Aspects of LGM Deglaciation in Flushing Meadows, Queens, New York City, NY

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Introduction

In a fieldtrip guidebook of the NJ/NYC area Stanford (2010b) presented a map of the Last Glacial Maximum (LGM) recessional ice margins and the associated glacial lakes. In the text he stated that during retreat there were numerous short glacial readvances along the EZ and particularly M1 ice margins in NJ, but there was no evidence of readvances elsewhere (Figure 1). Data obtained from the geotechnical investigation performed by MRCE for the new Citi Field Stadium indicated that the northern end of Flushing Meadows, Queens, NY also had short readvances along these lines (Moss 2013).

Since it was founded in 1910, MRCE has conducted numerous subsurface investigations in the Flushing Meadows area, and has a significant amount of geotechnical data in its archives. This additional information was used to gain insight into other aspects of NYC's Pleistocene glaciation extending south of the Citi Field site.

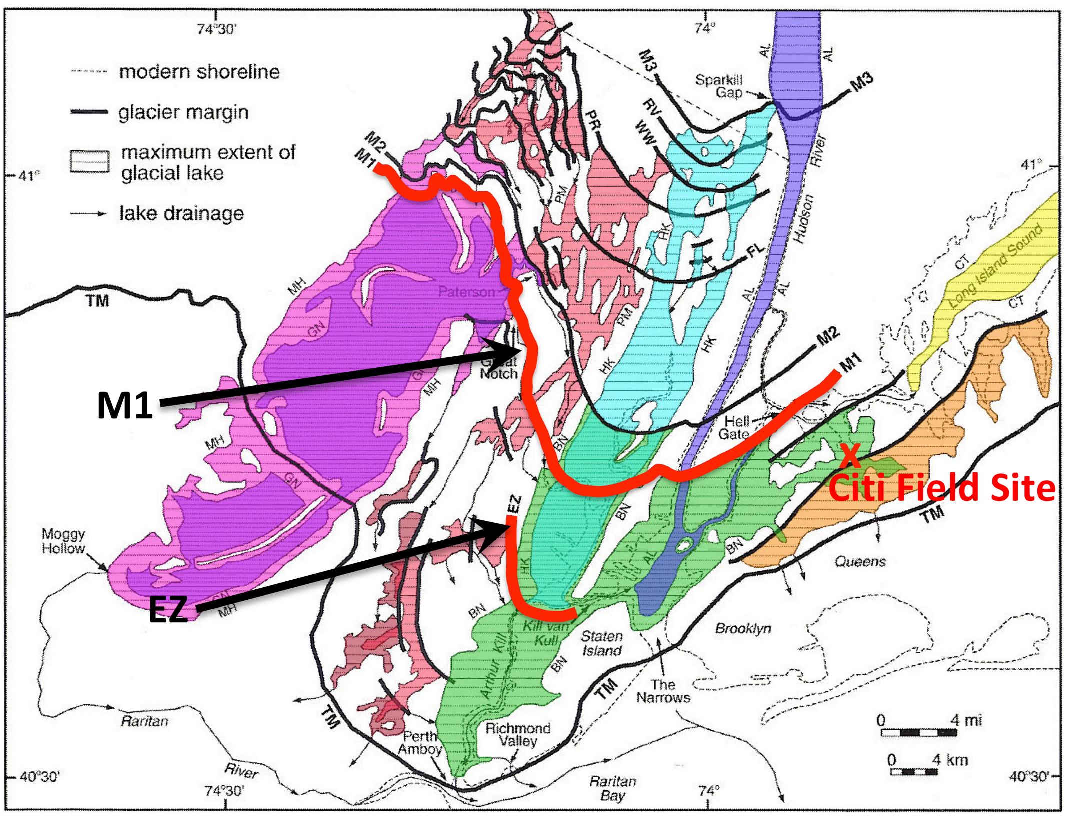


Figure 1 – LGM recessional ice margins and associated glacial lakes adapted from Stanford (2010b). Numerous short glacial readvances were noted along the EZ and particularly M1 ice margins in NJ, especially in the Passaic Lake basin (purple shades). Evidence for short readvances along the same lines in NYC are present at the Citi Field site located at the northern end of Flushing Meadows, Queens.

Boring information is available for Flushing Meadows dating back to before the 1939 World's Fair. Data south of the Long Island Expressway tends to be shallow and/or old, without associated engineering properties available. Consequently, limited information is available about the early stages of retreat from the LGM terminal moraine. The quality and quantity of data increases to the north over the 1939 & 1964 World's Fair Grounds, and especially over the National Tennis Center, allowing a better understanding of LGM glacial retreat before the ice paused and fluctuated at the M1 ice margin (Figure 2).

