

Evidence of Glacial Readvances During Recession from the Last Glacial Maximum From the Citifield Stadium Site, Queens, New York City, NY

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Introduction

During the Pleistocene several glacial advances came to a stop across the New York City region. The last event, the Last Glacial Maximum roughly 21 ka, eroded and/or buried evidence of the previous glaciations, making it difficult to determine specific details of New York City's glacial history. A few older key references (Soren 1978, Buxton & Shernoff 1999) provide general information and mapping for the city, but lump the Wisconsin events together as "upper Pleistocene deposits". Other than some references from Sanders and Merguerian (including 1998, 1994) that are mostly field trip guides, there is little information available to guide the interpretation of the different strata with different engineering properties typically found in a geotechnical investigation in the NYC area. Much of what is known about the region's events comes from older mapping in Long Island (Fuller 1914, Suter & Others 1949) and especially more recent detailed mapping in New Jersey (Stanford 2010a, 2010b, Stone & Others 2002) that can be extrapolated over to NYC (Figure 1).

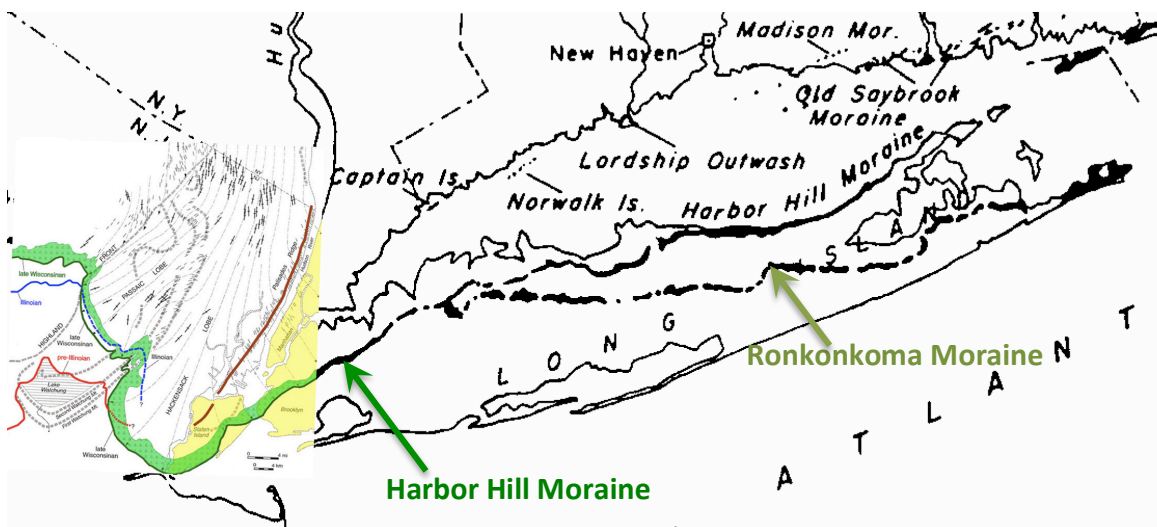


Figure 1 – Terminal moraines mapped across the NYC region. NJ mapping adapted from Stanford (2010a) superimposed over Long Island map from Flint and Gebert (1974). A pre-Illinoian terminus (red line at far left) is mapped in New Jersey, but the event has not been identified anywhere in NY, even in the subsurface. The Illinoian terminus (blue line) is mapped in NJ and possibly on Long Island (Montauk Till), but the location of the terminus in NYC is unknown. An earlier Wisconsin age Ronkonkoma moraine is present in LI, but its terminus across NYC is unknown. The LGM Harbor Hill terminal moraine is mapped from NJ (green line) across NYC and LI to New England. The Harbor Hill event eroded +/-or buried all evidence of previous advances in NYC.

a channel (300+ feet deep) through the Cretaceous sediments, down to the bedrock in northern Queens.

