EXTENT OF GLACIAL LAKE SEDIMENTS OVER INWOOD, NEW YORK CITY, NY

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Introduction

Modern surficial geologic maps (Stone & Others 2002; Stanford 2010a, 2010b) place 2 former glacial lakes – Lakes Bayonne and Hudson - over the New York City area (Figure 1), but as mapped these lakes do not account for the very deep and extensive glacial lake deposits present over parts of northern Manhattan, particularly over the neighborhoods of Harlem (Moss 2019) and Inwood (Figure 3).

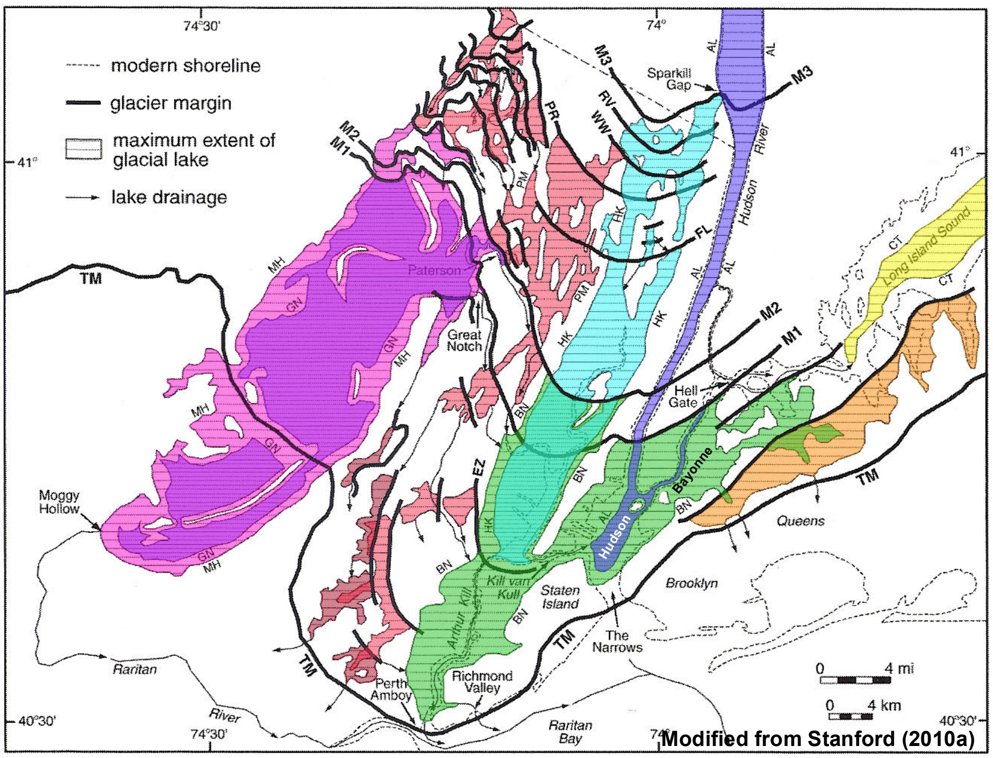

Figure 1 – Glacial lakes and ice margins mapped over New York City and New Jersey (Modified from Stanford 2010a). Modern surficial geologic maps only show glacial lakes Bayonne (colored green) and Hudson (colored blue) over New York City.

A couple of older maps show glacial lakes Flushing and Hudson over the city, but their ability to pinpoint the extent of the lake sediments is a bit vague. The map by Reeds (1927) uses a known association with glacial sands to deduce the locations of glacial lakes over the region rather than mapping all the lake deposits directly, and it is at a small scale that makes it difficult to find specific sites. Parsons (1973, 1976) uses the assumption that areas that don't have outcrops of rock or till generally have glacial lake deposits (Figure 2). This assumption is roughly correct but not precise.