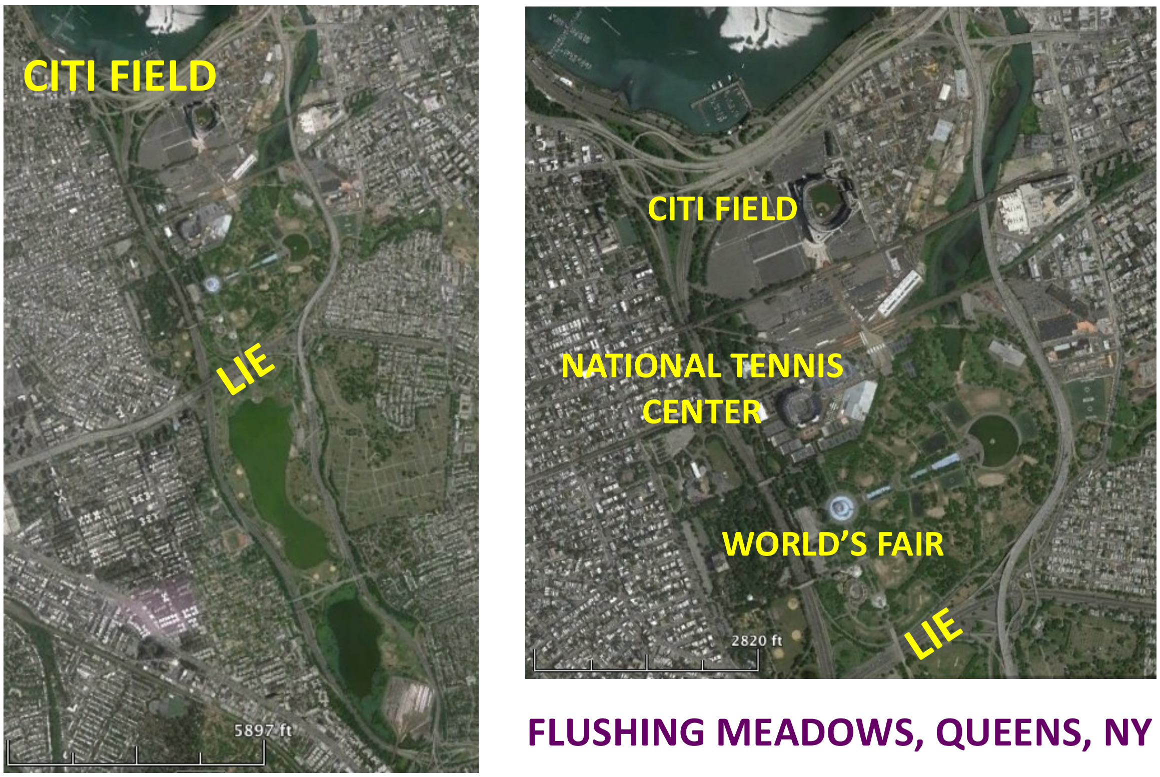


Figure 2 – Flushing Meadows, Queens from Google Earth. The former 1939 & 1964 World's Fair Grounds are located south of Citi Field Stadium, north of the Long Island Expressway. The National Tennis Center is built at the northern end of the Fair Grounds. Available boring information south of the Long Island Expressway is older +/or shallow, but the quantity and quality of data improves northward across the Fair Grounds and especially the Tennis Center.

Background Geology

Flushing Meadows in Queens, NY, lies above a deep buried valley. Paleozoic metamorphic bedrock lies roughly 300' to 400' below Flushing Meadows (Buxton & Shernoff 1999). Rock is overlain by Cretaceous soil – basal Lloyd Sand, then Raritan Clay, and the uppermost Magothy and Matawan Group Formations. During the Late Pliocene or Early Pleistocene (Stanford 2010b) the Hudson River changed direction, shifting its course over New York City and cutting across Queens to the Atlantic. By the mid-Pleistocene the river and tributaries cut a channel (300+ feet deep) through the Cretaceous sediments, down to the bedrock in northern Queens (Figure 3).