**Contours of Queens Ground Surface
After Hudson River Cut Across NYC –
Prior to Deposition of Illinoian Sediments**

**White – Paleozoic Bedrock
Blue – Cretaceous Lloyd Sand
Green – Raritan Clay
Yellow – Magothy & Matawan Fms.**

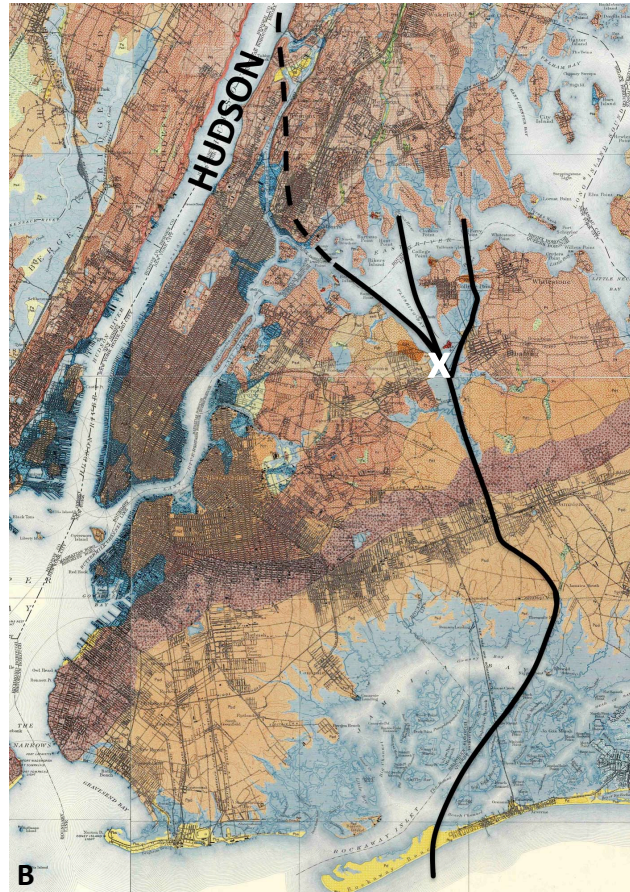
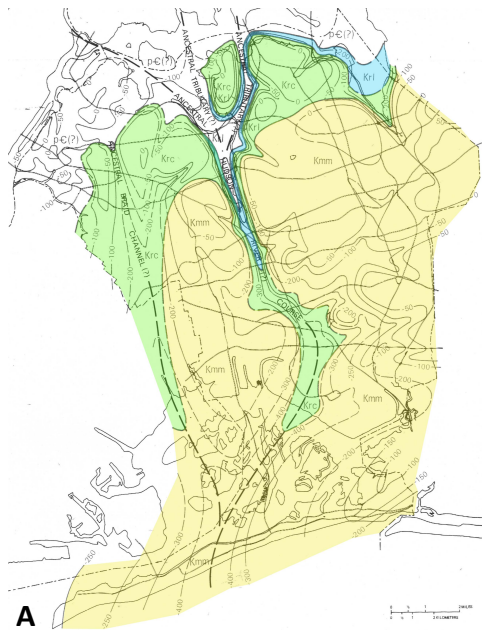


Figure 3 – An ancestral Hudson River course change cut across NY and Queens, carving a deep valley through Cretaceous sediments down to the bedrock in northern Queens. (A) shows contours of the ground surface after the stream erosion, prior to Illinoian deposition (adapted from Soren, 1978). (B) Citifield site (white X) is located in Flushing Meadows, Queens, NY above the deep valley (black line), shown on the Merrill & Others (1902) Folio surficial geologic map which mapped the city’s surficial glacial deposits.

There is evidence that during the Pleistocene there were at least 3 glacial advances across the NYC area (Figure 1). An Illinoian event deposited Jameco outwash gravel and sand across parts of Brooklyn and Queens (Figure 4), including filling in the bottom of the Queens valley (Soren 1978). The location of this glacier’s terminus across the city is not known. It is mapped in NJ (Stanford 2010a) and appears to be the Montauk Till found in Long Island. The interglacial, Sangamon age Gardiner’s Clay is deposited above the Illinoian sediments across southern Brooklyn, Queens and Manhattan. During an earlier Wisconsinian advance (~70 ka) the Ronkonkoma Terminal Moraine was deposited across Long Island, forming the island’s south fork. The location of this glacier’s terminus across NYC is also not known. The interstadial “20 Foot Clay” lies above sediments from the Ronkonkoma advance along the south shore of Long Island. The late Wisconsinian LGM advance (~21 ka) terminated across the city, depositing the Harbor

Hill terminal moraine which can be traced from NJ all the way through Long Island, where it forms the island's north fork. South of the moraine in NYC outwash covers all previous sediments. North of the moraine the soils were deposited by recessional events. In NYC all of the surficial glacial deposits date to the Harbor Hill advance and retreat, with older events found only in the subsurface, particularly filling in deep valleys (Moss & Merguerian 2006, 2008, 2009).

