



HOFSTRA UNIVERSITY 014F FIELD GUIDEBOOK GEOLOGY OF ISHAM AND INWOOD HILL PARKS, NYC

20 September 2008

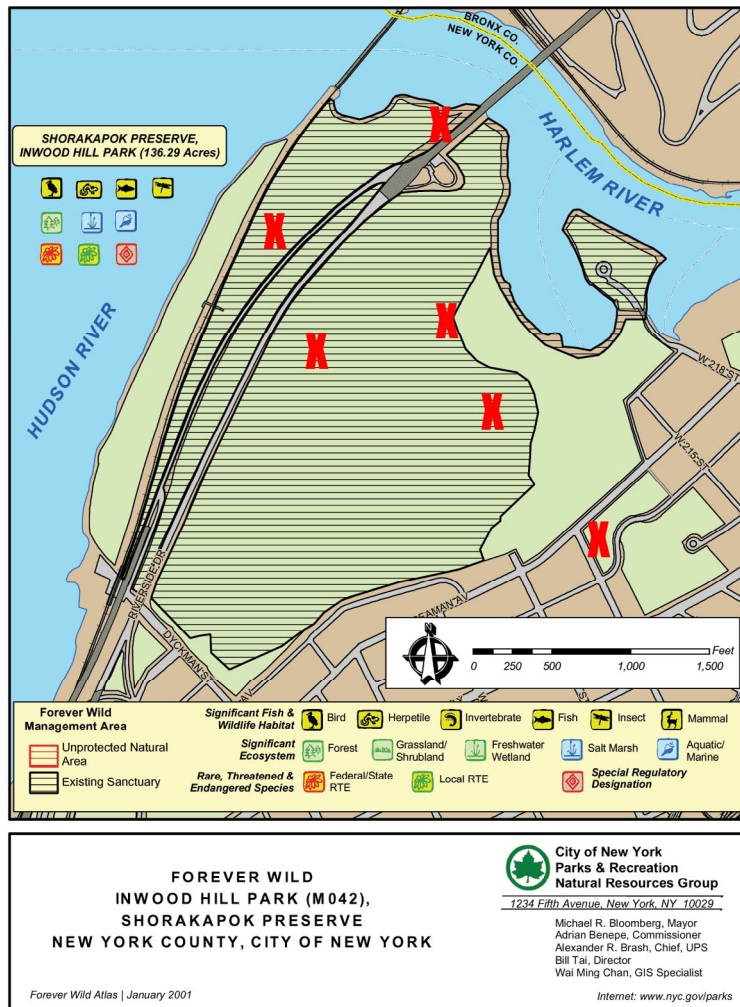


Figure 1 – Index map of Isham and Inwood Hill Parks showing the location of our field stops.

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Geology of Isham and Inwood Hill Parks, Inwood Section of Manhattan

[UTM Coordinates: 590.97E / 4524.72N, Central Park quadrangle and 590.66E / 4525.40N, Yonkers quadrangle, respectively.]

Today's field trip will concentrate where bedrock is exposed on the northernmost tip of Manhattan in Isham and Inwood Hill Parks (Figure 1, cover). The complex bedrock geology of New York City can best be explained in a layer cake fashion (Figure 2). To simplify matters, we will concentrate only on the major units found in the vicinity of Isham and Inwood Hill Parks. The oldest bedrock unit in NYC is known as the Fordham Gneiss (Yf) which is locally overlain by the Ned Mountain Formation (Zn), the Lowerre Quartzite (€l), and the Inwood Marble (€-Oi). The Inwood Marble is overlain by various schistose rocks (Ow, €-Om, and €-Oh) which are here collectively designated as the Manhattan Schist. The detailed mapping and analysis by Merguerian (1981, 1983, 1985, 1994, 1996, 2005); Merguerian and Baskerville (1987), Merguerian and Merguerian (2004); and Merguerian and Sanders (1991) suggests that these units can be subdivided into various subunits but for our purposes they are best left lumped together and discussed collectively as the Manhattan Schist. The interested reader is directed to the publications listed above for the sordid and often-times excruciatingly boring subunit details.