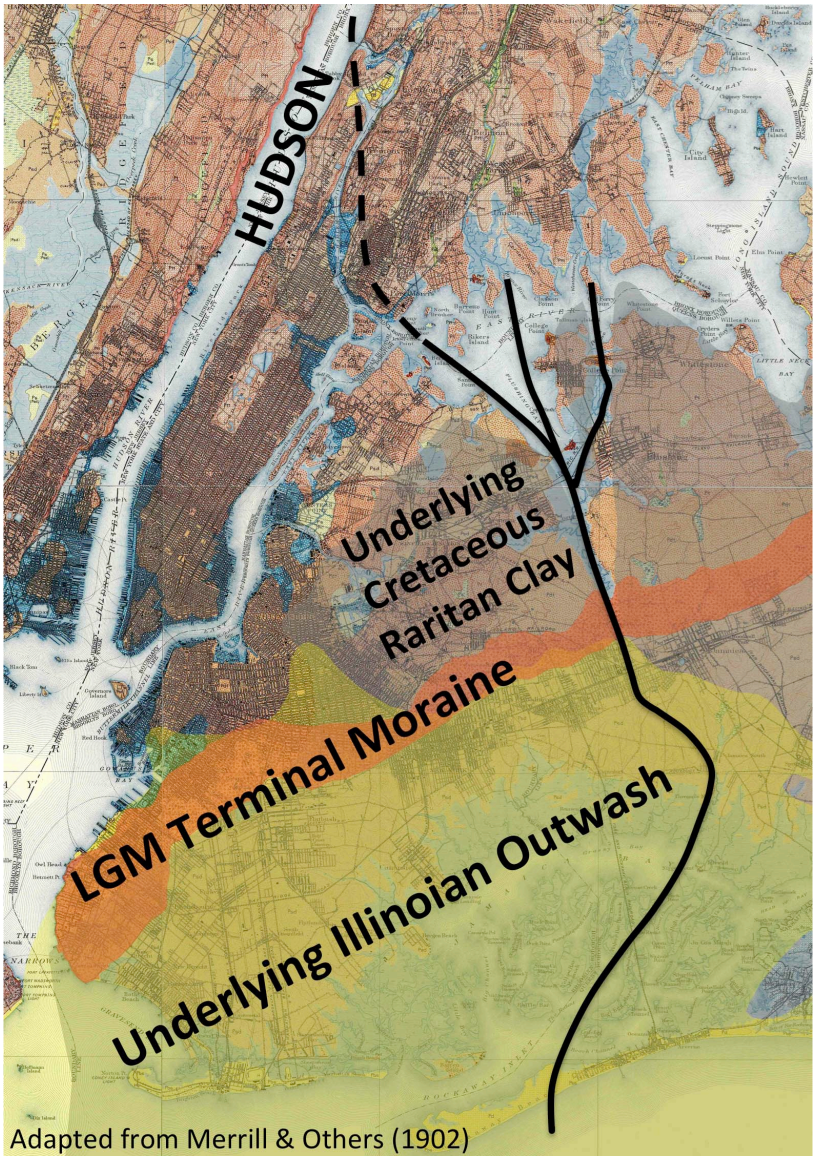


Figure 3 – The NYC Folio surficial geologic map with overlays showing some of the underlying deposits. An ancestral Hudson River course change cut across NY and Queens, carving a deep valley through Cretaceous sediments down to the bedrock in northern Queens. The gray overlay shows the extent of underlying Cretaceous Raritan clay, which is eroded away in the valley below Flushing Meadows. The yellow overlay shows that the Illinoian Jameco outwash is present across southern Brooklyn and Queens, but has been eroded away north of the LGM Harbor Hill terminal moraine (orange overlay) during Wisconsinan glaciation.

There is evidence that during the Pleistocene there were at least 3 glacial advances across the NYC area. An Illinoian event deposited Jameco outwash gravel and sand across parts of Brooklyn and Queens, 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 Wisconsinan 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 and NYC. The late Wisconsinan 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 (Figure 4). 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).

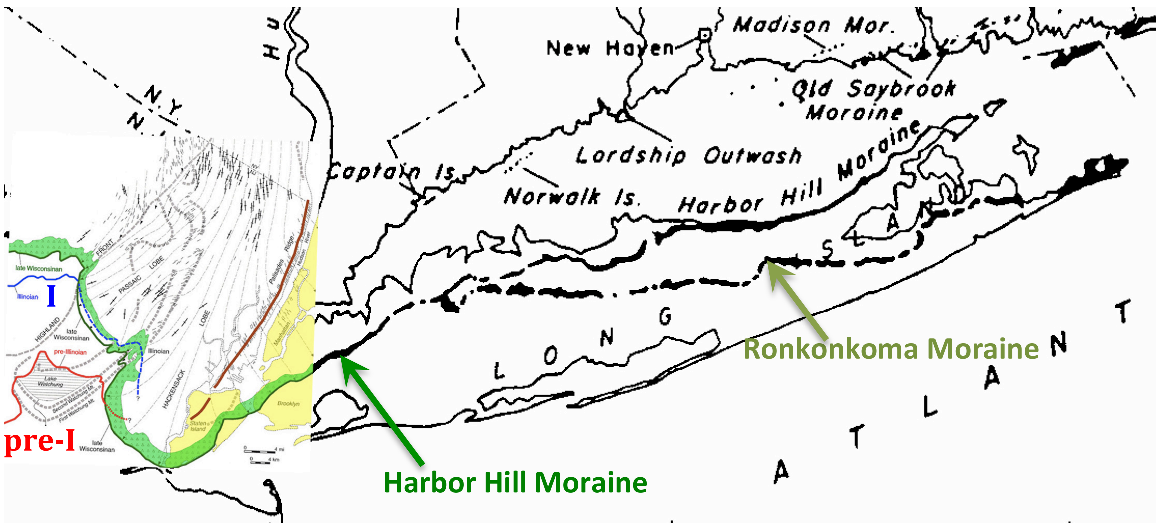


Figure 4 – Terminal moraines mapped across the NYC region. NJ mapping adapted from Stanford (2010a) superimposed over Long Island map from Flint and Gebert (1974). A pre-Illinoian terminus (pre-I – red line at far left) is mapped in New Jersey, but the event has not been identified anywhere in NY, even in the subsurface. The Illinoian terminus (I – 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.

The Harbor Hill moraine crosses the Queens valley at the southern end of Flushing Meadows. 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 (Figure 3). Presumably the Wisconsinan 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 alluvial sand from Flushing Creek, which was then covered 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, later as city parkland and then again as the 1964/65 World's Fair grounds (Canale & Others 2009).

Site Geology

The Citi Field investigation revealed that Cretaceous Raritan Clay largely forms the valley walls. The Raritan is overlain by extremely dense till, outwash sand and varved silt and clay (Figure 5). 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).