Wisconsinan Glaciation Eroded the Jameco North of the Terminal Moraine and Deepened Erosion of Cretaceous Raritan Clay – Mapped Surface Deposits Date to LGM Retreat

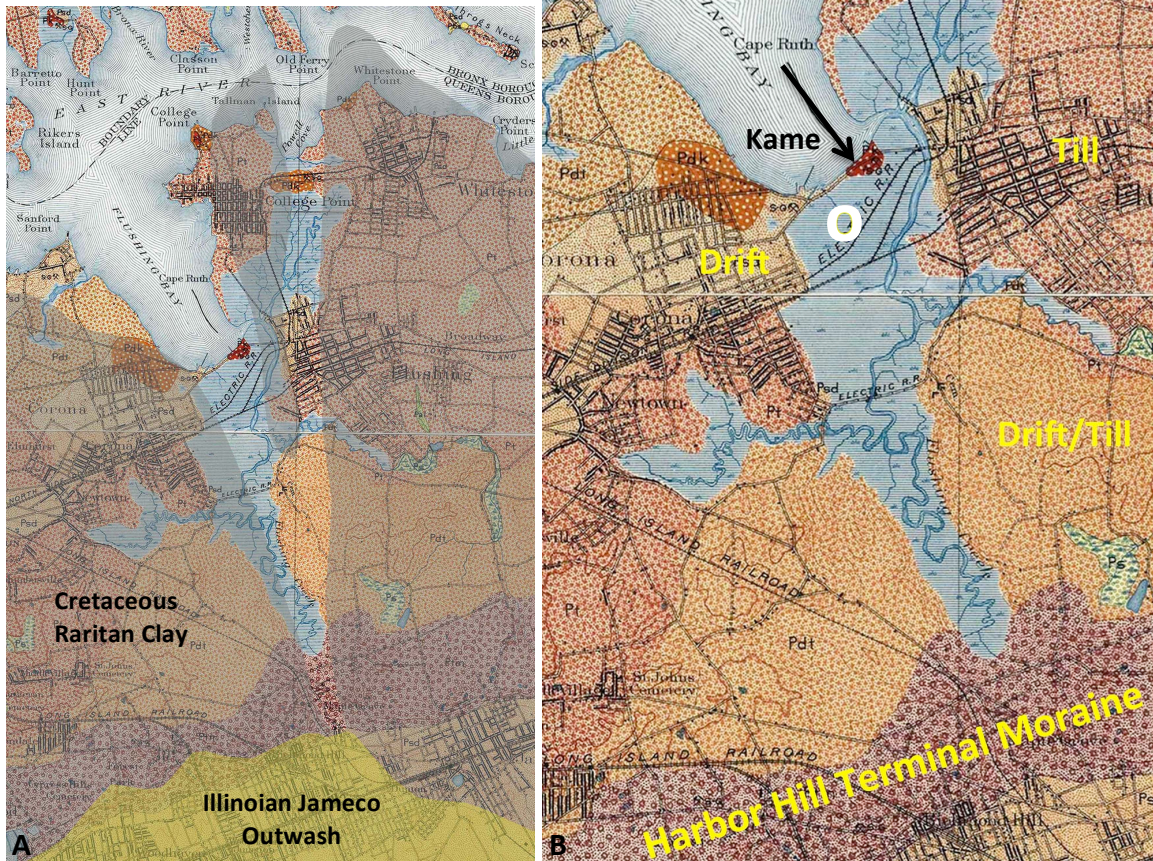


Figure 4 – Glacial geology around Flushing Meadows. (A) The overlay shows the extent of underlying Cretaceous Raritan clay (gray) which is eroded away in the valley below Flushing Meadows. Underlying Illinoian Jameco outwash (yellow overlay) is present across southern Brooklyn and Queens. Wisconsinan glaciation scoured away the Jameco north of the terminal moraine. (B) The moraine built a dam across the valley and a glacial lake formed behind it during LGM retreat. During the Holocene, sea-level rise filled the low-lying land with organic silty clay and marsh deposits (blue map unit). High ground just to the NE of Citifield (white circle) is mapped as a kame deposit on the Merrill & Others (1902) Folio. At Citifield a change in color at El. -85' is associated with this kame.