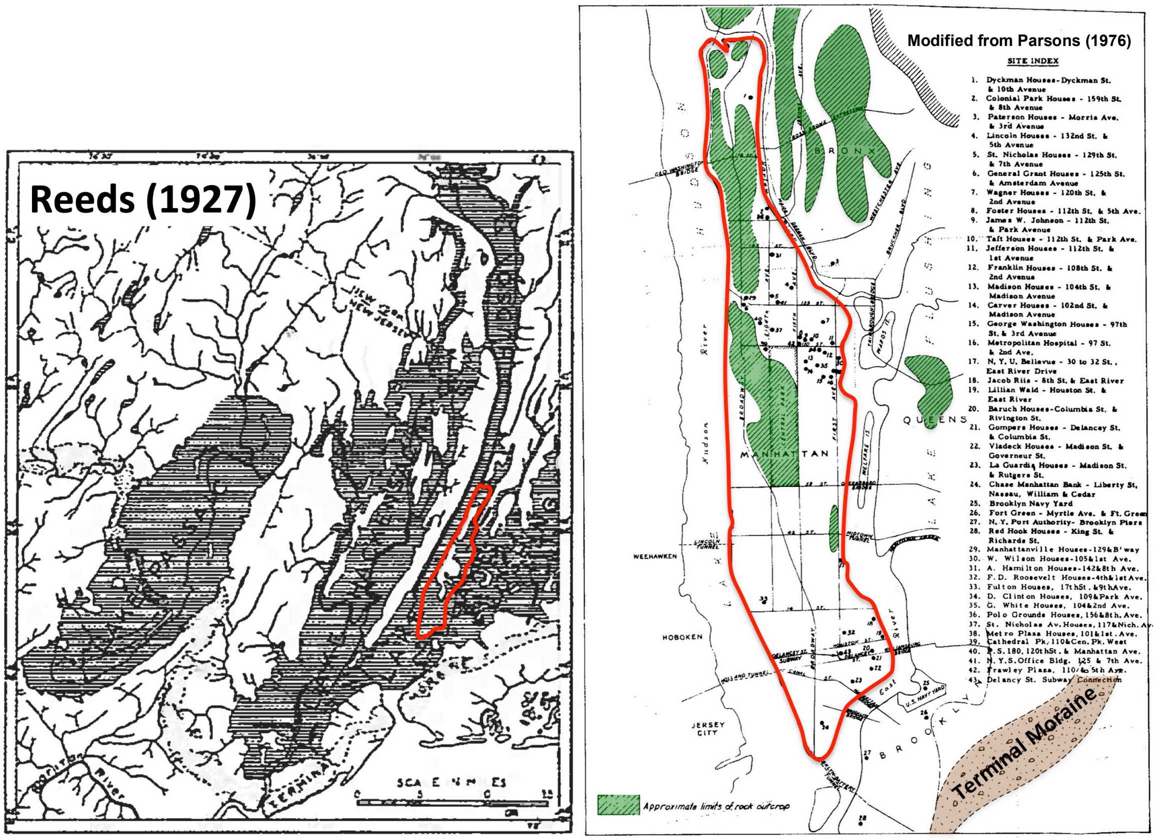

Figure 2 – Older maps show glacial lakes Flushing and Hudson over New York City, but they're not the most precise for locating sites with glacial lake sediments. Reeds (1927) maps glacial lakes (in gray) at a very small scale. Parsons (1976) assumes areas without rock outcrops often have glacial lake sediments. (Rock outcrops colored green.) (Modified from Reeds 1927 and Parsons 1976.)

New Mapping

MRCE has an extensive archive of subsurface geotechnical information, particularly over New York City. Moss (2019) used this database to map more precisely the extent of the glacial lake deposits over Harlem. As a continuation, this paper extends the mapping over the Inwood neighborhood at the northeast tip of Manhattan (Figure 3). The procedure and base map used here for the Inwood lake are the same as used for mapping the Harlem lake.

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.

