“Re-Mapping” Harlem’s Glacial Lake, New York City, NY

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Previous Mapping

In the 1920’s Chester Reeds studied glacial lake sediments in the New York City region (Reeds 1926). He knew that stratified sands were present across lower Manhattan, in the upper Manhattan neighborhood of Harlem and along Dyckman Street in the Inwood section at the northern tip of Manhattan. In other areas of the region these sands were associated with varved glacial lake deposits. He used these relationships to help deduce the locations of glacial lakes Hudson and Flushing across New York City (Reeds 1927) (Figure 1).

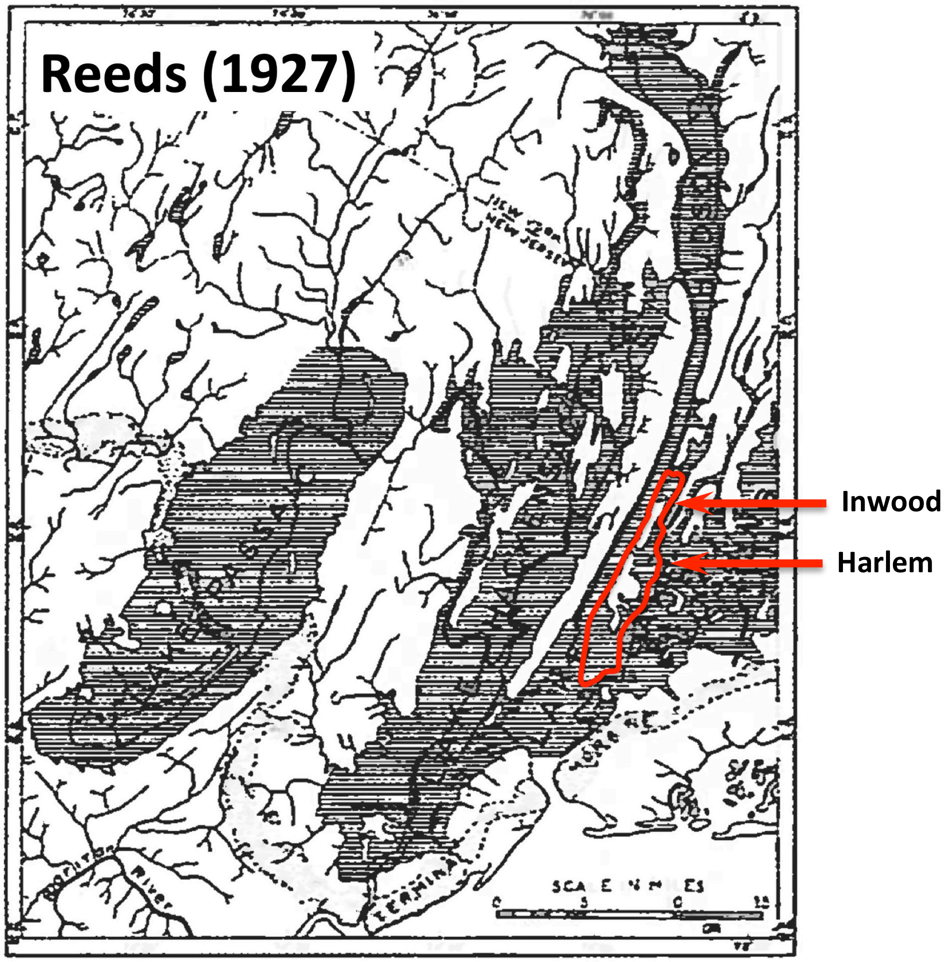


Figure 1 – Reeds’ 1927 map of glacial lakes in the New York City region. Manhattan is outlined in red. Areas shaded gray are glacial lakes, with the combined Lake Hudson and Lake Flushing covering much of New York City, including the Harlem and Inwood neighborhoods in northern Manhattan. (Modified from Reeds (1927)).

The engineers at Mueser Rutledge are very familiar with New York City's glacial sediments. MRCE (founded in 1910 and based in New York City with an in-house soils lab) has decades of data and experience working with these deposits. MRCE's James Parsons wrote several papers in engineering publications that described the engineering properties and challenges of foundation design in the glacial soils. He also produced a more detailed map of Lakes Hudson and Flushing over Manhattan (Parsons 1973, 1976) (Figure 2). In the city, he considered any area north of the terminal moraine that was without rock outcrops or shallow rock and till as likely to have some glacial lake sediments present.