Fordham Gneiss. The Fordham Gneiss (basal unit Yf in Figure 2) constitutes the oldest underpinning of rock formations in the NYC area and consists of a complex assemblage of massive Proterozoic (~ 1.1 billion year old) ortho- and paragneiss, granitoid rocks, metavolcanic and metasedimentary rocks. In NYC, only a few attempts have been made to decipher the internal stratigraphic relationships, hence, the three-dimensional structural relationships remain obscure. They have experienced a very high grade of metamorphic recrystallization with internal melting developed on a regional scale and the production of migmatite (mixed igneous and metamorphic rock – the transitional end game of the rock cycle). Locally, the Ned Mountain Formation of Brock (1989) has been found to occur between the Inwood and Fordham (Zn). It consists of interlayered K-feldspar-rich metasedimentary, metabasite, and metavolcaniclastic rift facies rocks of latest Proterozoic age.

Inwood Marble. The Inwood (€-Oi in Figure 2) consists of Paleozoic (~ 500 million year old) calcitic and dolomitic marble. The Inwood Marble underlies the Inwood section of northern Manhattan, the Harlem lowland NE of Central Park, occurs as thin belts in the East River channel and in the subsurface of southeastern Manhattan, and also crops out in The Bronx and Westchester County. These exposures are correlative with a laterally continuous outcrop belt of Cambrian to Ordovician rocks formed along the entire Appalachian chain along the east coast of North America.

Manhattan Schist. The Manhattan Schist (€-Om in Figure 2) consists of Paleozoic (~500 Ma [million year old]) massive rusty- to sometimes maroon-weathering, medium- to coarse-textured, biotite-muscovite-plagioclase-quartz-garnet-kyanite-sillimanite gneiss and, to a lesser degree, schist. The unit is characterized by the lack of internal layering, the presence of kyanite+sillimanite+quartz+magnetite layers and lenses up to 10 cm thick, cm- to m-scale layers of blackish amphibolite (metabasalt), and minor quartzose granofels. The unit is a major ridge former in northern Manhattan, a testament to its durability owing to the lack of layering and presence of weathering-resistant minerals quartz, garnet, kyanite, and sillimanite. All three

bedrock units (Fordham, Inwood, and Manhattan) are exposed (the Fordham is visually exposed) in the vicinity of Inwood Hill and Isham parks. Note in Figure 2 that the schistose rocks above the Inwood consist of internally sheared and imbricated rock units known as the Walloomsac (Ow), Manhattan Schist (€-Om), and Hartland (€-Oh) formations.

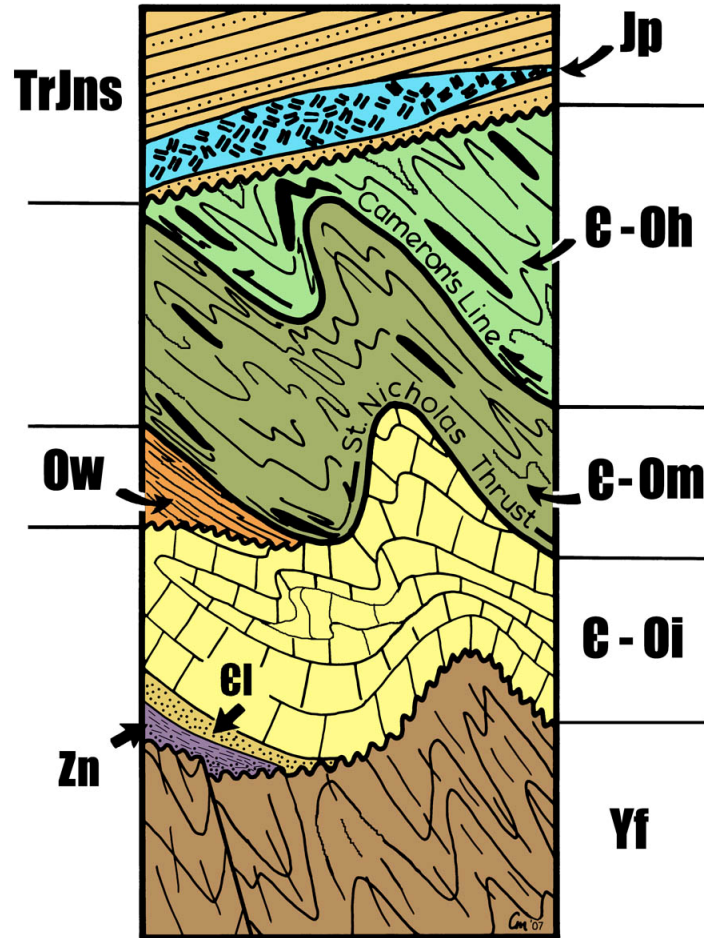


Figure 2 – Bedrock stratigraphy of New York City as described in text. Note that the polydeformed bedrock units are nonconformably overlain by west-dipping Triassic and younger strata (TrJns) and the Palisades intrusive sheet (Jp).