The Harbor Hill moraine crosses the Queens valley at the southern end of Flushing Meadows (Figure 4). Soren (1978) indicates that there is no apparent Illinoian Jameco outwash found in the channel north of the Harbor Hill, only south of the moraine. Presumably the Wisconsin glacial ice scoured out all of the older sediments filling the valley. The underlying Cretaceous soils are also scoured out more extensively to the north of the moraine. The terminal moraine formed a dam across the channel, and as the ice retreated a glacial lake formed in the valley, filling it with stratified drift.

Holocene sea-level rise allowed the surface of the valley to fill in with thick layers of organic silty clay and marsh deposits. A portion of the Meadows was used for an ash dump starting in 1909 and ash fill was later used to raise the ground surface so Flushing Meadows could be used as the 1939/40 World's Fair grounds and later as city parkland and again the 1964/65 Fairgrounds (Canale & Others 2009).



Figure 5 – The New Citifield stadium at the northern end of Flushing Meadows, Queens, NY. View is to the SW, with the NYC skyline in the upper right corner and Flushing Meadows Park, site of the National Tennis Center and remaining former 1964/65 Worlds Fair grounds running to the south (far center left). (Photo from MRCE archives.)

Site Geology

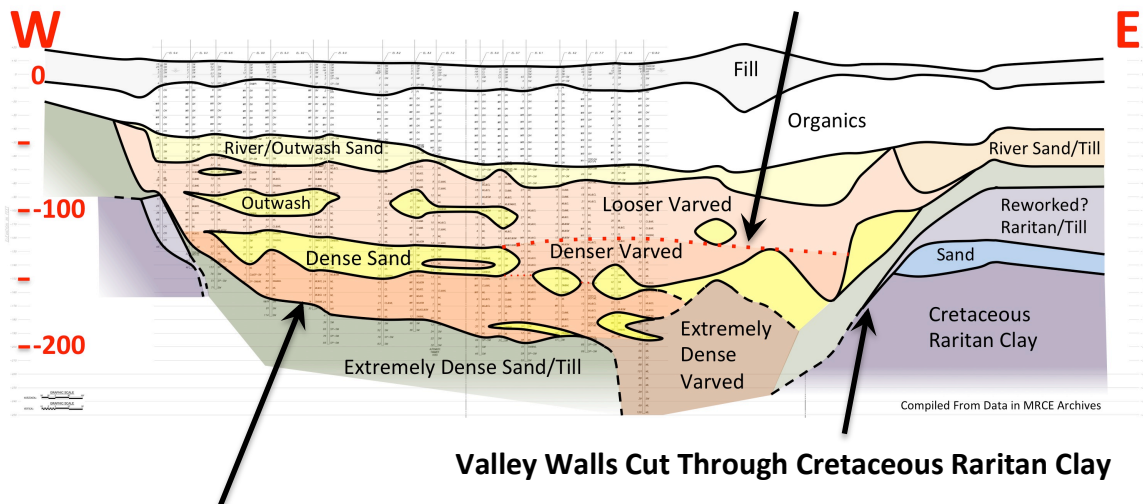
Between 1998 and 2005 a multiphase geotechnical investigation was conducted for the foundation design for the new Citifield Stadium (Figure 5), built to replace the old Shea Stadium. Strata found below the site provide information about the sequence of glacial events that affected the northern portion of Flushing Meadows.

For the design of foundations, borings were drilled as deep as El. -249'. No borings were extended to reach the underlying bedrock that presumably forms the very bottom of the valley. Cretaceous Raritan Clay largely forms the valley walls (Figure 6). The Raritan is overlain by extremely dense till and outwash sand. If there are in fact no Illinoian deposits north of the Harbor Hill moraine, then these lower glacial strata probably date to the Ronkonkoma advance and retreat. These soils were then glacially loaded (densifying them) and scoured out to approximately El. -190' by overriding ice (likely from the LGM advance).

**E-W Cross-Section (below) Runs
Along the Red Line
N-S Section (seen in Figure 7)
Along the Yellow Line**



**As Valley Filled With Stratified Drift During LGM Retreat
Short Readvances Densified The Soil Below**



**Glacially Loaded Valley Fill (Ronkonkoma Event?)
Densified and Scoured out to ~El. -190' by Harbor Hill Advance**

Figure 6 – E-W Cross-Section across Flushing Meadows (along red line) near the southern end of the Citifield site (includes additional data compiled from MRCE archives). Valley walls were cut through the Cretaceous strata. A glacial event (possibly the Ronkonkoma) filled the valley with till, sand and varved soil. Ice from a later advance, likely the LGM Harbor Hill event, densified and scoured out these older deposits to ~El. -190'. LGM retreat filled the valley at the southern end of the site with glacial lake varved silt and clay. Short readvances of the ice densified and placed outwash sand over the varved deposits below. Holocene sea-level rise filled the low-lying areas with organic silty clay and marsh peat, and fill was placed over the site in the 1900's.