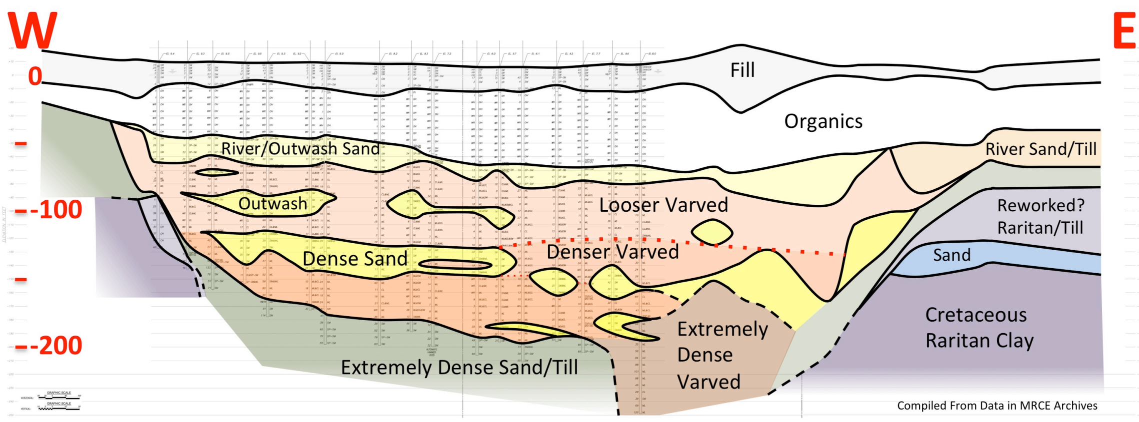


Figure 5 – E-W Cross-Section across Flushing Meadows near the southern end of the Citi Field site (includes additional data compiled from MRCE archives). Valley walls were cut through the Cretaceous strata. A glacial event (probably the Ronkonkoma) filled the valley with till, sand and varved soil. Ice 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 Citi Field site the valley filled in with varved silt and clay. 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 6).

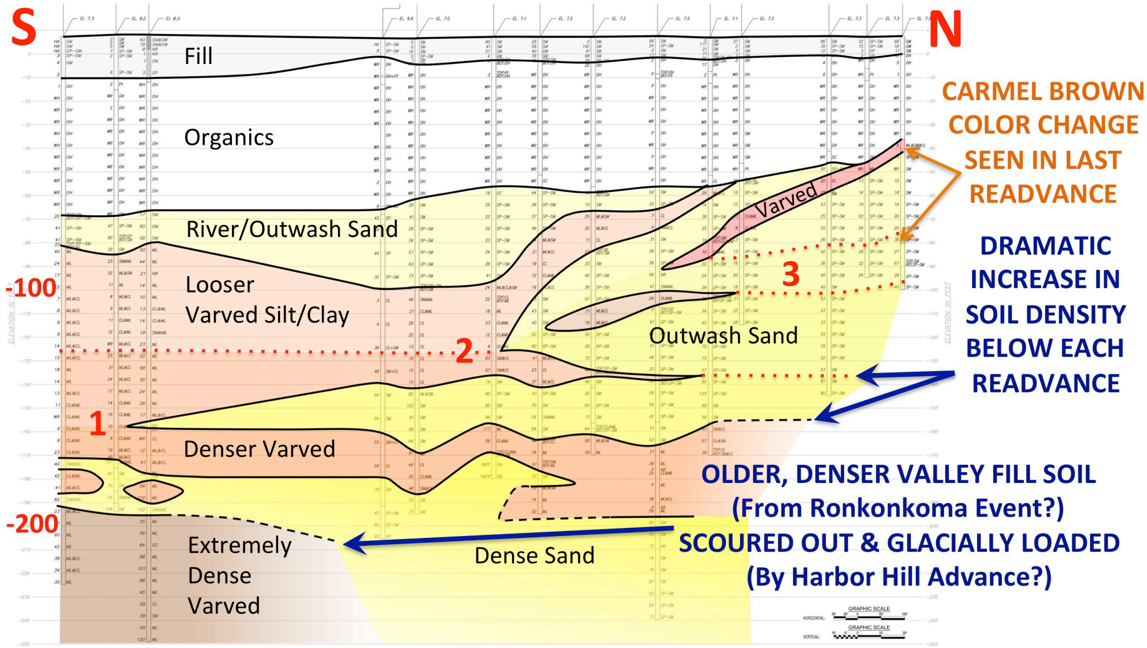


Figure 6 – N-S Cross-Section through the northern end of Flushing Meadows. Borings did not penetrate the very bottom of the valley, but did hit the extremely dense valley fill (from Ronkonkoma event?) scoured out to ~El. -190' (by the Harbor Hill advance). During LGM retreat the southern end of the Citi Field 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 Citi Field 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 Citi Field 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. 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).

Discussion of New Information

There is a small cluster of very old, but deep borings at the center of the very southern tip of Flushing Meadows just behind the terminal moraine. The data is vague (likely simple wash borings), but the borings show a stratigraphic sequence from bottom to top with bedrock (possibly decomposed) around an average elevation –463' overlain by boulders and clay, then gravel and sand, then clay, then a sand/gravel mix (Figure 7). If the Soren (1978) maps are correct in showing that the Cretaceous Lloyd sand and Raritan clay and Illinoian Jameco outwash have been scoured away from this portion of the valley, then the bottom of the sequence shows bedrock overlain by a fining upward sequence of till, outwash and glacial lake varves. The upper sand/gravel mix is likely Flushing Creek alluvium derived from the surrounding till. The borings did not mention the presence of boulders, gravel or coarser sand layers within the over 200' of glacial lake fine sand and clay that could signify readvances during early LGM retreat. However – this may simply mean that the borings were too basic to identify such information.