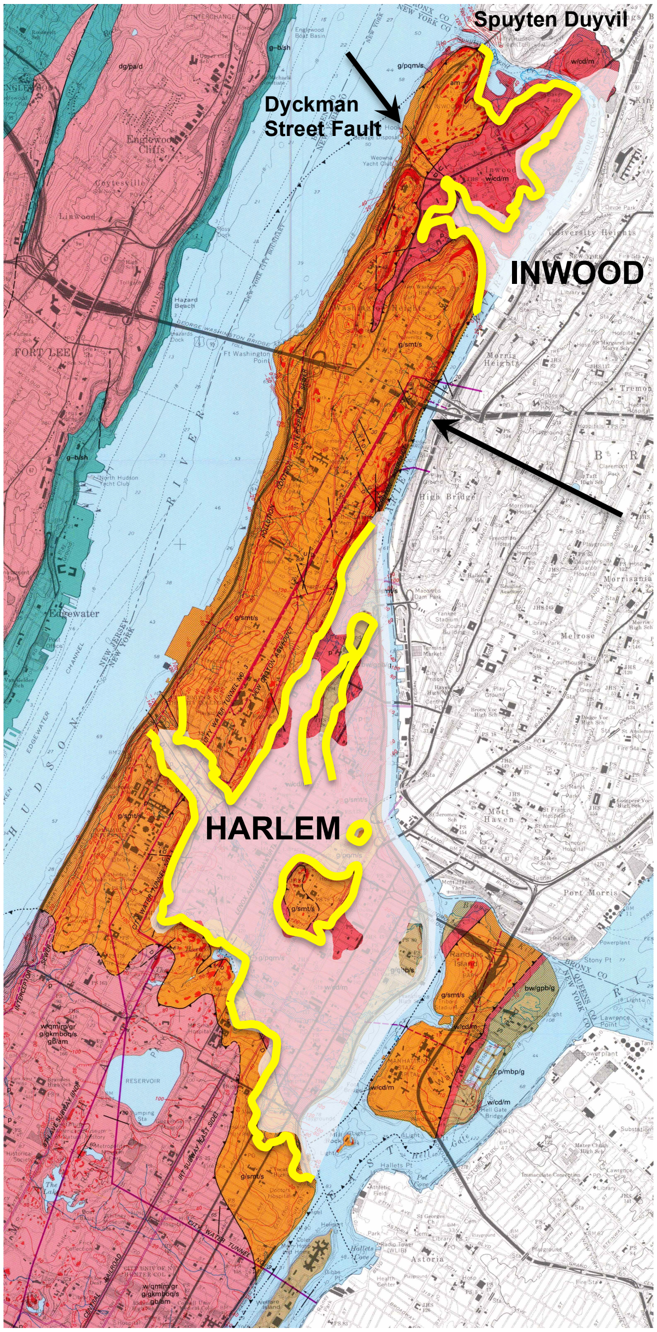

Figure 3 – Mapped extent of glacial lakes over Harlem and Inwood. Base map is the NYC geologic map - engineering sheet (Baskerville 1994), which has top of rock contour lines. Elevation 0' contours over Harlem and Inwood are highlighted in yellow. The extent of glacial lake sediments is colored white. In both the Inwood and Harlem neighborhoods glacial lake deposits are generally found where the top of rock and any overlying till is below elevation 0'. Boring information down the center of the Harlem River channel is limited, so it is not yet clear what the bedrock/till elevation is between the Harlem and Inwood lakes, but similarities between the 2 lakes suggests the 2 were eventually connected.

Bedrock Topography

Across the southern portion of New York City the bedrock played a limited role in determining the location of glacial lakes, which were initially dammed up between the terminal moraine and the ice front. The opposite is true, however, in upper Manhattan (and the Bronx) where the highly irregular bedrock topography was key in determining the location of glacial lake sediments.

New York City bedrock and structural geology is explained in more detail in other references (Merguerian 1994a, 1996; Moss 2010b), so it's very greatly simplified here. Basically a layer of relatively softer Inwood Marble was sandwiched between layers of harder schist and gneiss. These rock formations were thrust into tight, steep, NE trending folds that were later cut by NW trending faults (Figure 4). Subsequent erosion preferentially scoured out the softer marble and fractured fault zones where they were exposed at the bedrock surface, producing a highly irregular topography with steep hard rock ridges separating deep valleys and basins. As Pleistocene ice retreated, many of the depressions filled with glacial lakes.

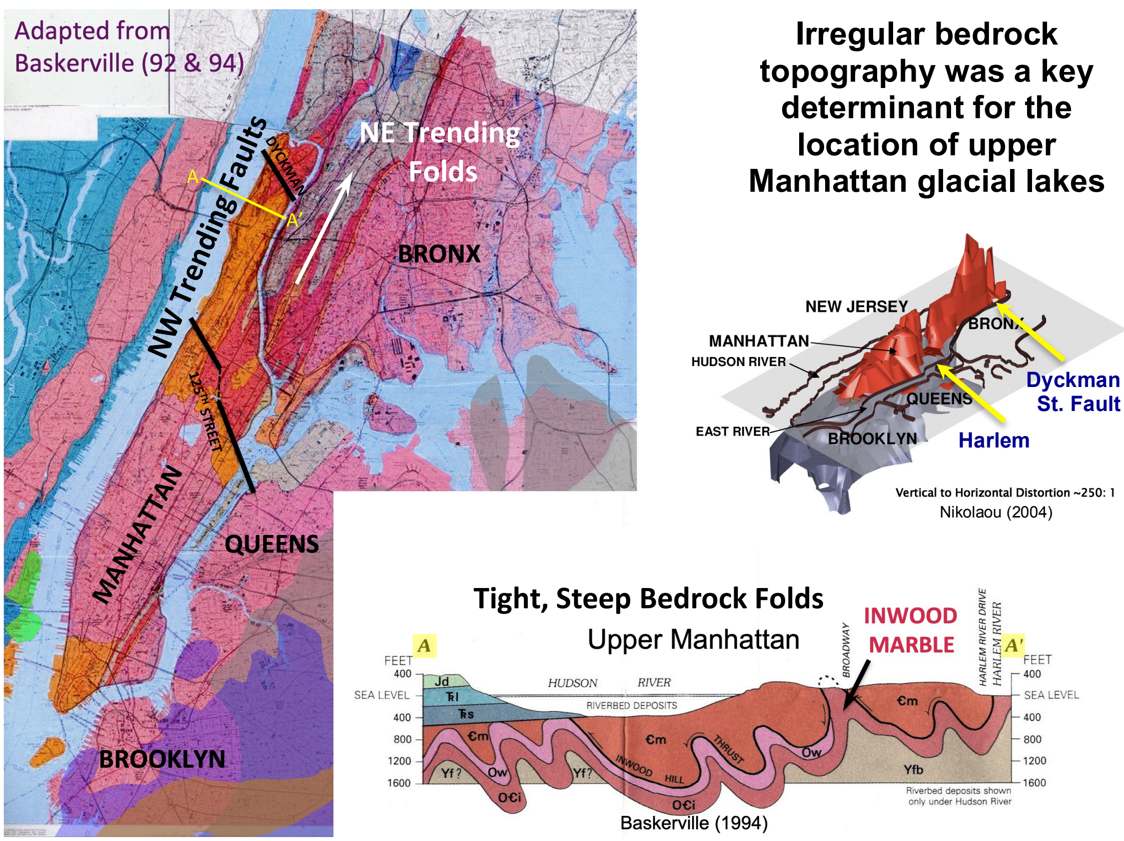

Figure 4 – Bedrock geologic maps of New York City (Modified from Baskerville 1992 & 1994). Softer Inwood Marble (dark pink color) was sandwiched between layers of harder schist/gneiss, all thrust into tight, steep, NE trending folds, then cut by NW trending faults. The major mapped fault in Inwood runs along Dyckman Street. Subsequent erosion, particularly along the softer marble and fault zones, produced a highly irregular bedrock topography that was key in determining where glacial lakes formed in upper Manhattan. (Bedrock topography modified from Nikolaou 2004.)

