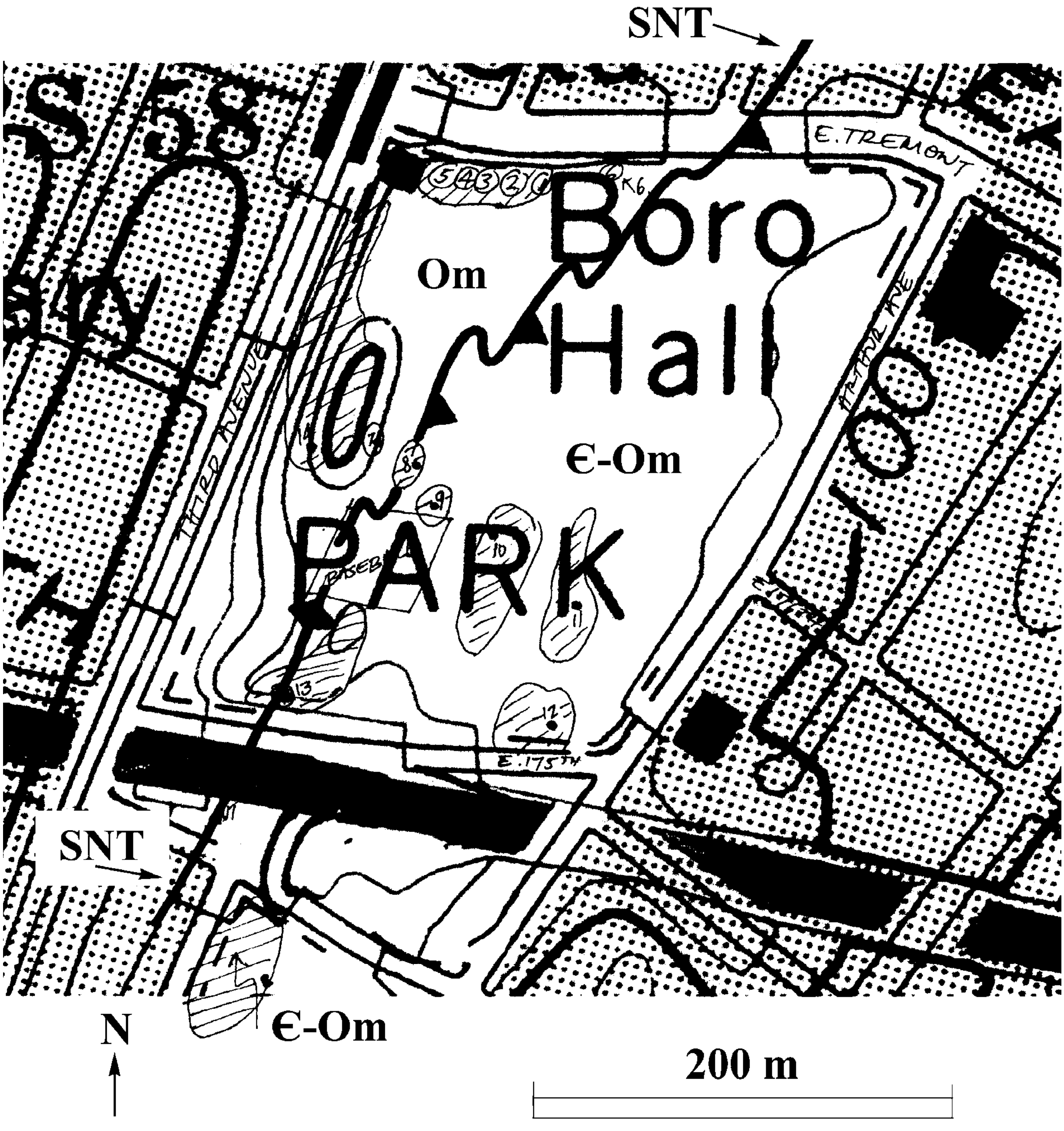

Figure 3 - Geologic map of Boro Hall Park showing the distribution of natural exposures (diagonal shading), field stops, and the trace of the St. Nicholas thrust (SNT). See text and refer to Figure 1 for descriptions of rock units Om and Є-Om.

At Stops 8 and 13 we noticed intermixed Є-Om and Om cut by a 15 cm thick lit-par-lit granitoid sill with mylonitic layering developed on a cm and smaller scale. Based on our mapping, we suggest that Stop 8 straddles the Saint Nicholas thrust zone. (See Figure 3.) At Stop 13, the SNT occurs again with the same tectonic mixing and mm-scale mylonitic layering. The subvertical SNT trends N30°E and is ranges in width from 6 m to 10 m. The thrust zone displays the effects of ductile shearing in the form of highly laminated mylonitic textures, F_2 shear folds, and low angle truncations of an earlier foliation (S_1). Serpentinized diopsidic marble stringers are also found at this locality. The presence of intense fracturing in exposures along the western edge of the park (Stop 14) suggest that brittle faulting may have modified the unconformable contact between Tippecanoe Unit Om and Sauk carbonates of the Inwood Marble found by drilling and engineering records to underlie the lowland to the west of Third Avenue.

Thus, based on mapping of contrasting lithologies and zones of tectonic intermixing we have identified the trace of the SNT through Boro Hall Park.

Crotona Park

Our findings from Crotona Park are based solely on one day of mapping in late 1998. On that day, we examined the exposures throughout the park and found a lithologic change between units Ꞓ-Om and Ꞓ-Oh. We base our distinction on the absence or presence of thick granofels (interpreted as former turbidites) and amphibolites (metabasalts), both distinctive subunits of the Hartland Formation (Ꞓ-Oh). These subunits occur near the center of Crotona Park and in areas to the east. As such, we tentatively place Cameron's Line near the center of Crotona Park and await warmer weather and the lack of manuscript deadlines to further refine our mapping.

Summary

Our joint investigations have allowed a reinterpretation of the positions of both the Saint Nicholas Thrust and Cameron's Line in The Bronx. Our interpretation differs from published maps and we intend to refine our mapping as this on-going project continues this year.

Acknowledgements

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