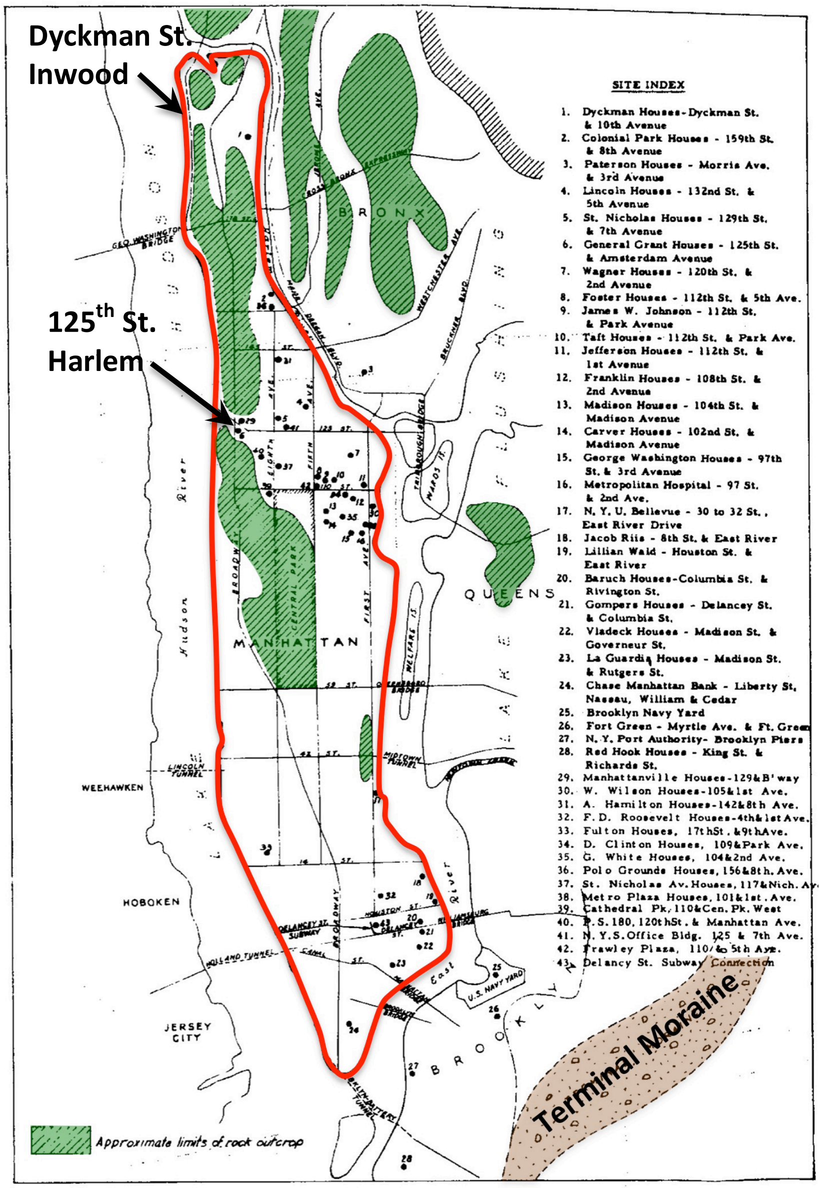


Figure 2 – Parsons' map of glacial Lakes Hudson and Flushing over Manhattan. The terminal moraine is shaded brown, rock outcrops are shaded green, and areas in the city that are left white likely have glacial lake deposits. The numbered locations are sites of MRCE projects that Parsons used in his analysis of NYC glacial lake sediments. (Modified from Parsons (1976)).

More recently, there has been extensive, detailed mapping of the glacial deposits in New Jersey that produced maps that extend over New York City (Stanford & Harper 1991, Stone & Others 2002, Stanford 2010a, 2010b). In these maps glacial Lake Flushing was eliminated, along with the glacial lake sediments in northern Manhattan (Figure 3). The region's lakes were reconfigured (Figure 4), instead placing Lake Bayonne over lower Manhattan and parts of Brooklyn and Queens. When glacial ice retreated north of Hell Gate an outlet to Long Island Sound opened. This allowed the lake to drop down to the Lake Hudson level. As mapped over the city, Lake Hudson was largely confined to the river valleys and did not extend over current land areas.