New York City Glacial Lakes

Recent surficial geologic maps of the region provide detailed mapping of the glacial lakes over New Jersey, but show only Glacial Lakes Bayonne and Hudson over New York City (Figure 5). Lake Bayonne formed as glacial ice started to retreat north of the terminal moraine. When an outlet to Long Island Sound opened up at Hell Gate in the East River, Lake Bayonne dropped down to the Lake Hudson level. The Hell Gate outlet initially flowed over till, but eventually cut down through it to stabilize approximately 20' lower on bedrock (Stanford email communication 2019). This was Lake Hudson's primary outlet until the terminal moraine was breached at the Narrows and Lake Hudson/Albany started to drain, eventually reestablishing Hudson River flow directly to the Atlantic Ocean.

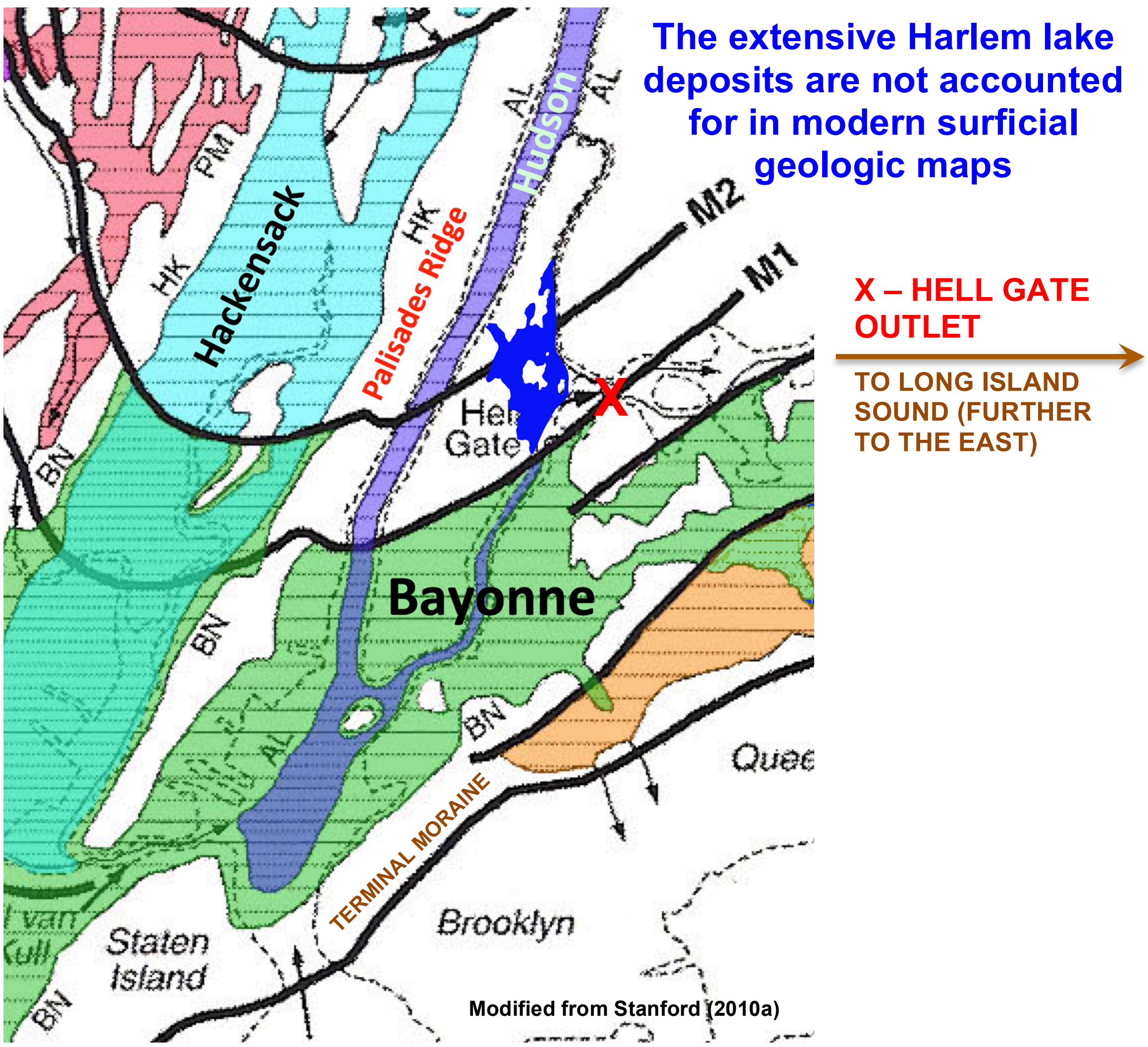

Figure 5 – Glacial lakes mapped over New York City (Modified from Stanford 2010a). Lake Bayonne (colored green) formed when the ice retreated north of the terminal moraine. When an outlet to Long Island Sound opened up at Hell Gate, Lake Bayonne dropped down to the Lake Hudson (colored blue) level. This map does not account for the deep and extensive glacial lake deposits present over Harlem (shown in dark blue) (Moss 2019).