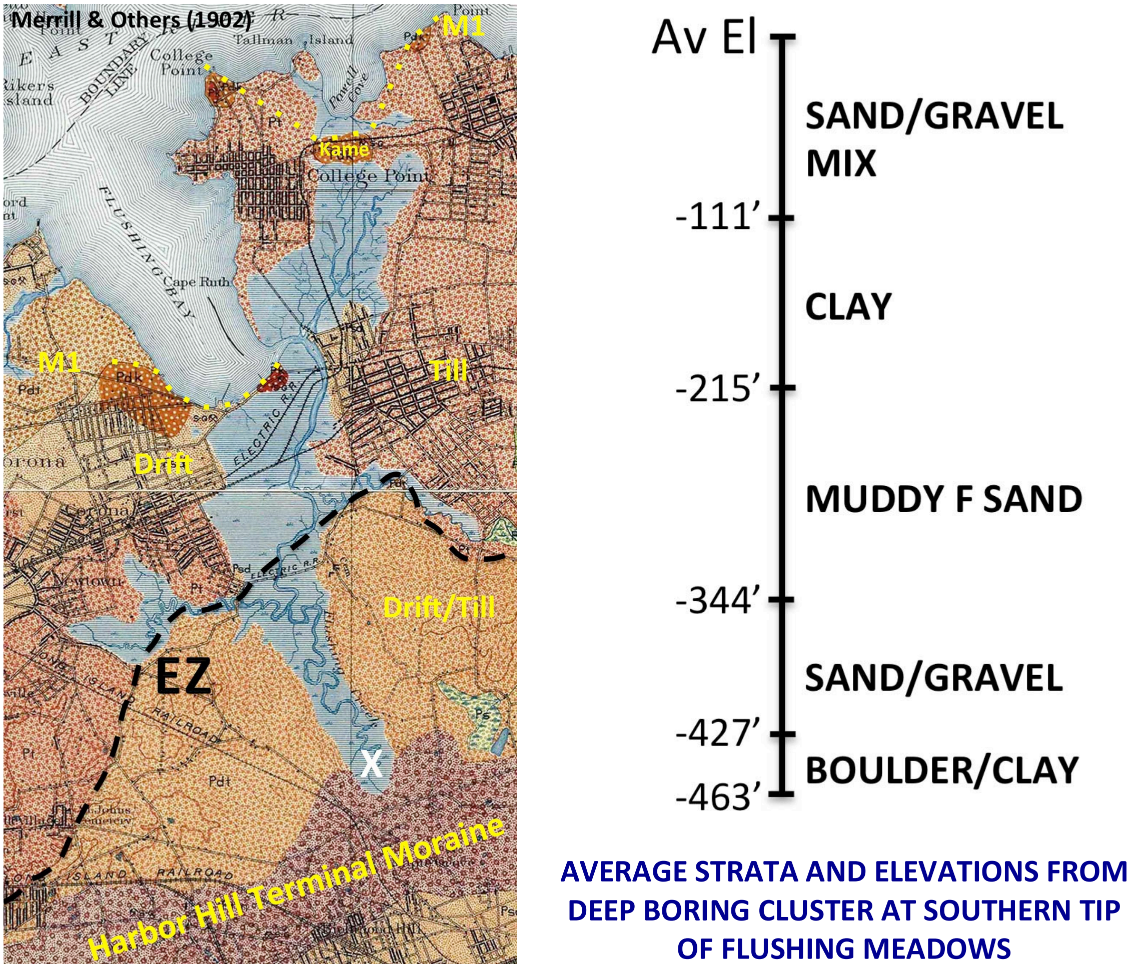


Figure 7 – Portion of NYC Folio surficial geologic map showing the surface glacial geology around Flushing Meadows. As LGM ice started to retreat north of the terminal moraine it paused, depositing till that aligns with the EZ ice margin in NJ. Flushing Meadows boring data is limited between these two lines, but there is a cluster of old, deep borings located at the southern tip (white X). The average elevations and strata descriptions for the group are shown to the right. Data is vague, but suggests till, outwash and lake deposits from the LGM advance and retreat. There is no clear indication of readvances during the early stages of glacial retreat from the terminal moraine.

The fining upward sequence appears to represent one glacial event – the LGM Harbor Hill advance. If this is the case, then either the earlier Ronkonkoma advance did not reach as far south as the Harbor Hill, or the Harbor Hill advance scoured away evidence of all of the previous glaciations. At the northern end of Flushing Meadows below Citi Field the older glacial sediments (likely from the Ronkonkoma advance) were scoured out down to around elevation -190' by the LGM advance. This pattern is present at least as far south as the southwestern end of the National Tennis Center, indicating that the Ronkonkoma advance went at least this far south (Figure 8).