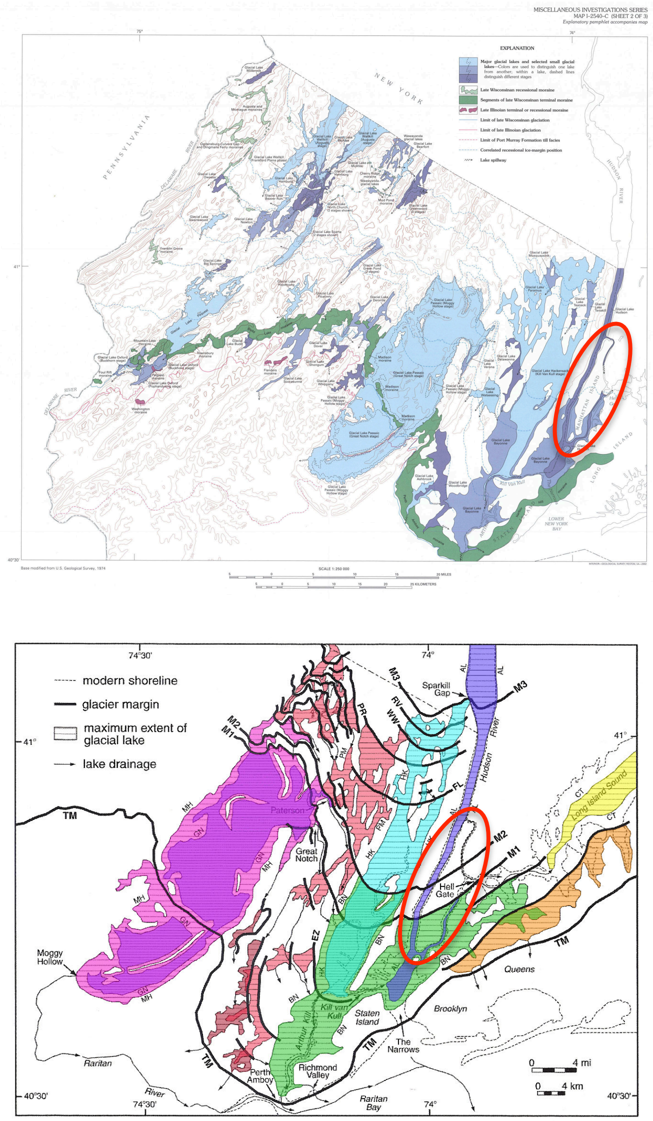


Figure 3 – Recent detailed maps of northern New Jersey's glacial lakes, such as Stone & Others (2002) on the top and Stanford (2010b) on the bottom, extend over New York City (Manhattan in red oval). These maps reconfigure the glacial lakes, eliminating Lake Flushing, and remove all of the glacial lake sediments previously mapped over northern Manhattan and the Bronx. (From Stone & Others (2002) and modified from Stanford (2010b)).

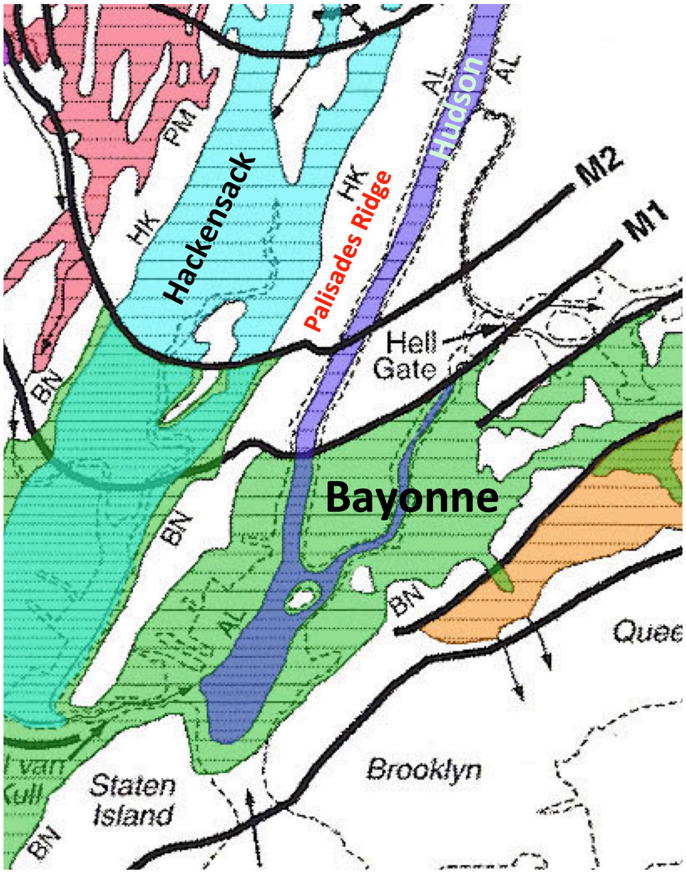


Figure 4 – Reconfigured glacial lakes over NYC. In NYC the new mapping places Lake Bayonne (colored green) over lower Manhattan and parts of Brooklyn and Queens. When glacial ice (ice margin M1) retreated north of Hell Gate an outlet to Long Island Sound opened. This allowed the lake to drop down to the Lake Hudson (dark blue) level. As mapped over the city, Lake Hudson was largely confined to the river valleys and did not cover current land masses. (Modified from Stanford (2010b)).