Inwood Hill Park is located in the extreme northwest corner of Manhattan Island (Figure 3). The park is bordered by Dyckman Street on the south, the Hudson River on the west, Spuyten Duyvil (Harlem Ship Canal) on the north, and Payson and Seaman Avenues on the east. Isham Park occupies the flat area northeast of Inwood Hill Park extending eastward to Broadway between Isham and West 214th Streets.

The area of Manhattan north of Dyckman Street is known as the Inwood section. Except for Inwood Hill Park, the region is underlain by the Inwood Marble marking the type-locality for that particular unit of NYC bedrock. This unit was originally called the Inwood Limestone by Merrill (1890). Isham Park contains near continuous low relief exposure of the Inwood Marble

cut by high-angle conjugate joints which have facilitated the weathering process by allowing aqueous solutions to permeate the rocks (Figure 4). The marble ranges from white- to blue-white to gray-white. Several lithologies occur such as coarse-grained dolomitic marble, fine-grained calcite marble, foliated calc-schist, and marble containing disarticulated siliceous layers (former chert?) and calc-silicate aggregates that stand in relief as cm-scale knots on the weathered surface (Figure 5). Abundant examples of boudinage of the siliceous and calc-silicate layers into lenses occur due to the marked ductility contrast between them and the surrounding marble (Figure 6). Depending on the amount of impurities it weathers gray or tan and produces a sugary-textured surface on outcrops that ultimately develops into residual calcareous sand. Overall, the outcrops illustrate differential weathering with dolomite-silicate units standing in higher relief and calcite marble forming local depressions. Note the weathered carbonate sand.

