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How the Ice Age Shaped New York

Long ago, the region lay under an ice sheet thousands of feet thick. It terminated abruptly in what are now the boroughs, leaving the city with a unique landscape.

By William J. Broad
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At the start of the last ice age, 2.6 million years ago, a sheet of frozen water formed atop North America that kept expanding and thickening until it reached a maximum depth of roughly two miles.

At its southern edge, the vast body deposited tons of rocky debris — from sand and pebbles to boulders the size of school buses. Then, some 18,000 years ago, the planet began to warm and the gargantuan sheet of ice began to melt and retreat.

Today, the southernmost edge of that frozen expanse is marked by a line of rubble that extends across the northern United States for thousands of miles. The largest deposits form what geologists call a terminal moraine.

The intermittent ridge runs from Puget Sound to the Missouri River to Montauk Point on Long Island, forming the prominence that supports its old lighthouse. The ancient sheet of ice also left its mark on a very modern phenomenon: New York City.

The ice over Manhattan would have buried even the tallest skyscraper and was so heavy that it depressed the underlying bedrock. As it melted, giant boulders embedded deep within its flanks landed throughout what became the city. Many are still visible in Central Park, unlikely obelisks scored by time.

But the island was the last hurrah, and the mammoth sheet of ice ended immediately to the south, in Brooklyn, Queens and Staten Island. The terminal moraine, the mounds of rubble left behind, form much of their high ground.

Boulders like this one in Forest Park in Woodhaven were deposited by the ice sheet as it retreated. They are called erratics. George Etheredge for The New York Times

While the line of glacial debris across the northern United States is often poorly delineated, the hilly ridge around New York City tends to be quite prominent. Its maximum height is roughly 200 feet, about that of a tall apartment building.

The rubble slowed the development of the other boroughs for centuries. Early developers sought flat land for homes and buildings and typically ignored the glacial ridges, especially their heights. Land there was too inaccessible, stony and yielding for easy construction.

Eventually, the neglected parcels became strings of parks, cemeteries, golf courses and, in time, some of the region's most attractive neighborhoods, often heavily landscaped and densely wooded.

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Today the ridgeline and its adjoining slopes hold Forest Park and Highland Park in Queens, as well as Prospect Park in Brooklyn. The nearby grounds of Green-Wood Cemetery include Battle Hill, a part of the glacial rise that represents the borough's highest point.

Many city neighborhoods take their names from the ridge's elevations, as well as its leafy embellishments: Glen Oaks, Hollis Hills, Jamaica Hills, Briarwood, Forest Hills, Ridgewood, Cypress Hills, Crown Heights, Prospect Heights, Boerum Hill, Cobble Hill, Park Slope, Greenwood, Bay Ridge, Lighthouse Hill and Arden Heights.

Why should remnants of the last ice age be so prominent in New York City, of all places?

Glacial Relics

It started long ago as the continental ice sheet developed one of its thickest regions over what is now eastern Canada. Vast fields of ice are incredibly weighty. Gravity pushes down hard. Any tilt or slant of the underlying terrain sends the ice moving slowly downslope.

For ages, the Canadian ice kept flowing into a long valley to the south that ran from the Lake Champlain area down through the Hudson River gorge. It was a reliable conduit. The river of ice and rock kept moving relentlessly southward until it hit a region warm enough to halt its slow advance.

During ice ages, glaciers advance and retreat in cycles. Paths differ. But overall, the southern end of the conduit saw massive buildups of boulders and rubble.

In recent times, the resulting moraine got much scrutiny from scientists because of its proximity to one of the nation's first big cities. Just as early maps of the United States often focused on New York, so did geologic inquiries — starting nearly two centuries ago.

Despite the ridge's prominence and early allure for scientists, it turned out to be no rival for skyscrapers and urban distractions. The moraine that shaped the city was all but forgotten.

"Clearly, it's not on the radar," said David E. Seidemann, a professor of geology at Brooklyn College. "The educational system here doesn't emphasize earth science. And there's so much else to do. I'll go to a Yankees game over geology any day."

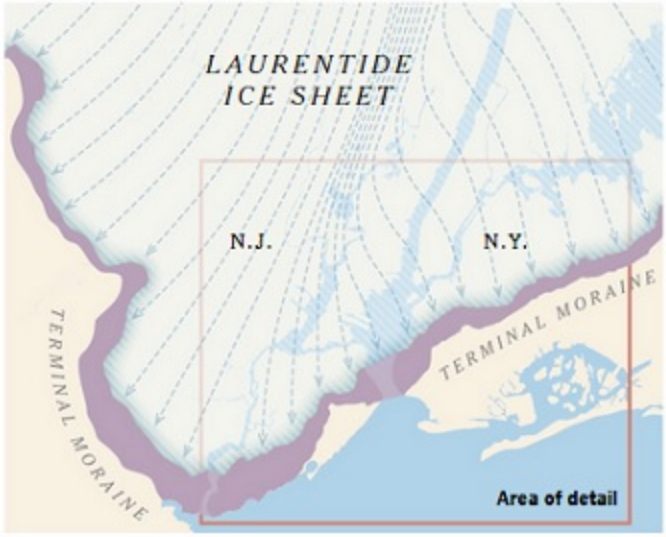
Springtime, noted Sidney Horenstein, a geologist and environmental educator emeritus at the American Museum of Natural History, turns the glacial rise into a band of leafy green and opens a season favorable to its rediscovery.