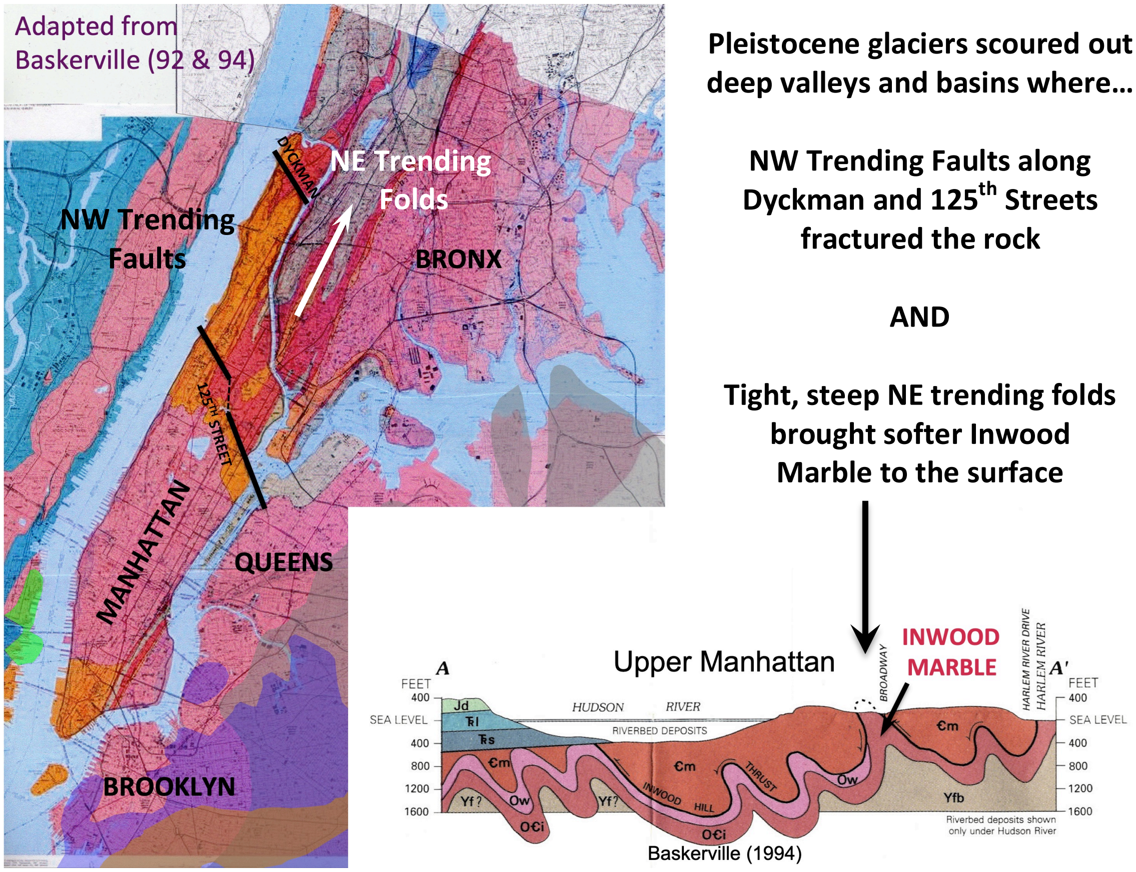
Updated "Re-Mapping"

None of this newer mapping accounts for the extensive glacial lake deposits that are still present over most of Harlem (over 2 square miles) and parts of Inwood and the Bronx. With a new configuration of lakes to consider, this presents several questions – exactly where are the currently "un-mapped" glacial lake deposits, and what is their relationship, if any, to each other and to Lakes Bayonne and Hudson. As a first step toward answering these questions information available in the MRCE archives, including decades of newer geotechnical data, was used to produce a more accurate map showing the location of lake sediments over Harlem.

Information such as top of bedrock elevation and strata breaks in boring logs was compiled from multiple sources including Rock Data Maps (WPA 1937), published geologic maps (Baskerville 1994, Stumm & Others 2015), and dozens of geotechnical investigations in the MRCE database. The USGS engineering geologic map sheet (Baskerville 1994), which has top of rock contour lines, was chosen to be the base map for the current glacial lake mapping. This map uses NGVD 29 as its vertical datum, so all of the data elevations were converted to NGVD 29. When published coordinates were not available, maps and plans with boring locations were overlain on Google Earth to obtain the coordinates of the borings. This allowed the glacial lake data to be placed more accurately on the geologic base map.

Bedrock Topography

The bedrock surface in NYC is extremely irregular and plays a role in determining where some of the glacial lakes formed. Depressions in the rock are typically filled with glacial sediments. For this reason, the engineering geologic map sheet with its rock contour lines is a good base map to use for identifying areas in upper Manhattan, especially in Harlem, that are likely to have glacial lake deposits. Parsons (1973) was on the right track looking for bedrock, though outcrops weren't quite the key, the top of rock elevation is.



Pleistocene glaciers scoured out deep valleys and basins where…

NW Trending Faults along Dyckman and 125th Streets fractured the rock

AND

Tight, steep NE trending folds brought softer Inwood Marble to the surface

Figure 5 – Geologic map of New York City – Engineering sheets combined and geologic cross-section through upper Manhattan (at ~187th Street). In NYC the bedrock surface is extremely irregular, due in part to differential erosion along folds of softer rock and fractured fault zones. The elevation of the resulting ridges, valleys and basins in the bedrock is a factor in determining the location of the city's glacial lakes. (Modified from Baskerville (1992, 1994).

In New York City the bedrock largely consists of layers of hard metamorphic rock that were thrust into generally tight, steep NE trending folds that were later cut by NW trending faults (Moss 2012). During the Pleistocene, glaciers scoured out valleys and basins, often quite deep, where the folds brought the relatively softer Inwood Marble to the surface and the NW trending faults along 125th Street in Harlem and Dyckman Street in Inwood fractured the rock (Figure 5). The 0' elevation rock contour line happens to outline the areas underlain by the Inwood Marble and the fault zones, especially in Harlem (Figure 6). Glacial lake deposits are often present within these mapped areas.