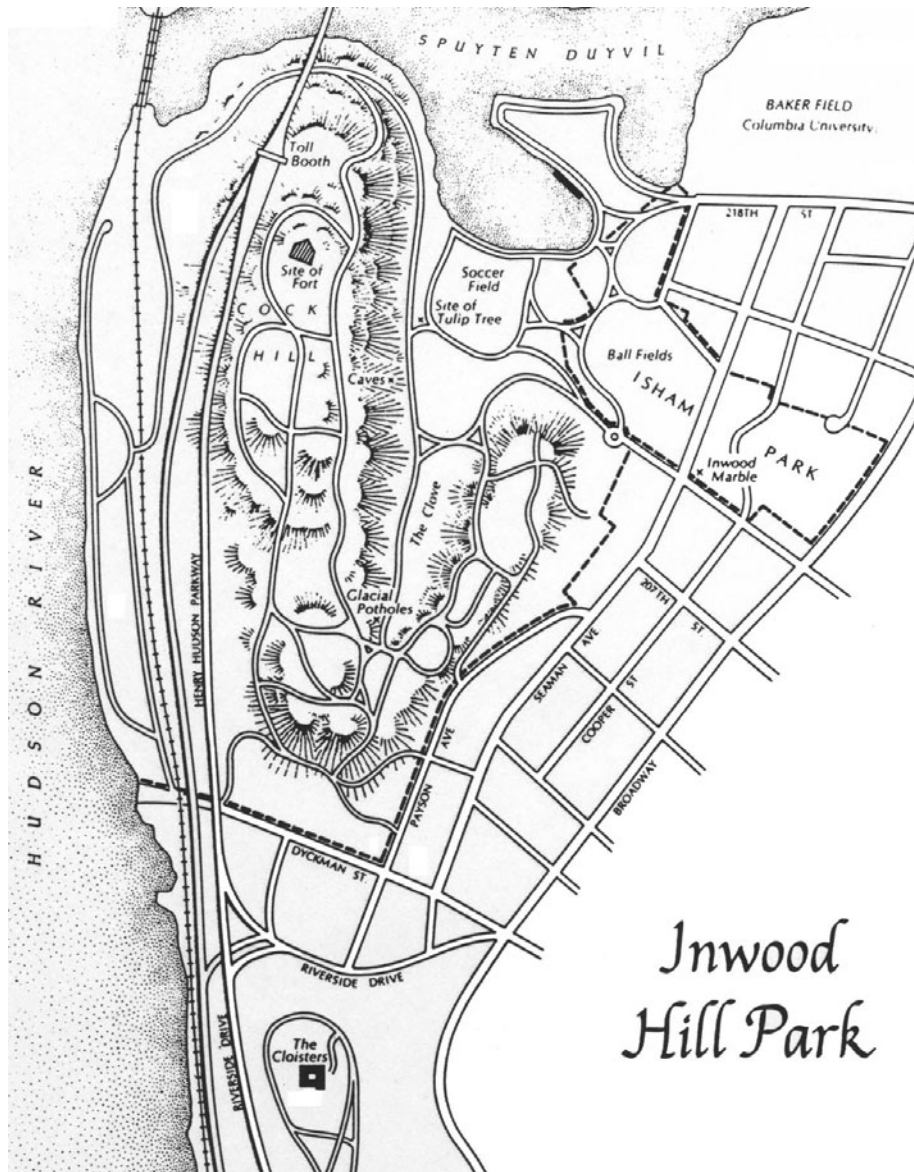


Figure 3 – Index map showing the location of our field trip area in Inwood Hill and Inwood Marble parks in northern Manhattan. You will use this map to put in the field stops for today’s trip.



Figure 4 – Northward view of highly jointed east-dipping Inwood Marble exposed in Isham Park in Manhattan. Although well-foliated, the obvious compositional layering preserves ancient bedding in the rock mass. (CM digital image taken 19 August 2007.)



Figure 5 – View of differentially weathered Inwood Marble exposed in Isham Park in northern Manhattan. Note the small knots of tremolite (a member of the amphibole family) weathering in high relief. (CM digital image taken 19 August 2007.)



Figure 6 – View of disarticulated layer of quartzite (former chert?) in differentially weathered Inwood Marble exposed in Isham Park in northern Manhattan. Such features result from the mechanical differences between the competent quartzite and the less competent marble which undoubtedly flowed around the resilient quartzite layers and lenses. Note the black pocket knife for scale. (CM digital image taken 19 August 2007.)



Figure 7 – View of a south-plunging fold of layering and foliation in the Inwood Marble of Isham Park in northern Manhattan. (CM digital image taken 08 Sept 2007.)

Although locally variable, the exposure of Inwood Marble in Isham Park trends about N45°E and dips 73°SE. It forms the eastern overturned limb of a large syncline which is cored to the west (in Inwood Park) by kyanite-garnet gneiss of the Manhattan Schist formation. Tight south-plunging folds are locally developed in the Inwood (Figure 7). Older internal structures are not obvious but do occur as isoclinal and asymmetrical folds with shallow plunges and as highly sheared intervals within the seemingly simple eastward-dipping sequence (Figure 8).



Figure 8 – View on internal deformation in the Inwood Marble of Isham Park in Manhattan showing shearing and disarticulation of large meter-scale blocks of marble and the complex patterns of folding displayed by resistant quartzite interbeds. (CM digital image 08 Sept 2007.)

We enter Inwood Park by following the path past the playground. The first prominent ridge to your left is composed of Manhattan Schist which also dips steeply toward the SE, essentially parallel to the orientation of the Inwood Marble exposed in Isham Park. Both units are in contact but the contact is covered with soil. They form part of a huge south-plunging syncline with the Manhattan Schist preserved in the central core of the structure (Figure 9). Strangely, the downfolds (synclines) hold up ridges and the upfolds (anticlines) underlie the flat valleys in northern Manhattan. Such inverted topography results from the marked contrast in weathering susceptibility afforded by the marble and schist. In the overall wet temperate climates such as we experience in this region, carbonate rocks (such as the Inwood Marble) weather and dissolve much more readily than do silica-rich rocks of the Manhattan Schist. As a result, structural synclines tend to be preserved to form topographically high ridges and structural anticlines are breached by weathering and erosion and commonly underlie the low valleys. (See Figure 9.) Such topographic inversions are well known in the folded central and northern Appalachians.