As mapped, Lakes Bayonne and Hudson explain the presence of glacial lake sediments across lower Manhattan and portions of western Brooklyn and Queens. Unfortunately, they cannot account at all for the very deep and extensive lake deposits that are present across other large portions of NYC, including the ones found over Harlem (Moss 2019) or the Inwood section of northern Manhattan (Figures 3 & 7).

Inwood Lake Extent

In the Inwood section of Manhattan the location of glacial lake sediments is determined largely by the bedrock topography. The Harlem River follows a bedrock valley that for most of its length cuts into a layer of the Inwood Marble (Figures 3 & 7). A large NW trending fault runs along Dyckman Street at the southern end of the neighborhood. The northern end of the Harlem River was largely confined with limited outlets prior to construction of the Harlem Ship Canal in 1895. In this basin continuous lake deposits are generally found where the bedrock and any overlying till is below elevation 0'. This is the same pattern that is seen to the south at the Harlem lake. The Inwood lake extended from the northern end of the Harlem River southward down the river valley to the Dyckman Street fault zone where the lake turned westward into the fault valley. There are scattered locations above El. 0' that have some fine grained sediments, but these appear to be either filling small depressions or may be some of the presumed eolian soil mapped in the neighborhood (Merrill 1902) (Figure 6).

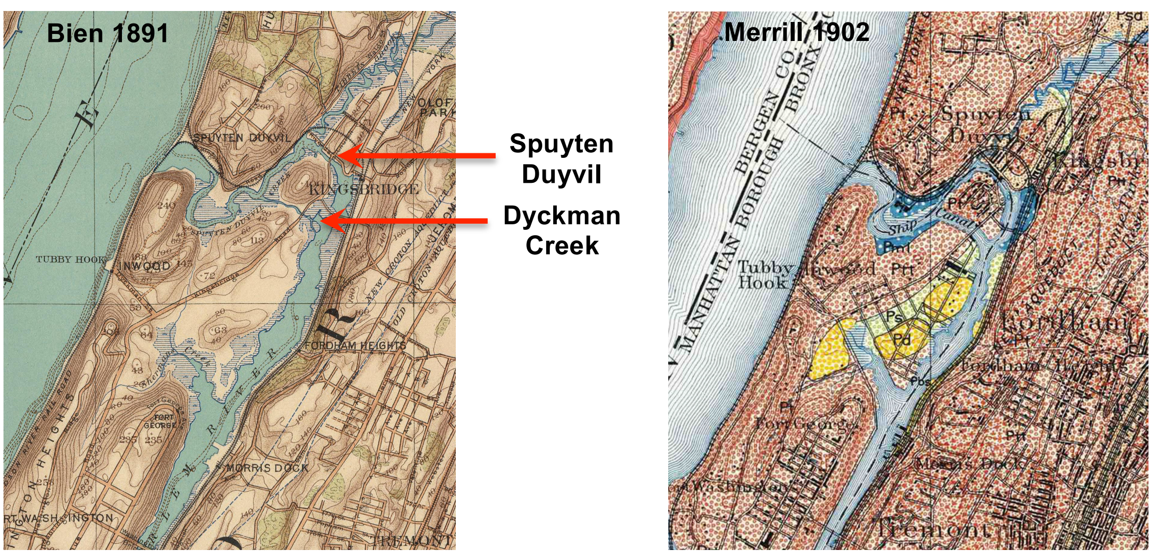

Figure 6 – Historic topographic map (Bien 1891) showing limited drainage at the Inwood basin before the Harlem Ship Canal (left) was constructed along Dyckman Creek, and surficial geologic map showing drainage shortly after (right). The geologic map (Merrill 1902) also shows the location of presumed eolian sand (pd – in yellow) that could account for fine grained sand found at elevations above 0'. Rock is so shallow along Spuyten Duyvil Creek around Kingsbridge that only rowboats could pass from the Hudson through to the Harlem River. Rock at the western end of Dyckman Street may have been too high to allow any significant connection between the Harlem and Hudson rivers through the fault zone.