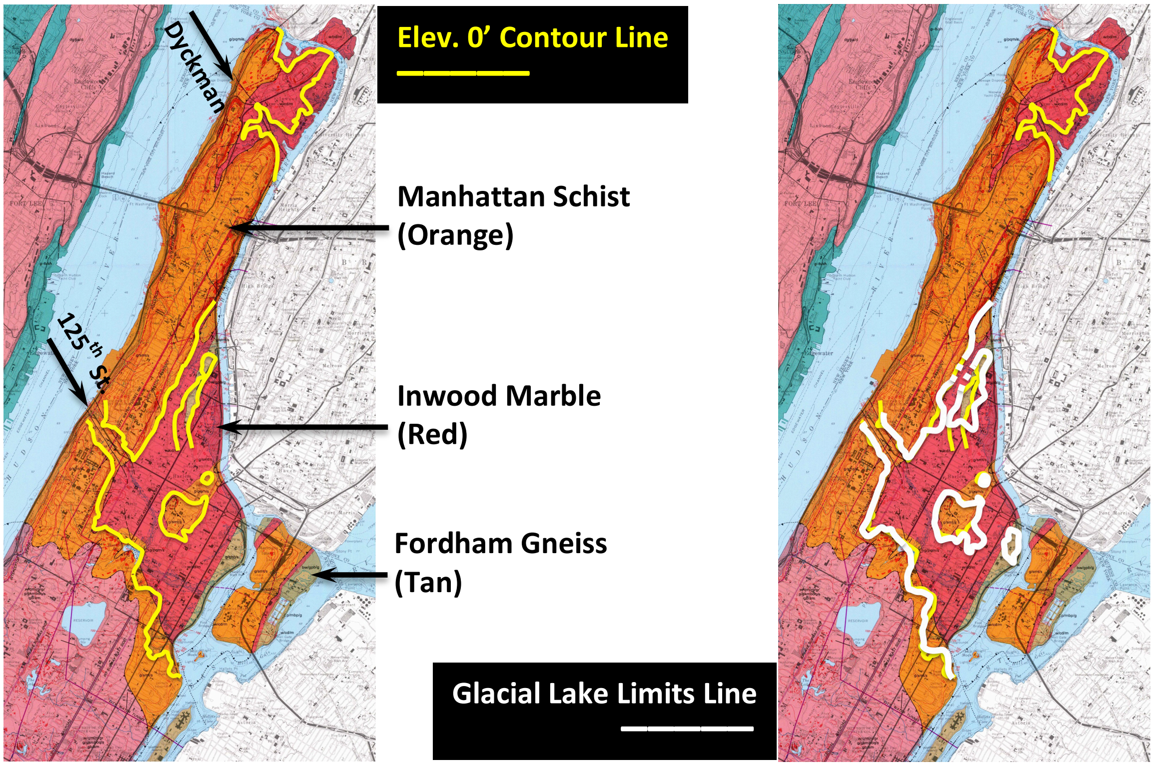


Figure 6 – The geologic map - engineering sheet has top of rock contour lines. Pertinent elevation 0' contours have been highlighted in yellow (left side). Particularly in Harlem, the El. 0' contour outlines valleys and basins scoured into the softer Inwood Marble (red map color) and fractured fault zones (to the right of the black arrows). The harder Manhattan (orange) and Fordham (tan) formations tend to form ridges. White lines (right side) mark the limits of glacial lake sediments over Harlem, basically coinciding with El. 0'. Glacial lake sediments are also present at the northern tip of Manhattan (Inwood), but have not yet been analyzed in detail. (Modified from Baskerville (1992)).

Harlem Lake Extent

In general, across Harlem, glacial lake deposits such as varved silt and clay and layers of silty fine sand are often present in areas where top of bedrock is below elevation 0' (Baskerville 1992 & 1994) (Figure 7). A high ridge of hard Manhattan Schist runs along the west side of upper Manhattan, largely forming the lake's western margin. An island of harder schist that runs along Park Avenue roughly separates Harlem's lake into 2 segments. To the west of the island, the top of the glacial lake deposits is generally between elevations 0’ and -15’. To the east, where the basin is more open to the Harlem River and East River drainage, the top of the lake deposits is typically between elevations -15’ and -25’ (Figure 8).