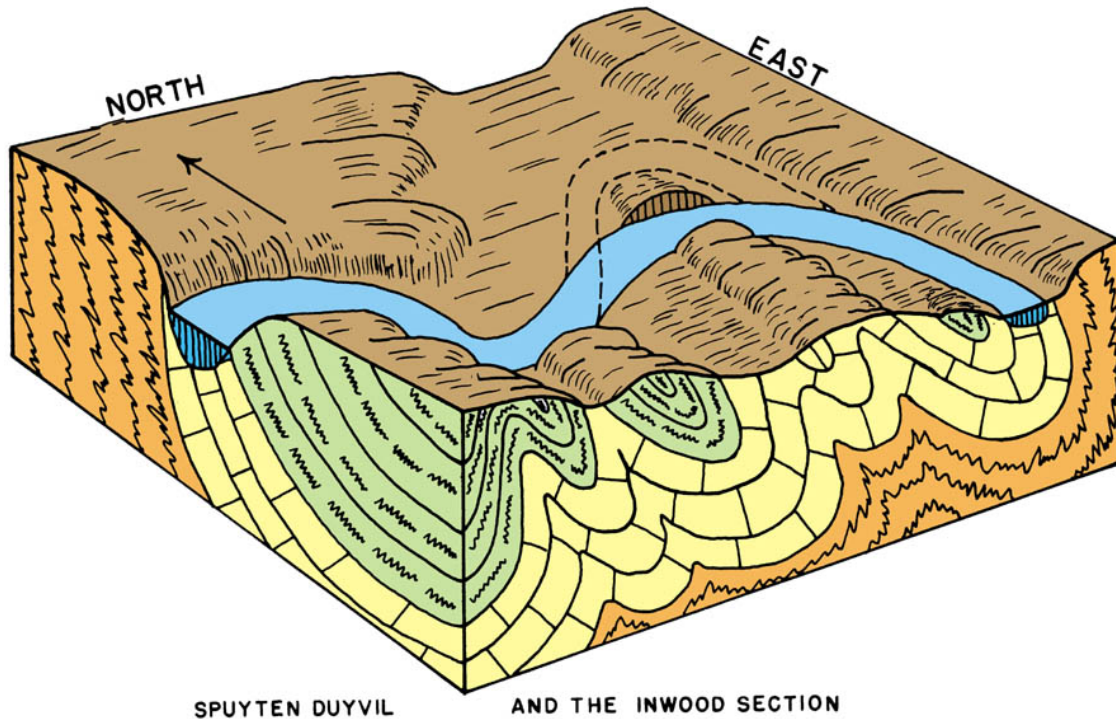


Figure 9 – Block diagram illustrating the structural geology of Inwood and Isham parks. Note that the topographically higher portions of Inwood Park are underlain by the Manhattan Schist (green) and that the topographically lower portions are underlain by the Inwood Marble (yellow). This is the result of the difference in weathering susceptibility of the Inwood and Manhattan. In overall humid, wet climates such as we experience in this region, carbonate rocks (such as the Inwood) weather much more readily than do silica-rich rocks of the Manhattan Schist. Note how the topographically higher ridges are structural synclines (downfolds) yet the valleys are underlain by structural upfolds (anticlines). Such relationships are common in the folded Appalachians and are termed “inverted topography”.

Take the “high-road” path going southward to examine the dual potholes drilled into the east-facing slope of the westernmost synclinal ridge. The structure of the westernmost ridge is another south-plunging syncline overturned toward the northwest. (See Figure 9.) The foliation in the schist is related to folds with axial surfaces oriented N41°E, 75°SE with south-plunging hingelines. Visible in many exposures south of the Henry Hudson bridge approach ramp, at the north end of the ridge the foliation changes trend from NE to NW and wraps around the synclinal trough.

At the top of the trail, two circular potholes were produced by torrents of meltwater during the Pleistocene deglaciation (Figure 10). Clearly the potholes are cut into an already glacially polished rock outcrop. Here, we assume that resistant glacial drift boulders settled into a small depression (perhaps in ridge hugging drift) and then began to drill downward in response to vortices produced during turbulent flow associated with glacial meltback. A self-fulfilling prophesy, once the drilling begins the resistant boulders are constantly replenished by boulders moved by water. In this case the upper pothole skipped over to drill a second, adjacent pothole. Since the potholes are developed on a sloping glaciated surface (pre-Woodfordian?), it may be possible to envision that the potholes formed during a younger glaciation (Woodfordian?).



Figure 10 – View of dual potholes “drilled” by resistant boulders driven by glacial meltwater torrents. (CM digital image 13 Nov 2004.)