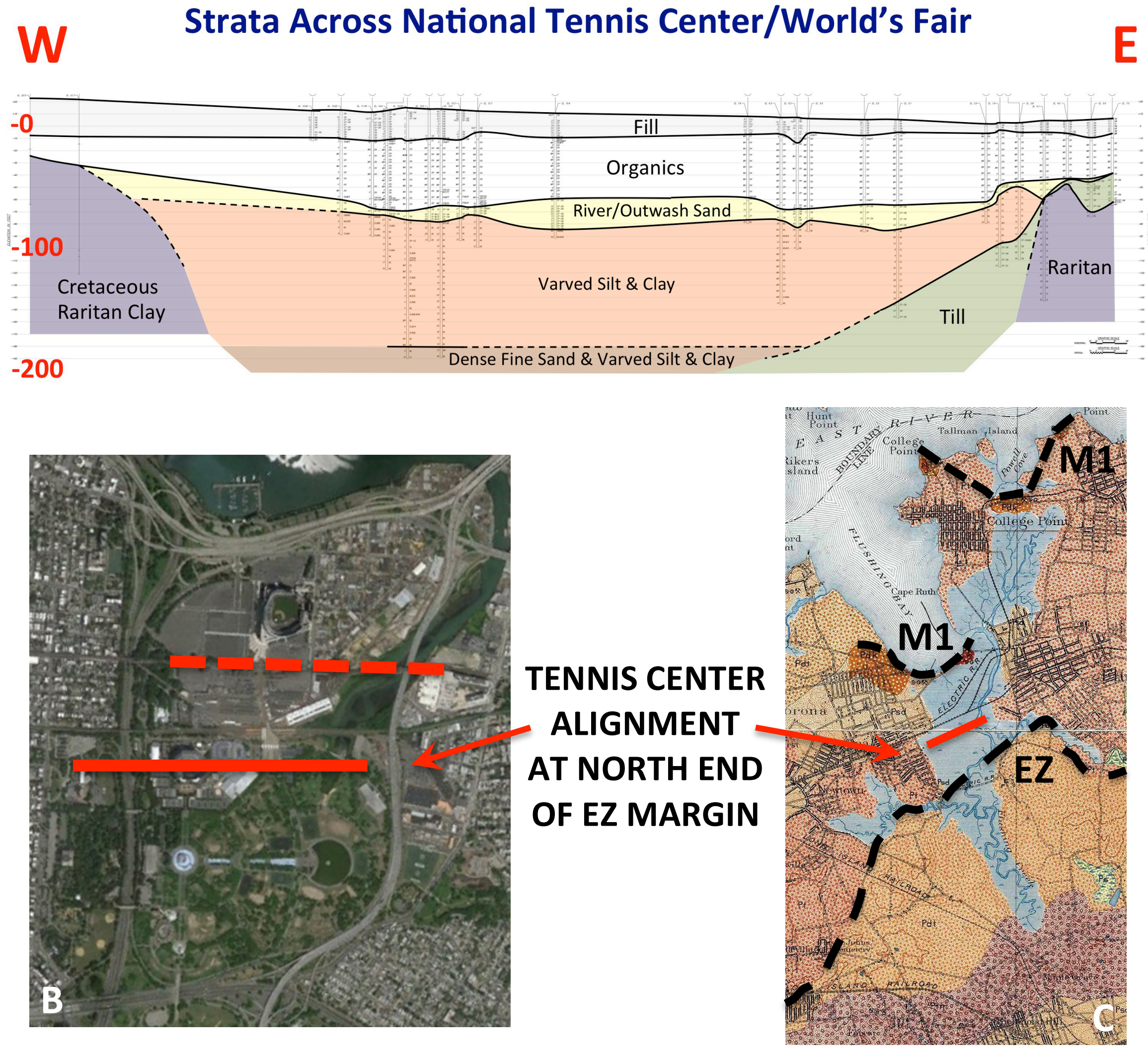


Figure 8 – E-W Cross-Section across Flushing Meadows through the National Tennis Center (includes additional data compiled from MRCE archives). This alignment (solid red line in B and C) lies just north of the EZ ice margin (in C), reflecting conditions shortly after ice resumed its retreat. The strata present are essentially the same units seen to the north through Citi Field (Figure 5, located along dashed line in B). Valley walls of Raritan clay covered with till, a valley filled with older glacial sediments (Ronkonkoma) scoured out and densified around elevation -190' by the younger Harbor Hill advance, then filled with varved lake deposits during LGM retreat are all present. The main difference is that the layers of outwash from the M1 ice margin seen at Citi Field are not present this far south across the Tennis Center.

During LGM retreat a thick layer of glacial lake varved silt and clay filled in much of the valley north of the Harbor Hill terminal moraine. Northward retreat of the ice paused (at the southern edge of the 1964 World's Fair grounds where the Long Island Expressway crosses over Flushing Meadows) depositing till along the valley sides directly above the Raritan Clay. This recessional moraine (mapped in Merrill & Others, 1902) aligns best with the EZ ice margin (Figure 7). The deep boring data is too sparse to interpret the details of deglaciation between the terminus and this margin, but data improves over the feature's northern half (beneath the National Tennis Center) where varved soils lie above the till (Figure 8). As the ice resumed its retreat north of the EZ margin, there is no sign in the thick glacial lake deposits of outwash and till layers and/or glacial loading that would be associated with an early readvance of the ice.