To the south, the Harbor Hill terminal moraine formed a dam across the channel at the southern tip of Flushing Meadows, allowing a glacial lake to develop in the valley as the ice receded. At the southern end of the Citifield site the valley filled in with varved silt and clay (Figure 7). Heading northward, layers of outwash sand start to appear, eventually becoming the dominant soil type. Much denser soil (determined by significant increases in the SPT blow-counts) below major strata breaks at roughly elevations -150', -120' and -85', indicates the outwash layers were deposited by glacial readvances during the overall retreat.

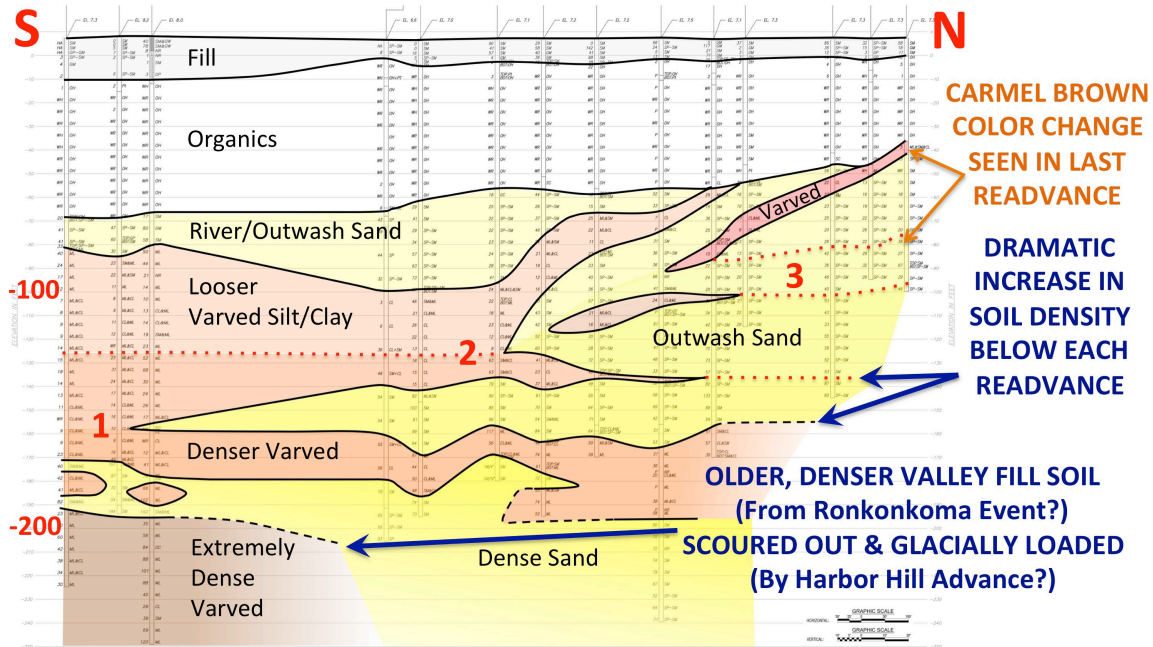


Figure 7 – N-S Cross-Section through the northern end of Flushing Meadows (along yellow line in Figure 6). Borings did not penetrate the very bottom of the valley, but did hit the extremely dense valley fill (from Ronkonkoma event?) scoured out to ~El. -190' (by the Harbor Hill advance). During LGM retreat the southern end of the Citifield site filled up with varved silt and clay, but several short readvances (numbered) carried ice and outwash sand over the soil below. Outwash layers increase to the north, becoming the dominant soil type. As seen in the borings, advances around elevations -150', -120' and -85' are identified by a change in soil type +/- or a significant increase in the density of the underlying soil (as indicated by SPT blowcounts). The last advance at the far northern end of Citifield includes a distinctive carmel brown color change that is associated with a nearby kame deposit, along with another readvance that flowed down the East River.