"It makes it much easier to see," he said recently, while gazing at the ridge from the Staten Island Ferry.

Mr. Horenstein, 81, sought to deepen the re-examination by sharing with The Times a vast trove he had assembled of scientific studies, official reports, news clippings, magazine articles and old books that mention or profile the city's glacial relic.

A City Built on the Glacier's Edge

A ridge of rubble deposited by an ice age glacier shaped the later development of New York City. The ridge, called a terminal moraine, is visible today as a band of hills, parks, golf clubs and cemeteries across three boroughs.



The edge of an ice sheet
During the last ice age, ice sheets covered most of Canada and many northern states. The Laurentide ice sheet ended in a sheer cliff across what is now New York City.

Polished rock
The glacier carried boulders hundreds of miles, smoothing and polishing them along the way. Many of these glacial erratics remain in Central Park.

A great weight
North of the terminal moraine, the ice was about 2,000 feet thick over Manhattan.

An outwash plain
As the glacier melted, streams carrying sand and sediment formed a broad outwash plain. Without this sediment, most of Long Island would be underwater.

Parks and cemeteries
The terminal moraine was often the last land to be developed, and parts of this inexpensive land were set aside for parks, cemeteries and golf courses.

Carving the Narrows
Staten Island and Brooklyn were once connected by the terminal moraine, but glacial floodwaters pouring down the Hudson River some 13,000 years ago burst through the ridge and formed the Narrows.

The moraine exposed
The only exposed part of the terminal moraine in the city is at the tip of Staten Island, in Conference House Park.

Forming Long Island
Advancing glaciers deposited twin moraines of rubble to form Long Island's North and South Forks, and sediments carried by glacial meltwater built up much of the island's South Shore.

By Jonathan Corum | Sources: U.S. Geological Survey; City of New York; New York City Dept. of Parks & Recreation; New York State Museum; National Oceanic and Atmospheric Administration; Sidney Horenstein

Sidney Horenstein, geologist and environmental educator emeritus at the American Museum of Natural History. George Etheredge for The New York Times

His collection also sheds light on how moraine study in general helped geologists in New York and elsewhere discover that the planet had experienced a series of ice ages. That breakthrough came in the mid 1800s.

Ridges, mountains and even flatlands are typically rooted in rocky strata, such as the bedrock that underlies Manhattan and makes it ideal for erecting skyscrapers. But early investigators found the hilly ridges to be composed of clay, silt, sand, pebbles, cobbles and boulders, all jumbled up together.

A related clue was that nearby rocks often looked quite smooth, even polished. At times, their faces also displayed parallel lines of groves and striations.

In 1843, an official report on the natural history of New York State cited vast glaciers as a possible explanation “now attracting much attention” for what geologists were uncovering. But it also listed a dozen other theories, including “the deluge of Noah,” or the biblical flood.

By the 1860s, a growing body of evidence had convinced most scientists that the Earth had endured ages in which rivers of ice transported rocks and coarse sediments over long distances — at times, it turned out, for hundreds of miles.

In the 1880s, the term “ice age” was coming into wide use, and experts began looking into some of the practical consequences.

Then in 1902, the United States Geological Survey published a large folio on metropolitan New York that detailed its rocky underpinnings, including the ridge. Multicolored maps showed the glacial rise amid emerging street grids and neighborhoods.

The accompanying report said the rise exhibited strings of “hillocks and hollows, or interrupted ridges and troughs.” It noted that some depressions held ponds, marshes and small lakes. The report put the feature’s overall width at up to two miles.

A 1902 United States Geological Survey folio shows how the city's grids grew around the glacial ridge. George Etheredge for The New York Times

Ridgewood Reservoir in Highland Park, along the Queens-Brooklyn border. Early reservoirs often were established on the city's moraine. George Etheredge for The New York Times

At first, the city used the stony ridge for woodlots and rain catchments. Slowly, the uses expanded to reservoirs, recreational areas and, in time, neighborhoods in which buildings and houses were built on strong footings and foundations for stability.

Today, despite the wide development of the ridge's lower slopes, a Google Earth view of New York City — a composite of images from April, June and September — shows the glacial relic as an intermittent band of green.