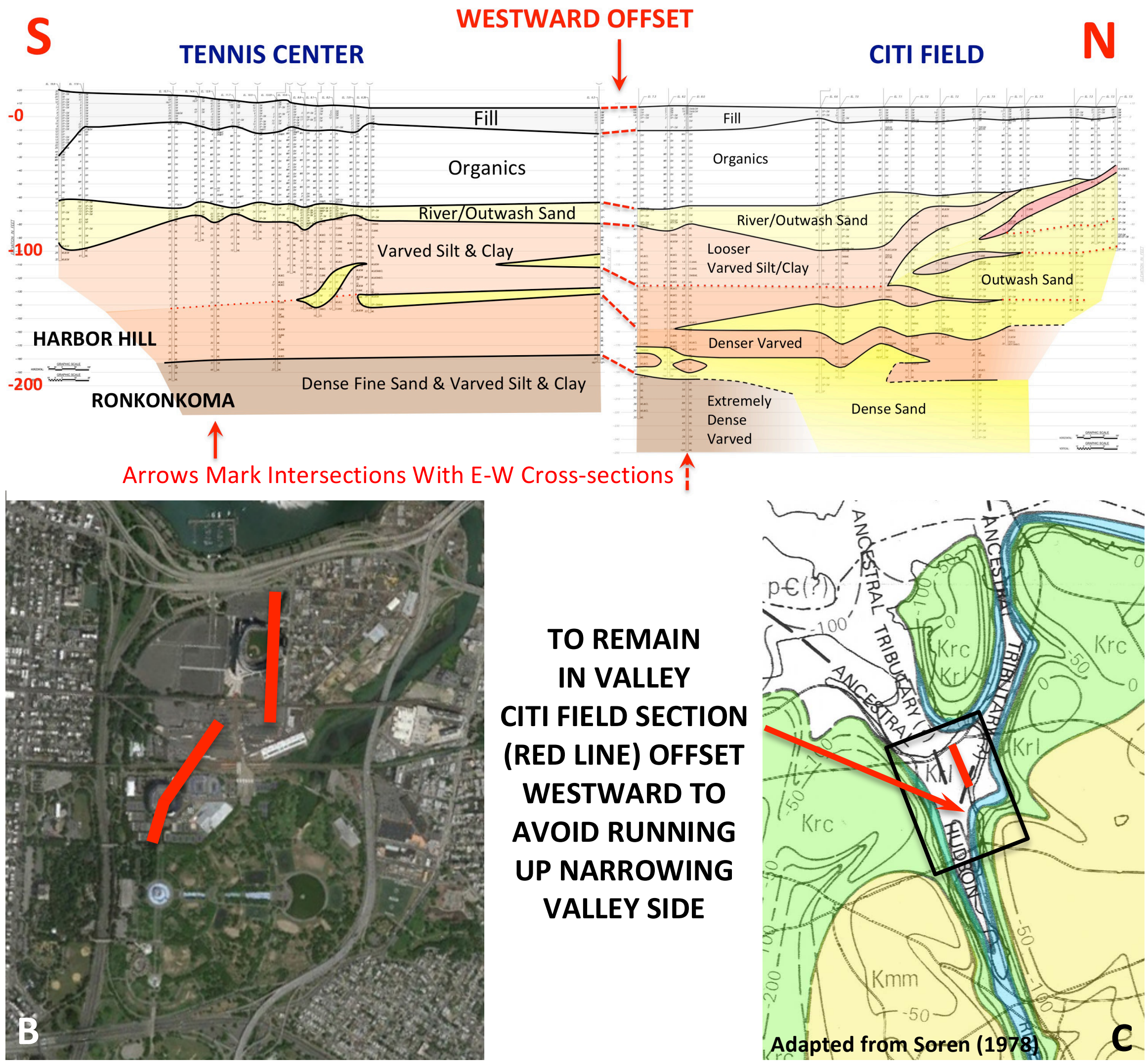


Figure 9 – N-S Cross-Section through northern Flushing Meadows. The section through Citi Field was offset westward before extending southward, in order to avoid running up the side of the narrowing valley wall that consists of till covered Raritan (green Krc overlay in map C). Area in black box enlarged in B to show the adjusted alignment (red lines on photo). Dense older (Ronkonkoma) sediments scoured out by the LGM advance are present at least as far south as the southwest corner of the National Tennis Center. The outwash layers seen at the Citi Field site are associated with readvances from the M1 ice margin into the glacial lake filling Flushing Meadows. The outwash layer at elevation -150’ reaches as far south as the northern edge of the Tennis Center. The later readvances are limited to the Citi Field area.

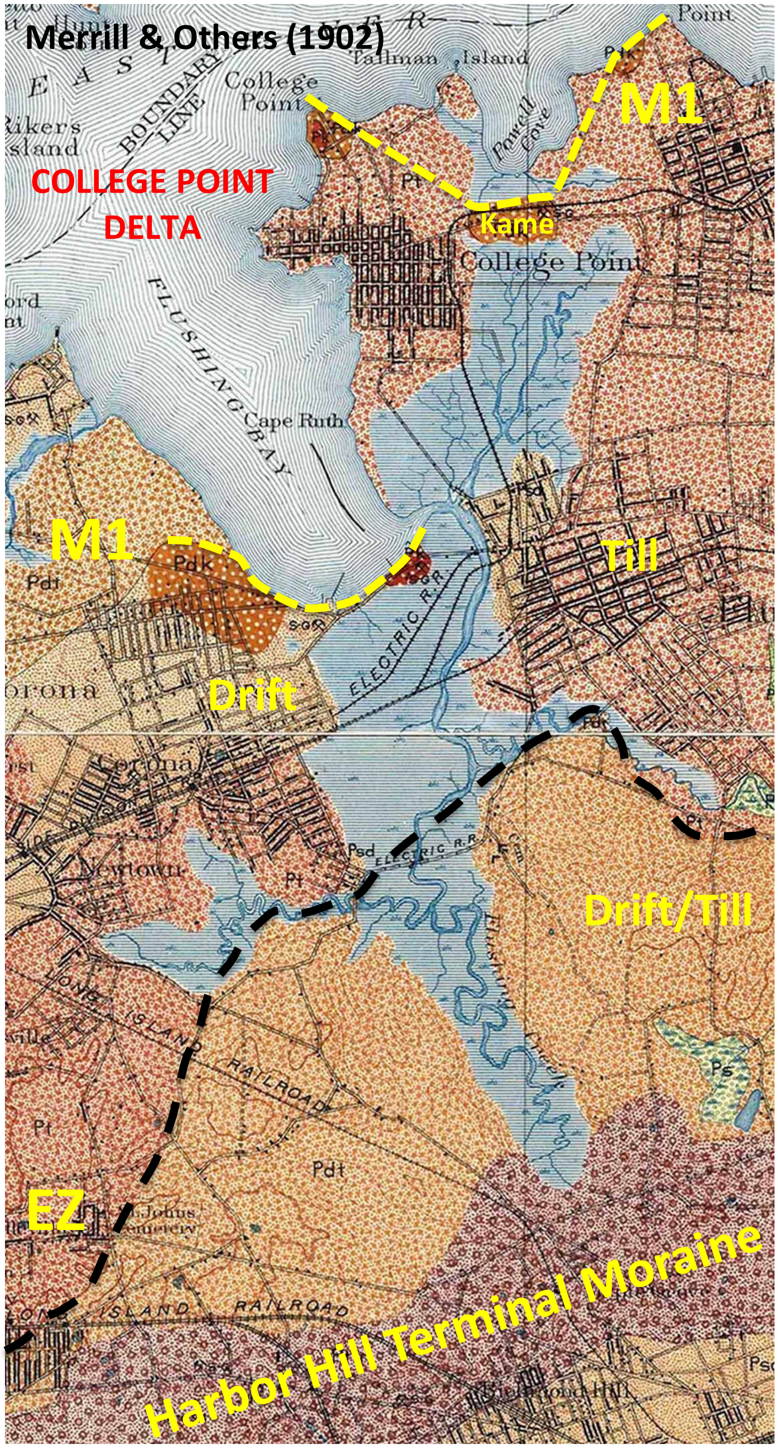
Heading further northward, layers of outwash sand from later glacial readvances finally start to appear within the varved deposits, ultimately becoming the dominant soil type at the northern end of the valley (Figure 9). These layers align best with the M1 ice margin. Outwash from an early advance, at roughly El -150’, reaches the northern edge of the