Farther up at the top of the trail past the potholes but before the trail bends into a hairpin turn to the right, note the highly polished outcrop of Manhattan Schist (Figure 11.) The glacial striae and grooves are oriented N35°W to S35°E indicating the same glaciation that brought Palisades boulders from New Jersey. As suggested by Merguerian and Sanders (1996), this glaciation (from the NW to SE) was responsible for most of the deep glacial erosion in the NYC area and produced the prominent Harbor Hill moraine that extends across Staten Island, Brooklyn, Queens, and Long Island (Figure 12). Based on superposition and stratigraphic relationships discovered elsewhere (Sanders and Merguerian, 1991, 1994a,b, 1995, 1998), the glacier that flowed from NW to SE across the NYC area is of pre-Woodfordian age, that is, one notch older than the youngest glacial event which was characterized by flow from NNE to SSW.

To Lunch Stop Overlook

Continue up the trail on top of the westernmost ridge and jog left after awhile to get to the fine overlook across the Hudson to the Palisades ridge of New Jersey (Figure 13.) Here, the columnar joints of the Palisades ridge are quite visible forming a steep wall of mafic rock that was intruded at shallow depth during the late Triassic-Early Jurassic split up of Pangea. Thus, we view across the Hudson, the products of a totally different type of tectonic activity than we have been viewing today. The metamorphic rocks of New York City were produced during deep-seated compressive deformation while the sedimentary and igneous rocks of New Jersey were produced by extensional tectonics associated with initial formation of the Atlantic Ocean basin. Is it little surprise that the chemistry of the Palisades intrusive sheet and the associated Watchung basalts of the central Newark Basin are similar to oceanic crust basalts? Indeed, a cross sectional view from Manhattan to central New Jersey (Figure 14) shows that the entire Newark Basin is a rotated block of the earth’s crust with downward motion and westward tilting

accommodated along the Ramapo fault. In this way the ancient Newark Basin is analogous to the modern rift basins of East Africa. The red-colored sandstones and shales of the Newark Basin and lakebed strata of the underlying Lockatong formation are lithically identical to modern sediments forming in the East African rift basins. In order to explain this similarity, geologists argue that the climate during the late Triassic and early Jurassic periods of eastern North America were analogous to those in East Africa today. What goes around - comes around!



Figure 11 – View from the NNW of a glacially polished outcrop of Manhattan Schist in Inwood Hill Park showing a smooth up-glacier side (foreground) and steep, rough down-glacier side (behind White Fang). The glacial striae and grooves are oriented N35°W to S35°E, a product of the pre-Woodfordian glaciation.

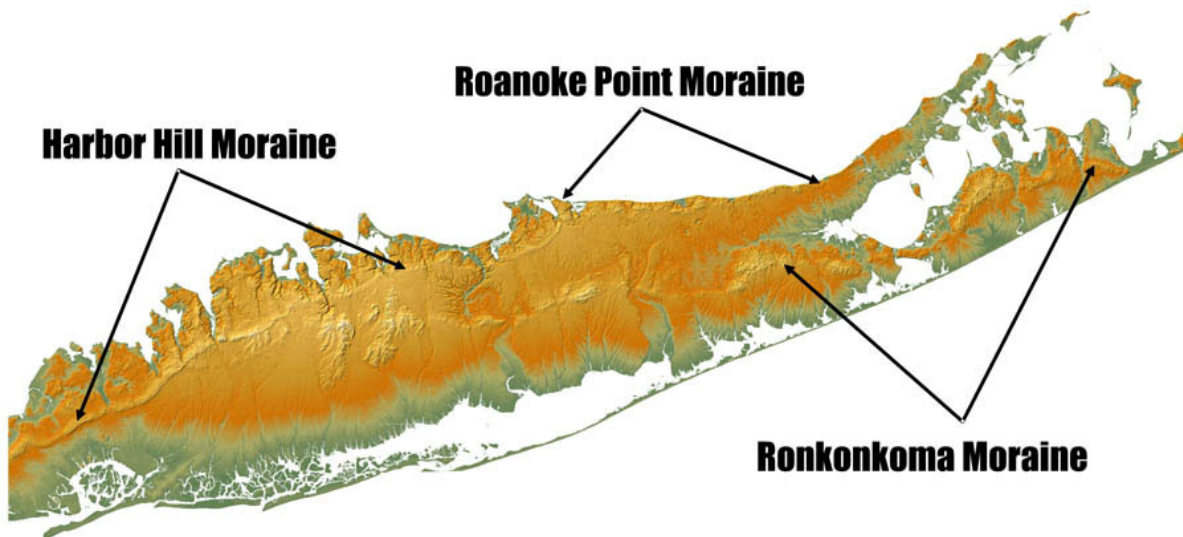


Figure 12 – Digital elevation model diagram of Long Island showing the prominent moraine ridges. (adapted from J Bret Bennington and Gil Hanson.)