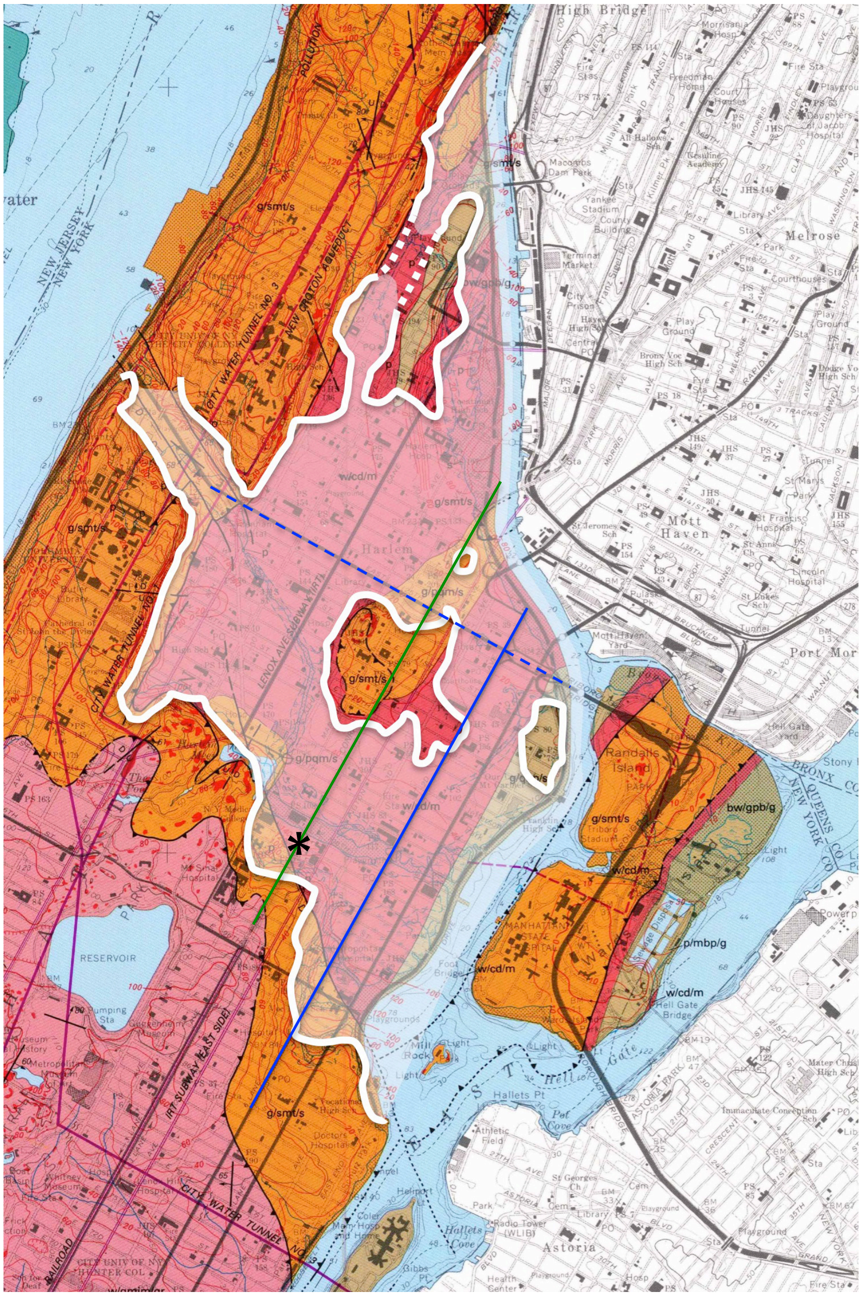


Figure 7 – Harlem glacial lake. Area shaded white generally has glacial lake sediments present. It is unclear if lake deposits are present in the unshaded area at the top between the dotted lines. Boring information was not available for that stretch, but valleys are cut into the underlying marble at either end. An island of harder Manhattan and Walloomcac schist (orange map color) is present along Park Avenue (green line) that separates the basin into 2 slightly different segments to the east and west. The dashed blue line shows the alignment of the cross-section along 125th Street in Figure 8, the solid blue line is the alignment along Second Avenue. The * shows the location of Gardiners Clay referenced in Figure 8. (Modified from Baskerville (1992)).

It is not yet clear to what extent, if any, the Harlem lake connects to Lakes Bayonne and Hudson, or to other glacial lake deposits identified in upper Manhattan or across the Harlem River in the Bronx. Mapping that connection is a subject for future study.

Typical Glacial Lake Stratigraphy

While the stratigraphy varies by location across Harlem, there is a strong trend in the strata across the area (Figure 8). A small area around East 105th Street and Park Avenue has a layer of the Gardiners Clay at the bottom of a basin directly above the rock. The Gardiners is an interglacial marine clay of presumed Sangamon age.