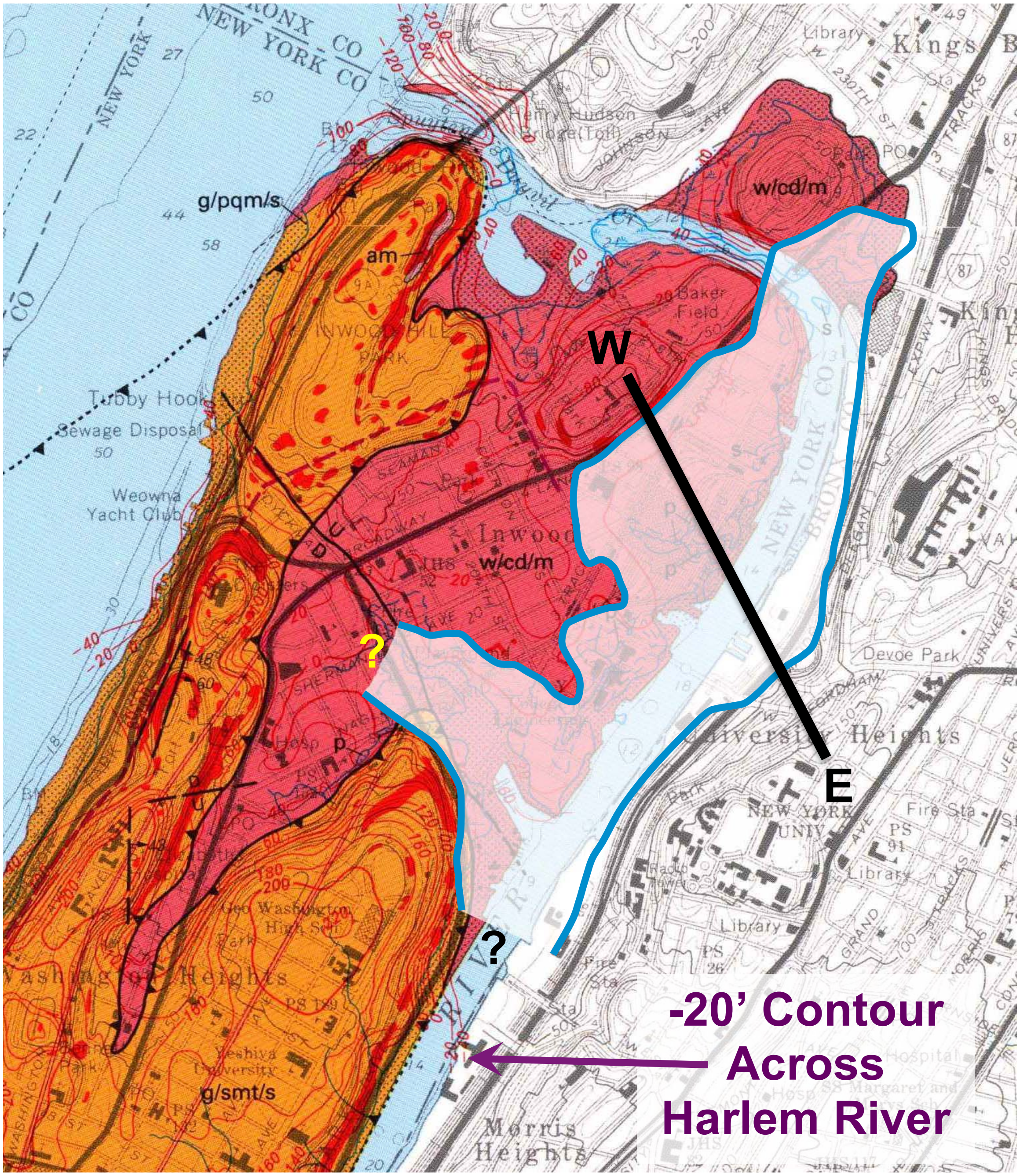

Figure 7 – Extent of glacial lake over Inwood shown in white with blue outline. The black line W-E shows the alignment of the general stratigraphic cross-section shown in Figure 8. Lake sediments are generally present where the original bedrock surface and any overlying till is below elevation 0'. (Red lines are top of rock contours.) The Inwood basin was initially isolated with limited outlets. A connection to Lake Hudson through Spuyten Duyvil Creek may not have been deeper than elevation -20', and around elevation 0' through the Dyckman Street fault zone. If the -20' rock contour crossing the Harlem River around 190th Street is accurate, then any connection to the Harlem lake to the south may have also been around elevation -20'. It is not clear if the lake extended beyond the question marks shown in the Dyckman Street fault and Harlem River channel.

Inwood Lake Stratigraphy

In the Inwood basin the bedrock is generally covered with a layer of glacial till (Figure 8). Varved silt and clay is present above the till. It is often more clayey at the base, becoming more silty as you move upwards through the stratum. The varved silt and clay continues to grade upward into varved fine sand and silt. This is often covered with a layer of fine to silty fine sand. The modern Harlem River cuts through the basin, so in places the glacial lake sediments were eroded out and overlain by river sand and estuarine organic silty clay and peat.