Figure 13 – View from the overlook atop the westernmost ridge of Inwood Hill Park across the Hudson River towards New Jersey. Note the glacially polished exposure of schist and the NW-SE trending grooves and striae pointing to the Palisades sheet of New Jersey.

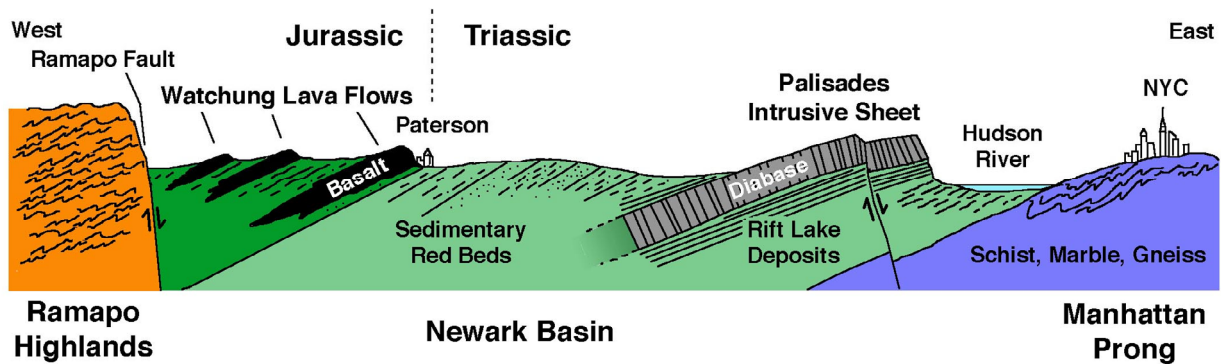


Figure 14 – Cross section showing the geology of the Newark Basin and its relationship to the basin marginal Ramapo fault. Note also the disconformable contact with the complexly deformed rocks of New York City. The unconformity spans roughly 300 million years of missing time and projects with regional tilt of about 12° above Manhattan. (From Bennington and Merguerian, 2007.)

Enough arm-waving for after lunch. Walk northward toward the Henry Hudson bridge and note that the foliation in the schistose rocks is oriented northwesterly at the end of the trail before it heads downward. As explained earlier, this is the result of the wrapping of the early foliation in the schists about the southward-plunging keel of the overturned syncline that holds up the westernmost ridge.

The contact between the middle and lower schist units (the St. Nicholas thrust of Figure 2) is exposed in a 20 m zone from beneath the Henry Hudson Bridge abutment to river level. Structurally beneath the Manhattan Schist unit, a 0.5 m layer of sheared (mylonitic) amphibolite is deformed by folds. Unlike the amphibolite in the schist unit above, which contains subidioblastic hornblende, this exposure of Manhattan amphibolite has been retrograded by intense shearing. Green hornblende porphyroclasts are set in a wavy, anastomosing foliation consisting of colorless amphibole, biotite, and quartz ribbons. The thrust zone is structurally complex consisting of intercalated lithologies of the lower and middle schist units together with mylonitic amphibolite.

Directly beneath the bridge, where a dirt trail leads down to the river, a coarse-grained gray-white calcite marble with differentially eroded calc-silicate nodules is exposed at low tide. It is unknown whether the marble exposed at the low-tide mark is an interlayer in the lower schist unit (Ow in Figure 2) or the Inwood Marble. Unquestionably, the Inwood Marble lurks nearby as it wraps around the westernmost ridge of Manhattan Schist and underlies the Spuyten Duyvil, Marble Hill in the Bronx, and the Hudson River. As a geometric result of the southward plunge of the major folds, the oldest unit of the NYC bedrock (Fordham Gneiss) projects up to the surface in the Bronx in a huge vertical exposure immediately across the Harlem Ship Canal. Here, in the Bronx, the Fordham is painted blue with the Columbia University “C”.

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