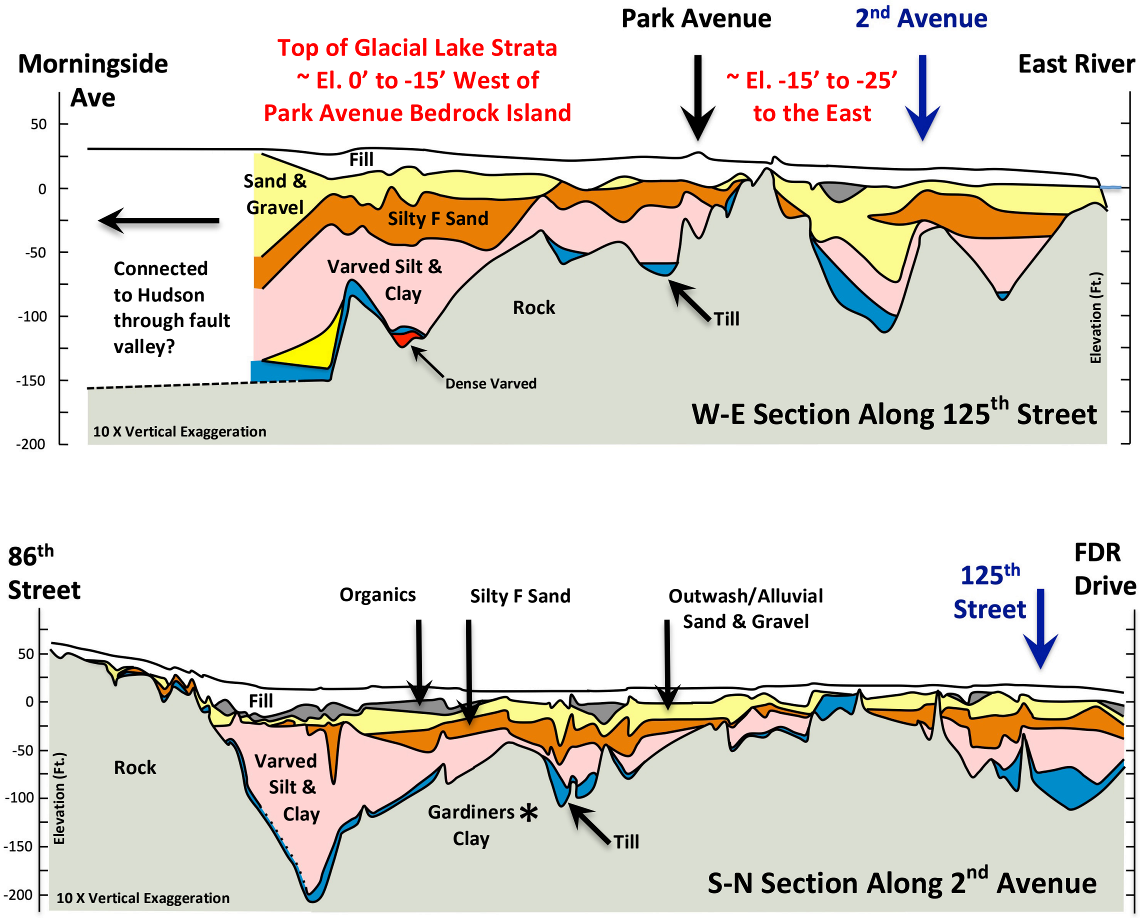


Figure 8 – Stratigraphic cross-sections along 125th Street (top) and Second Avenue (bottom), alignments of sections are shown in Figure 7. Elevation is in feet with Vertical:Horizontal scale of 10:1. Throughout the basin the strata from bottom to top is typically bedrock, till, varved silt and clay grading up to fine sand. These lake deposits are overlain by clean outwash and/or alluvial sand and gravel. Low lying areas are filled in with recent organic estuarine sediments and miscellaneous fill material covers the area. A small area around Park Avenue and 105th Street (* in Figure 7) has a layer of interglacial Gardiners Clay above the rock, below the till. The asterisk shows its approximate location projected ~1500' into the 2nd Avenue section. The top of the glacial lake strata is at roughly El. 0' to -15' to the west of a bedrock island along Park Avenue, and El. -15' to -25' to the east.

This indicates that the overlying glacial sediments were deposited during the Wisconsinan. Occasional pockets of very dense sand or varved soil may be present just above the rock. Elsewhere the bedrock is covered with a layer of till. Boulders are especially common in the lower part of the till in the deepest valleys. This trait is often seen in deep valleys across the city (Moss 2016b).

Layers of varved brown and sometimes gray silt and clay typically lie above the till or rock. The varved deposits are usually covered with a layer of silty to clean fine sand, often grading upward into it. A layer of clean outwash or alluvial sand and gravel normally covers these glacial lake sediments. As a result of post-glacial sea-level rise, estuarine organic silty clay and marsh sediments fill in low-lying areas. Miscellaneous fill material covers areas without rock outcrops.