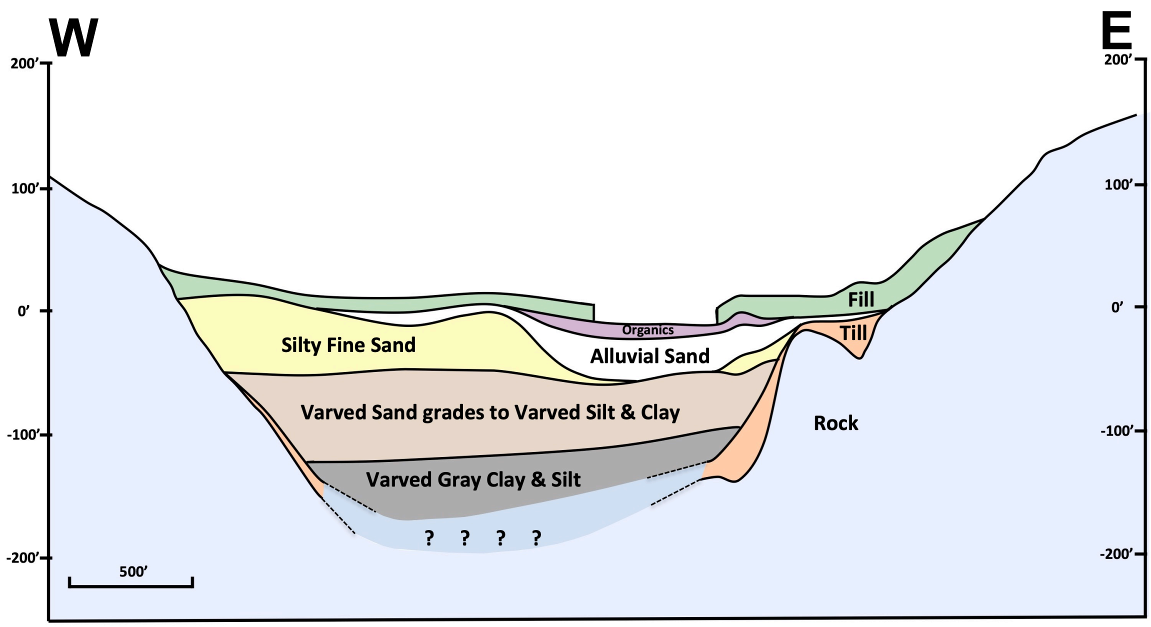

Figure 8 – Generalized West-East stratigraphic cross-section across the Inwood basin. The stratigraphic sequence seen in the Inwood lake is basically the same as what is present in the larger and more varied Harlem lake (Figure 9) at the southern end of the Harlem River. The strata from bottom to top are bedrock/till/varved silt and clay that grades upward to varved sand with silt/fine to silty fine sand/alluvial sand/estuarine organic soils/Fill. What is unique about the Inwood basin is that the varved clay and silt just above the till is often exclusively gray, especially in the deeper parts of the basin. When the color switches to the more typical brown with gray and red brown varves, it occurs over a short distance indicating a rapid shift from a local sediment source to a regional source.

This stratigraphic sequence is mostly the same as the generalized stratigraphy seen in the otherwise larger and more varied Harlem lake (Figure 9). The Inwood basin, however, does have a distinctive feature that differentiates it from other glacial lakes over NYC. The varved soil is often gray and clay rich immediately above the till, especially in areas where the basin is below elevation -50'. (It is not yet clear if El. -50' is significant or if this is just a coincidence.) Where it is present in shallower zones near the edges, the gray soil is a thin coating, while it is a thicker layer in the deep basin. Moving upward the soil color changes to brown, with some gray and red brown varves, which is the color mix more commonly seen in other glacial lake deposits across the city. The transition from gray to brown is fairly sharp, marking a

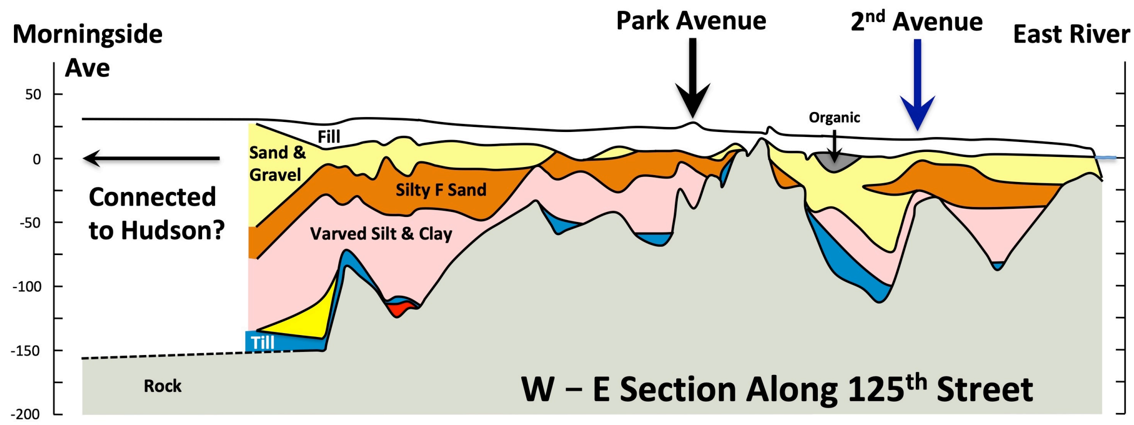

Figure 9 – West-East stratigraphic cross-section across Harlem lake along 125th Street (Moss 2019). The stratigraphic sequence seen in the Inwood lake (Figure 8) is basically the same as what is present in this larger and more varied Harlem lake at the southern end of the Harlem River. The general strata in Harlem, from bottom to top, are bedrock/till/varved silt and clay/fine to silty fine sand/outwash +/or alluvial sand/estuarine organic soils/Fill.

rapid shift from a local bedrock sediment source to a more regional one. This suggests the Inwood basin was isolated until the lake level rose high enough to connect with the otherwise similar Harlem lake to the south via the Harlem River +/or Lake Hudson just to the west (most likely through Spuyten Duyvil).