At the far northern end of Citifield the last readvance (around El. -85') is also marked by a change in the color of the soil that is associated with the nearby kame deposit shown just to the NE on the Merrill & Others (1902) NYC Folio (Figure 4). The same yellow brown color is seen in the ablation till over transported basal Cretaceous clay found in the minor readvance that flowed down the East River along western Queens and Brooklyn (Moss 2011 & 2012, Moss & Merguerian 2007) (Figure 8).

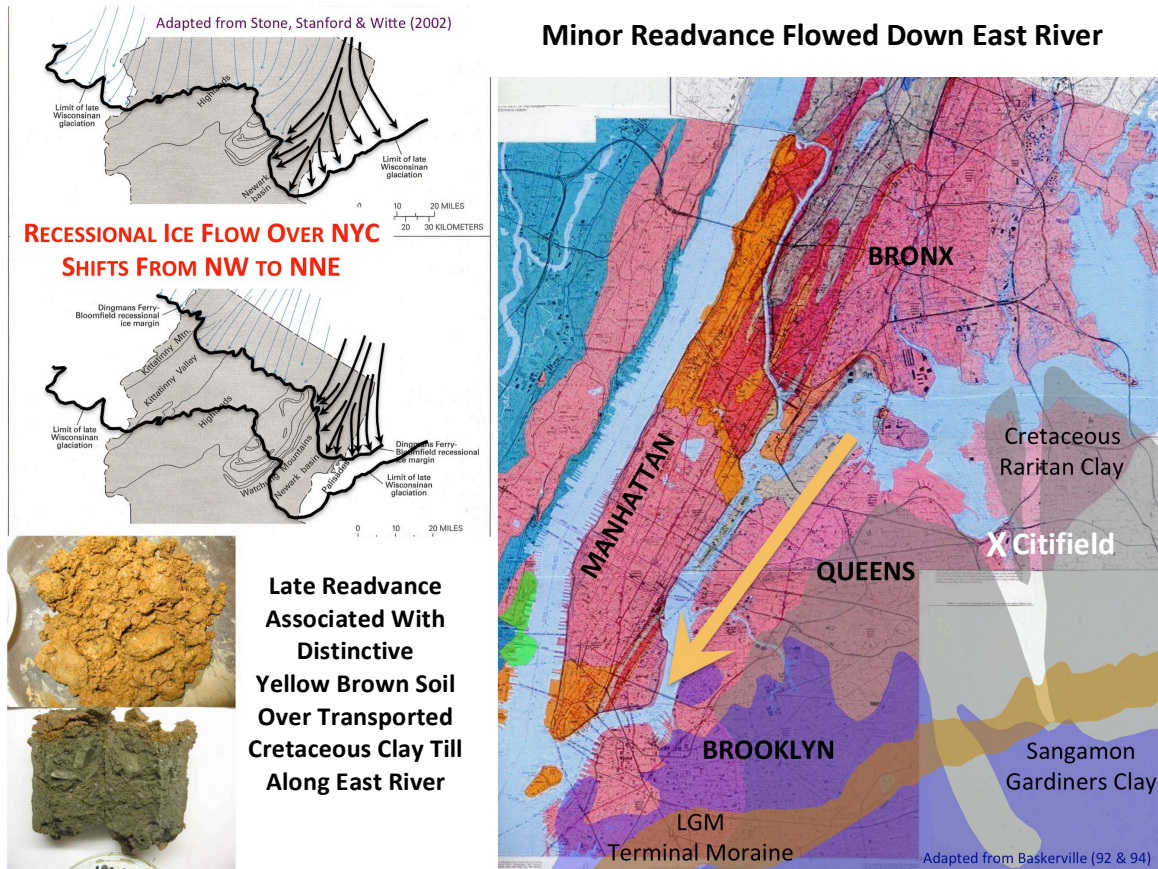


Figure 8 – During recession from the LGM ice flow over NYC shifted away from flowing from the NW to flowing from the NNE. Geotechnical investigations from several sites across the city indicate a late readvance flowed from the NNE down the East River along western Queens and Brooklyn. A distinctive characteristic of this advance is the presence of transported Cretaceous clay (often in basal till) and especially a yellow brown soil (often in ablation till and nearby varved deposits), seen here in samples from a site in the NW corner of Brooklyn. The last Citifield readvance also has a shift to soil with the same carmel brown color.