Tennis Center. Below the western side of Citi Field this sand layer is present between elevations -150' and -120', where it appears to have been planed off by a later, less extensive readvance at elevation -120'. Below the north end of the Tennis Center between elevations -150' to -120' the outer edge of the earlier outwash sand layer is interlayered with varved silt and clay, indicating the ice was advancing into a glacial lake. The soil is noticeably denser below the bottom of the sand layer around elevation -150, but density is fairly consistent above that. This suggests that the ice from the later advance at elevation -120' stopped over Citi Field and did not reach as far south as the Tennis Center, which would have densified the soil further. A later advance at El -85' did not extend south of the middle of the Citi Field site.

A very preliminary look at the engineering properties of the varved soil directly below each outwash sand layer suggests that the top of the lake clay was desiccated, at least in borings near the edges of the valley. If this proves to be the case, then between advances the ice retreated north of the valley far enough to allow the glacial lake filling Flushing Meadows to drain into the East River and/or Long Island Sound. The drop in ground water level would allow the varved soils that were exposed or above the water table to dry out, changing their properties.

In Flushing Meadows retreat from the EZ line was fairly steady until the ice stalled at the M1 margin located at the mouth of Flushing Creek. At this point the ice front fluctuated, periodically surging into the Flushing Meadows glacial lake. As mapped by Merrill and Others (1902), the ice also built up a series of kame and kame-like deposits starting at the northern edge of Flushing Meadows, then moving north to spots along the northern shore of Queens (where the College Point delta also formed in the East River/Flushing Bay) before the ice made its final retreat north of Queens (Figure 10).

Speculation – Across NYC there is stratigraphic evidence above the Sangamon Gardiner's Clay of 2 major Wisconsinan ice advances with an inter-stadial sea-level rise, followed by minor post-LGM readvances. Since there are 2 distinct moraines in the area, the Ronkonkoma and the Harbor Hill, it is assumed that signs of 2 significant post-Sangamon advances are associated with these 2 events. Assigning the denser sediments below elevation -190' to the Ronkonkoma event is based on this assumption. Detailed borings deeper than elevation -190' were only available north of the EZ line. In theory, the ice could have retreated from the Harbor Hill terminal moraine to a point north of Citi Field, then readvanced to the EZ line where it scoured out LGM deposits to an elevation of -190'. Since this would require a significant retreat and readvance of the ice sheet, and the EZ ice margin is presumed to be largely a recessional feature, it is more reasonable to link the soil below elevation -190' to the Ronkonkoma advance.



FLUCTUATING M1 ICE MARGIN LEFT BEHIND KAMES, KAME-LIKE DEPOSITS AND THE COLLEGE POINT DELTA ALONG A DISCONTINUOUS IRREGULAR LINE

EZ ICE MARGIN LEFT BEHIND A CONTINUOUS LINE OF TILL

Figure 10 – NYC Folio map showing the surface glacial deposits formed during LGM retreat around Flushing Meadows. As LGM ice started to retreat north of the terminal moraine it paused, depositing till that aligns with the EZ ice margin in NJ (black line). Retreat from the EZ line was fairly steady until the ice stalled at the M1 margin (yellow lines) located at the mouth of Flushing Creek. At this point the ice front fluctuated, periodically surging into the Flushing Meadows glacial lake. The map shows that the ice also built up a series of kame deposits starting at the northern edge of Flushing Meadows and formed the College Point delta in the East River/Flushing Bay before making its final retreat north of Queens.

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References

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., 2014b, Aspects of LGM Deglaciation in Flushing Meadows, Queens, New York City, NY: in Hanson, G. N., Chm., 21th Annual Conference on Geology of Long Island and Metropolitan New York, 12 April 2014, State University of New York at Stony Brook, NY, Long Island Geologists Program with abstracts, 13 p.