Conclusions

At the eastern end of Spuyten Duyvil Creek where it meets the Harlem River, the bedrock channel is quite narrow and shallow (Figure 6). The same appears to be true for what was originally Dyckman Creek. For this reason the Harlem Ship Canal was cut through the bedrock along Dyckman Creek to make the Harlem River more navigable. Until its' opening in 1895, only rowboats were able to pass through Spuyten Duyvil to the Harlem River (Engineering News 1895). Information about the original bedrock elevation prior to construction of the Ship Canal is limited, but the connection between the Inwood basin and Spuyten Duyvil may not have been much deeper than elevation -20', and it was possibly more shallow.

Stanford (2010a) places the Lake Hudson shoreline at Spuyten Duyvil at approximately elevation -10' (Figure 10), though it initially may have been up to roughly 20' higher before the till at the Hell Gate outlet eroded down to the bedrock (Stanford email communication 2019). If this is the case, then a connection between Inwood and Lake Hudson is definitely possible. Bedrock at the very western end of the Dyckman Street fault zone may reach up to just above elevation 0', so any connection between the Inwood basin and Lake Hudson through the fault zone is probably less significant than one through Spuyten Duyvil.

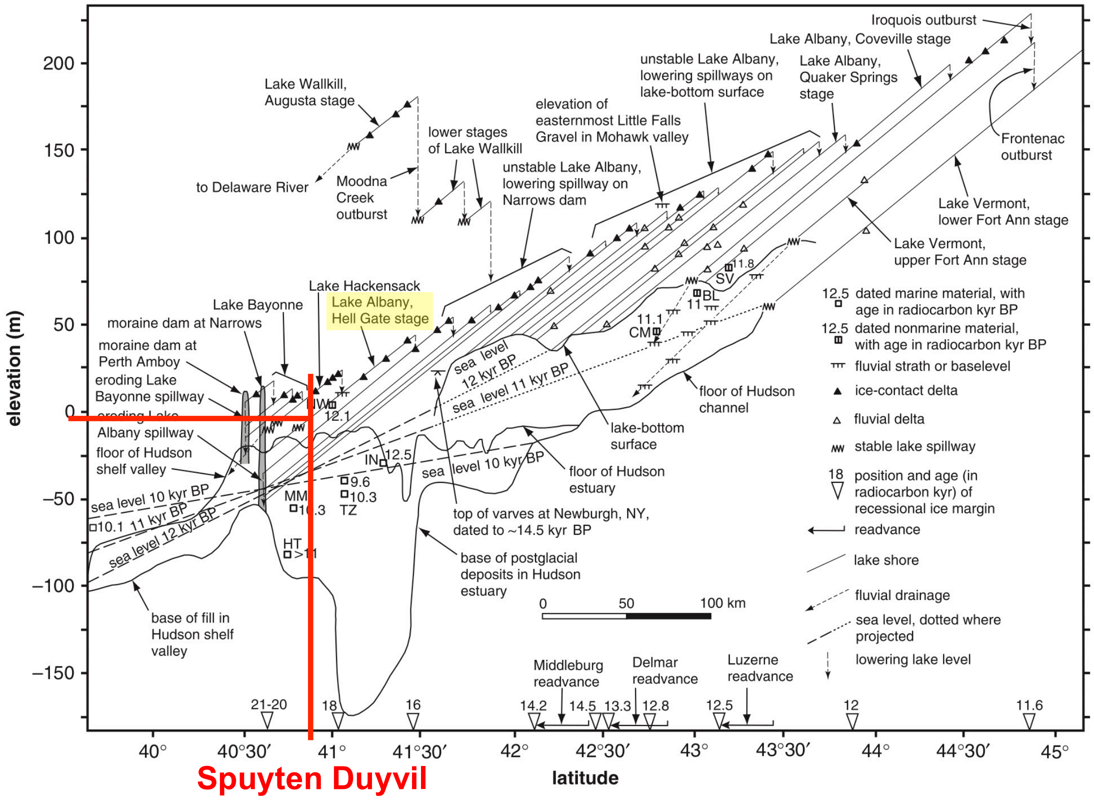

Figure 10 – Projected elevation of Lake Hudson/Albany shoreline at Spuyten Duyvil (Stanford 2010a). The lake level stabilized at approximately elevation -10' (note the scale is shown in meters) and it initially may have been around 20' higher before till at the Hell Gate outlet was eroded down through to bedrock.

The Harlem River valley between the Inwood and Harlem lakes consists of a narrow valley between steep rock walls (Figures 3 & 7). Information about the bedrock elevation down the center of this channel is also limited. The top of rock contour lines on the engineering geologic maps don't really show bedrock elevations under this stretch of the Harlem River. Only one location near West 190th Street has contour lines that cross the river, placing rock at elevation -20'. If this contour is accurate then the Harlem and Inwood lakes were almost certainly connected at some point. The fact that the two lakes are generally similar – present where rock/till is below elevation 0' with roughly the same stratigraphy – indicates that an eventual connection between the two basins was likely. More research is needed to determine to what extent, if any, these lakes were directly connected to Lakes Bayonne and Hudson.

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