Discussion

Strata below the Citifield site show that an earlier glaciation (possible Ronkonkoma advance) cut further through the Cretaceous soils and left glacial deposits behind. A later glaciation (likely LGM Harbor Hill) cut a shallower U-shaped channel into the older layers and during retreat filled that valley with stratified drift. Varved silt and clay were deposited in the glacial lake when the ice front was further to the north. Retreat was not continuous, however, with periods when the ice paused and readvanced. Each minor readvance would carry ice over the older outwash and varved soil, loading and densifying it, before depositing a new layer of outwash sand above it as it resumed retreat. The stratigraphic sequences present suggest that there were at least 3 minor readvances over the Citifield site. Kame deposits mapped just to the north likely represent a longer pause for the ice front before the rate of final retreat picked up.

Stanford (2010b) states that the short readvances were especially present at the M1 margin in the Lake Passaic basin where deep water buoyed the ice and increased margin mobility. This is also likely the setting present at Flushing Meadows, where the glacial lake formed in a deep valley dammed on the south by the terminal moraine and at the north by the ice front itself. The lake facilitated the glacial readvances seen below Citifield. This may have also been the situation present in the East River during its readvance. New York Harbor was dammed to the south by the terminal moraine across the Narrows and an ice front still present in Long Island Sound blocked drainage of the glacial lake northeastward into the Sound.

During much of the Wisconsin ice flowed from NJ in the NW southeastward over the Palisades Ridge across NYC. As the LGM ice receded, flow across the region shifted, coming from a more north to northeasterly direction (Figure 8). The uppermost glacial soil at some sites along the east side of the East River in Queens and Brooklyn have a basal till containing transported Cretaceous clay overlain by a yellow brown ablation till. This sequence belongs to a minor glacial readvance coming more from the N–NNE over NY rather than the earlier ice flow from the NW with a NJ source.

Sediments in the last readvance at the Citifield site have the same change in color associated with the yellow brown kame mapped just to the NE and the ablation till found along the East River. By the time this Citifield readvance and last ice stand took place the glacial flow and sediment source had made the shift away from the NW to the NNE. It's possible that at this point the ice over NYC no longer had a significant connection to the sheet over NJ, with little or no NJ soil being carried over the Palisades to NYC.

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References

Baskerville, C.A., 1992, Bedrock and engineering geologic maps of Bronx County and parts of New York and Queens Counties, New York: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2003, scale 1:24000.

Baskerville, C.A., 1994, Bedrock and engineering geologic maps of New York County and parts of Kings and Queens Counties, New York, and parts of Bergen and Hudson Counties, New Jersey: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2306, scale 1:24000.

Buxton, Herbert; and Shernoff, Peter, 1999, Ground-water resources of Kings and Queens Counties, Long Island, New York: U.S. Geological Survey Water-Supply Paper 2498, 113p.

Canale, T. D.; Quinlan, J. F.; Kaufman, J. L.; Smilow, J.; and Thompson, A, 2009, Diamond in the Rough, Civil Engineering-ASCE, vol. 79, No. 5, p. 48-59, 85.

Doriski, T. P.; and Wilde-Katz, F., 1983, Geology of the “20-Foot” Clay and Gardiners Clay in southern Nassau and southwestern Suffolk counties, Long Island, New York, U.S. Geological Survey Water-Resources Investigations Report 82-4056.

Flint, R. F.; and Gebert, J. A., 1974, End moraines on and off the Connecticut shore (abstract): Geological Society of America, Abstracts with Programs, v. 6, no. 7, p. 738-739.

Merguerian, Charles; and Sanders, John E., 1996, Glacial geology of Long Island: Guidebook for On-The-Rocks 1996 Fieldtrip Series, Trip 39, 01 + 02 June 1996, Section of Geological Sciences, New York Academy of Sciences, 130 p.

Merrill, F. J. H.; Darton, N. H.; Hollick, Arthur; Salisbury, R. D.; Dodge, R. E.; Willis, Bailey; and Pressey, H. A., 1902, Description of the New York City district: United States Geological Survey Geologic Atlas of the United States, New York City Folio, No. 83, 19 p.

Moss, Cheryl J., 2011a, Geotechnical Evidence of Multiple Glacial Advances in New York City’s Subsurface, Geological Society of America Abstracts with Programs, v. 43, no. 1, p. 95.