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Forest Park Golf Course in Woodhaven, Queens. Unused land atop the glacial ridge eventually became parkland. George Etheredge for The New York Times

A Geological Guide

Talkative and outgoing, his shirt often untucked, the model of a rumpled geologist, Mr. Horenstein is a native New Yorker with boyish enthusiasm for the city's hidden faults and early beginnings, for ancient blows and catastrophes. A compendium of geologic jokes, he refers to himself not as a raconteur but a *rock*conteur.

Though long retired, Mr. Horenstein regularly gives public tours of the city's geology, some of them organized by the museum. Recently, at a reporter's invitation, he turned his attention to the glacial ridge.

At Umpire Rock in Central Park, overlooking baseball fields, the geologist noted places where glacial ice and rubble had carved massive grooves, wider than a human body.

Yet the rock's overall surface was quite smooth. The reason, Mr. Horenstein said, was that ages of glacial abrasion had acted like sandpaper.

"Kids can slide down the rocks," he said of many Central Park outcroppings.

Umpire Rock in Central Park, whose distinctive grooves were formed by glacial ice and rubble.
George Etheredge for The New York Times

Left, Mr. Horenstein at the American Museum of Natural History. Right, finer grooves etched into Umpire Rock. George Etheredge for The New York Times

Throughout the park are places where the retreating ice had dropped giant boulders that geologists call *erratics*, after the Latin word *errare*, to wander. By definition, the boulders differ in composition from surrounding rocks. Some of the park's erratics sit perched atop flat rocks, looking at times like alien monuments.

"They're rounded," Mr. Horenstein said, because rivers of ice kept "dragging them around."

Later, on a visit to Staten Island, he pointed to the much-celebrated skyline of Lower Manhattan. Current estimates put the ice's thickness there at roughly twice the early calculations — not 1,000 feet, but closer to 2,000 feet, and possibly more.

“It was taller than any building,” Mr. Horenstein remarked, “even the Freedom Tower.” The skyscraper at the very top of its spire measures 1,776 feet high, after the nation’s birthday.

The forward edges of glaciers can be inclined or sheer, like a cliff. Mr. Horenstein said geologists believe the local face was sheer. Its precipitous edge shed not only tons of rocky debris but gargantuan blocks of ice.

The ice’s overall weight was so immense that it depressed the bedrock of the New York City region — and then, following the sheet’s retreat, the rocky depths slowly rebounded. Mr. Horenstein said the rise is calculated at more than 150 feet.

The ice sheet is estimated to have been 2,000 feet or more thick, taller than One World Trade, whose spire measures 1,776 feet. George Etheredge for The New York Times

At Fort Wadsworth, a historic battlement next to the Verrazano Bridge, we stood atop the moraine and looked across the Narrows, the strait between Staten Island and Brooklyn. The land that would become the two boroughs had originally been connected by the glacial ridge.

Some 13,000 years ago, a large accumulation of icy water from melting glaciers was suddenly unleashed upstate. A towering wave of destruction crashed down through the Hudson gorge and proceeded to smash the southern end of the local moraine to smithereens.

“It was biblical,” Mr. Horenstein said. The wave created the Narrows, which now connects the Atlantic Ocean to one of the world’s largest natural harbors.

In the metropolitan area, the southern tip of Staten Island overlooks the Arthur Kill and Raritan Bay, and represents the southernmost part of the glacial rise. The site hosts the Conference House Park. It takes its name from an unsuccessful peace conference held there in 1776 during the Revolutionary War.

As we walked past a stone manor house where the meeting took place, Mr. Horenstein pointed to the rounded rocks in its walls and, based on color and texture, proceeded to tick off their likely sites of origin — some from upstate New York, some from New Jersey, and so on.

What fraction came from the glacial ridge?

“All of them,” he replied. “It was the local building material.”

We walked down to the nearby beach and wandered a few hundred feet to where the land formed a sandy bluff. It offered a rare glimpse into the heart of the ridge: a jumble of clay, silt, pebbles and boulders in a fragile matrix laid bare by the action of tides, hurricanes and pounding waves.

In all of New York City, “this is the only place you can see the moraine clearly,” Mr. Horenstein said, leaning into the wind. “This is it, the southernmost end.”

Mr. Horenstein held up a rounded stone. Somehow, it ended up in reporter’s backpack as a souvenir of the day.

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The moraine once joined Brooklyn and Staten Island, but was smashed 13,000 years ago by a catastrophic wave, leaving the Narrows. George Etheredge for The New York Times

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Left, a stone recovered by Mr. Horenstein and kept as a souvenir. Right, the wall of the stone manor that housed the failed 1776 peace conference. George Etheredge for The New York Times

Remarkably, millions of people live on or near the glacial ridge.

In all, it runs for roughly 30 miles beneath New York City. Invisibly, it links three boroughs, offering mute testimony to the power of vanished ice.

If the ridge is lost history to most of the city's inhabitants, at least one knows something about the art of bringing it back to life.

"It keeps me young," Mr. Horenstein said. "There's always something to see, something you missed, something new."

George Etheredge for The New York Times

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