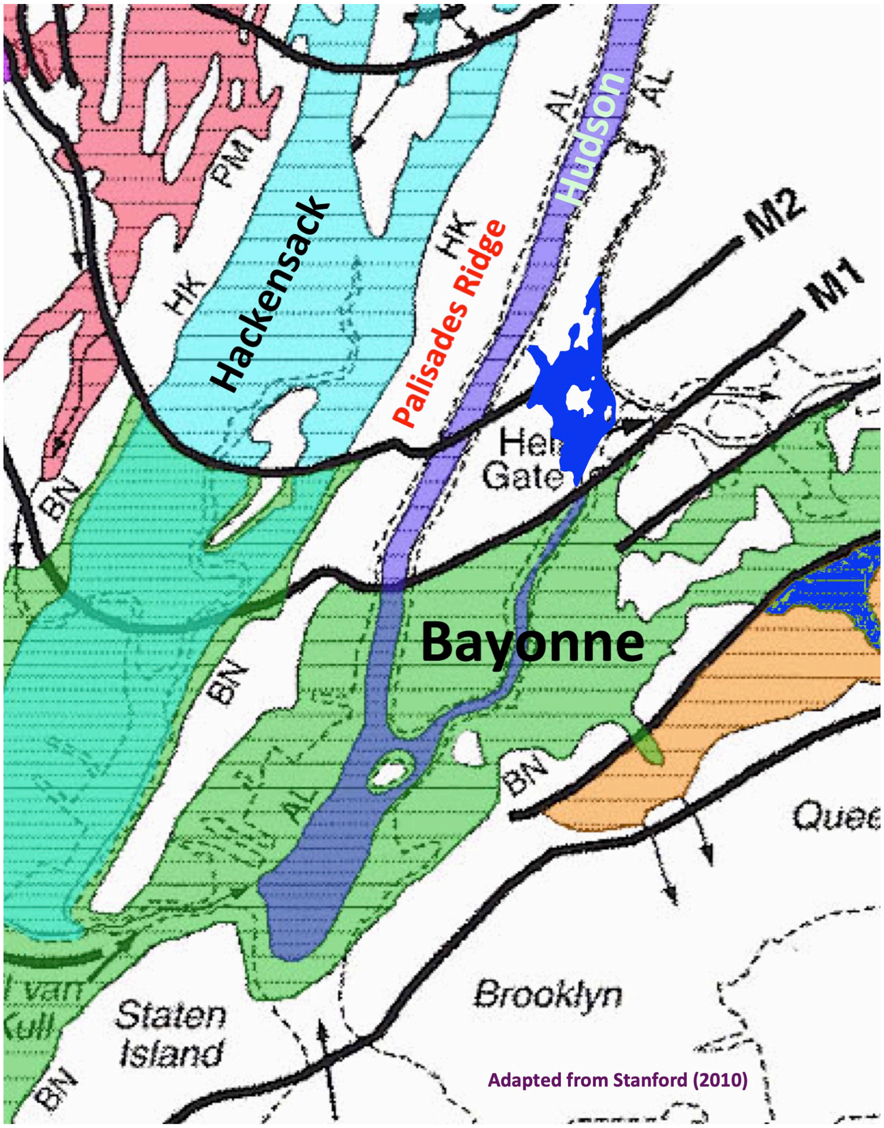
In some locations, layers of outwash sand and/or till are mixed in with the lake sediments, marking readvances of the ice front. In places, changes in the engineering properties of the soils (compactness, strength, preconsolidation stress, water content, etc.) vertically and laterally, also indicate areas that have experienced loading by ice readvances and/or desiccation as glacial lake levels dropped.

Conclusions

When the Harlem lake is added to Stanford's map of ice fronts and glacial lakes (Figure 9), it plots just to the north of the ice front that blocked Hell Gate to form Lake Bayonne to the south. This suggests that the lake started to form in Harlem shortly after Lake Bayonne dropped down to the Lake Hudson level. If the ice front retreated up the Hudson, but remained in Long Island Sound longer, thus delaying the drop to Lake Hudson, then it's possible that at least the southeast portion of Harlem was connected to Lake Bayonne.

The valley formed by the 125th Street Fault runs completely across Harlem from the Hudson River eastward to the East River. Multiple layers of glacial lake sediments are present in this valley below Manhattanville, which is on the east shore of the Hudson River, west of the high ridge of Manhattan Schist that runs along the west side of upper Manhattan (Moss 2018b). Harlem's lake deposits fill the fault valley to the east of the ridge and extend westward at least partway through the ridge. It is likely that there is some drainage connection between the Manhattanville and Harlem basins, but it's not yet clear if the glacial lake strata are continuous all the way through. If they are, then the Harlem lake could be connected to Lake Hudson through the 125th Street fault. The Harlem lake is open to the East River on the east and the Harlem River to the north and east. It's possible there also could be a Lake Hudson connection through these river valleys.

The scope of this paper was to map the areal extent of the glacial lake sediments in Harlem. The next step is to add to the map other nearby locations with lake sediments such as Manhattanville, Inwood, the Harlem River and the bedrock valley below Yankee Stadium to see if they are interconnected, and if so, in what way. Similarly all of these locations would then be compared to Lakes Hudson and Bayonne and the glacial lake deposits in Flushing Meadows in northeastern Queens (Moss 2013b, 2014b).



Adapted from Stanford (2010)

Figure 9 – Harlem glacial lake (blue) placed relative to lakes Bayonne and Hudson. If ice margin M1 is accurate, then the Harlem lake started to form shortly after Lake Bayonne dropped down to the Lake Hudson level. It is not yet clear if the lake was connected to Lake Hudson through the western end of the 125th Street fault zone, or through connections to the Harlem and East Rivers to the north and east, or if it was a completely isolated lake. (Modified from Stanford (2010b)).

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