Moss, Cheryl J., 2011b, Use of Engineering Properties to Identify Multiple Glacial Advances in New York City’s Subsurface: in Hanson, G. N., Chm., 18th Annual Conference on Geology of Long Island and Metropolitan New York, 9 April 2011, State University of New York at Stony Brook, NY, Long Island Geologists Program with abstracts, 13 p.

Moss, Cheryl J., 2012b, Evidence of Two Wisconsin Age Glacial Advances in a Bedrock Valley Below the New Yankee Stadium, Bronx, New York: in Hanson, G. N., Chm., 19th Annual Conference on Geology of Long Island and Metropolitan New York, 14 April 2012, State University of New York at Stony Brook, NY, Long Island Geologists Program with abstracts, 13 p.

Moss, Cheryl J.; and Merguerian, Charles, 2005, Loading patterns in varved Pleistocene sediment in the NYC area: in Hanson, G. N., chm., Twelfth Annual Conference on Geology of Long Island and Metropolitan New York, 16 April 2005, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts.

Moss, Cheryl J.; and Merguerian, Charles, 2006, Evidence for multiple glacial advances and ice loading from a buried valley in southern Manhattan: in Hanson, G. N., chm., Thirteenth Annual Conference on Geology of Long Island and Metropolitan New York, 22 April 2006, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 16p.

Moss, Cheryl J.; and Merguerian, Charles, 2007, Different and Distinct – Implications of Unusual Glacial Strata in Brooklyn: in Hanson, G. N., chm., Fourteenth Annual Conference on Geology of Long Island and Metropolitan New York, 14 April 2007, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 19 p.

Moss, Cheryl J.; and Merguerian, Charles, 2008, Bedrock control of a boulder-filled valley under the World Trade Center site: in Hanson, G. N., chm., Fifteenth Annual Conference on Geology of Long Island and Metropolitan New York, 12 April 2008, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 13 p.

Moss, Cheryl J.; and Merguerian, Charles, 2009, 50 Ka Till-Filled Pleistocene Plunge Pools and Potholes Found Beneath the World Trade Center Site, New York, NY: in Hanson, G. N., chm., Sixteenth Annual Conference on Geology of Long Island and Metropolitan New York, 28 March 2009, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 19 p.

Sanders, John E.; and Merguerian, Charles, 1994, Glacial geology of the New York City region, p. 93-200 in Benimoff, A. I., ed., The geology of Staten Island, New York: Geological Association of New Jersey

Annual Meeting, 11th, Somerset, NJ, 14-15 October 1994, Field guide and proceedings, 296 p.
Sanders, John E.; and Merguerian, Charles, 1998, Classification of Pleistocene deposits, New York City and vicinity – Fuller (1914) revived and revised: p. 130-143 in Hanson, G. N., chm., Geology of Long Island and metropolitan New York, 18 April 1998, State University of New York at Stony Brook, NY, Long Island Geologists Program with Abstracts, 161 p.

Soren, Julian; 1978, Subsurface geology and paleogeography of Queens County, Long Island, New York: U. S. Geological Survey Water-Resources Investigations 77-34 Open File Report, 17p.

Stanford, Scott D., 2010a, Onshore record of Hudson River drainage to the continental shelf from the late Miocene through the late Wisconsinan deglaciation, USA: synthesis and revision, Boreas, vol. 39, p 1–17.

Stanford, Scott D., 2010b, Glacial Geology and Geomorphology of the Passaic, Hackensack, and Lower Hudson Valleys, New Jersey and New York, p. 47-84 in Benimoff, A. I., ed., New York State Geological Association 82nd Annual Meeting Field Trip Guidebook, Staten Island, NY, 24-26 September 2010, 190 p.

Stone, B.D.; Stanford, S.D.; and Witte, R.W., 2002, Surficial geologic map of northern New Jersey: U.S. Geological Survey, Miscellaneous Investigations Series Map I-2540-C, scale 1:100000.

Suter, R.; De Laguna, W.; and Perlmutter, N., 1949, Mapping of geologic formations and aquifers of Long Island, New York: State of New York Water Power and Control Commission with the U. S. Geological Survey, Bulletin GW-18, 211 p.

Moss, Cheryl J., 2013b, Evidence of Glacial Readvances During Recession from the Last Glacial Maximum From the Citifield Stadium Site, Queens, New York City, NY: in Hanson, G. N., Chm., 20th Annual Conference on Geology of Long Island and Metropolitan New York, 13 April 2013, State University of New York at Stony Brook, NY, Long Island Geologists Program with abstracts, 11 p.