CITY AT THE WATER'S EDGE McCULLY

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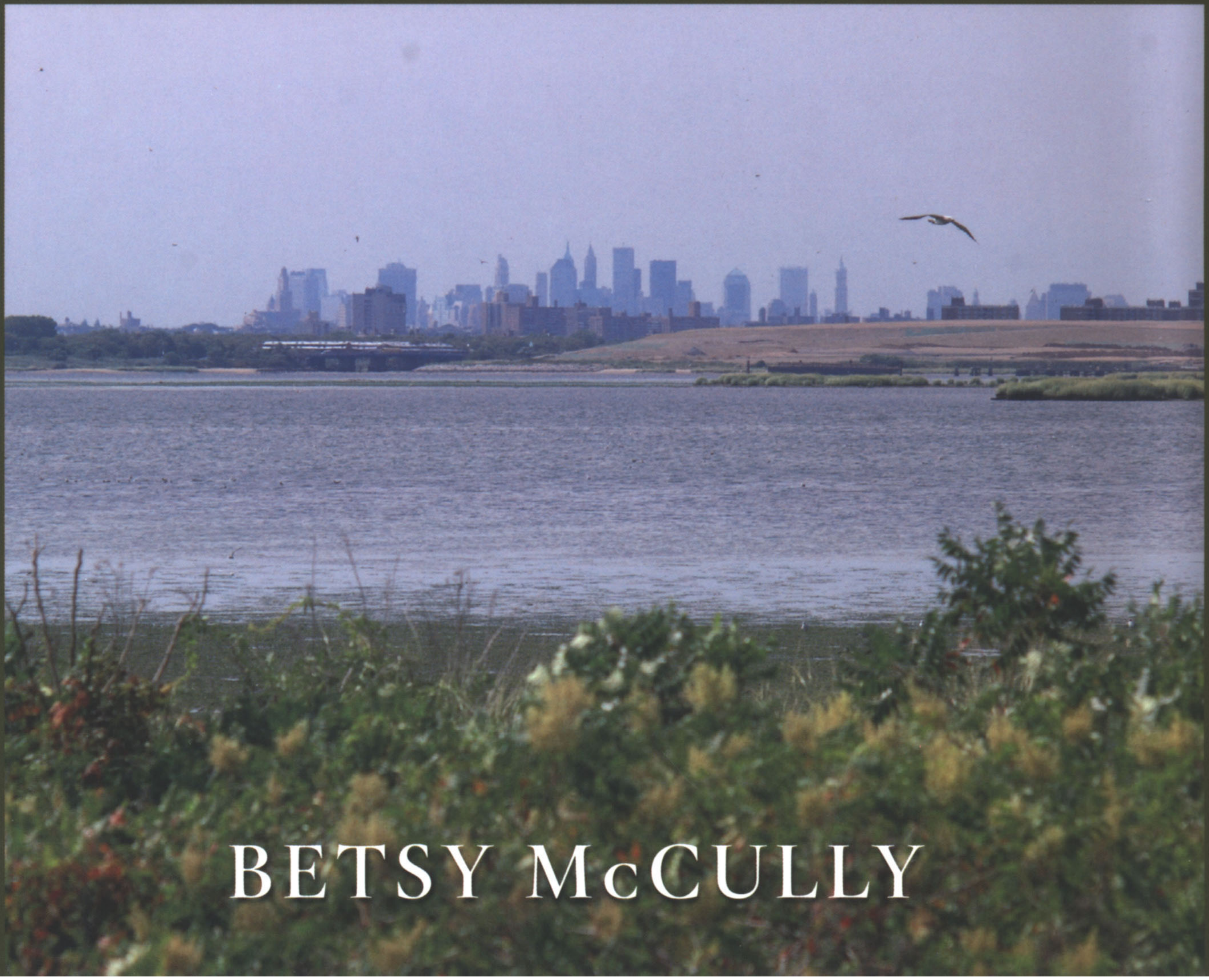
A NATURAL HISTORY OF NEW YORK



BETSY McCULLY

City at
the Water's Edge

Dear Charles,
Thank you for your important contribution to my book.
Wishing you a productive 2007!
Betsy McCully

Acknowledgments

This book is the culmination of a fifteen-year project. It could not have been completed without the help of many people.

I thank my first reader, Kirkpatrick Sale, whose book *Dwellers in the Land* inspired me, and whose belief in my project encouraged me to go forward. The urban bioregionalist Peter Berg was an invaluable resource of ideas and materials on the sustainable city. I also wish to acknowledge Charles Merguerian of Hofstra University, who read and corrected a first draft of the geology chapter, and Robert Grumet, who read and commented on an early draft of the chapter on the Lenapes.

I thank my colleagues at Kingsborough Community College who have expressed confidence in my endeavor and enthusiasm for the project. I especially wish to acknowledge Gene McQuillan, Tara Weiss, Robert Singer, Len Green, Lea Fridman, Norah Chase, and Bonne August. I could not have completed the book without generous research grants from the Professional Staff Congress of the City University of New York during the years 2003 to 2005.

I spent many hours researching materials at the excellent libraries of New York City, including the library of the American Museum of Natural History, the rare book room of the Brooklyn Botanic Garden, and the New York Public Library.

In the final stages of writing my book, the meticulous editing of Audra Wolfe, senior science editor at Rutgers University Press, has made me a better writer and I believe made a better book. I am also grateful to Steven Handel of Rutgers University, who generously sent me materials on habitat restoration projects in New York City.

I wish to express special thanks to my son, Ben Cooper, who has supported me in untold ways. He has trekked with me in the wilds of New York City, as we explored its many parks and snapped countless pictures of the plants and animals which inhabit them. A professional photographer, Ben has taken several of the photos that appear in this book.

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Bedrock New York

A cold day in January is a good time to walk the beach. Only hardy, beach-loving souls are out here on Coney Island, drawn to the shining expanse of the Atlantic lit by the low winter sun as it arcs across the southern sky. A few gulls warm their breasts in the sun, a dog races ecstatically along the water's edge distantly trailed by his bundled-up owner, and a human scavenger sweeps her metal-detector across the sand. I search for what the tide has disgorged—an interesting piece of driftwood, an unbroken conch shell—and a jagged piece of rock that glints and glitters when the sun strikes it catches my eye. I pick it up and turn the rough, flaking stone in my hand, knowing I am touching the bedrock of New York City.

This rock connects me to both the natural and human history of this place. The jetties that protect beaches and homes from the ocean's direct onslaught are comprised of ripped-up bedrock, called rip-rap. These were quarried during Manhattan's great building boom at the turn of the last century, the by-products of subways and skyscrapers. The rock I hold in my hand is a piece of Manhattan schist, one of three layers of rock that form the bedrock of New York City. The rocks bear testimony to the rich geological history of the city, a story that takes us back a billion years. Imagine a Manhattan skyline of jagged mountain peaks.[1]

This piece of schist tells me that around 450 million years ago, volcanoes erupted off the northeastern coast, spewing lava that cooled and gradually formed a volcanic island arc. Winds blew volcanic ash into a shallow marine basin, where sediments accumulated in mineral-rich layers that were gradually compressed into shale. The sediment-laden oceanic crust slid beneath the lighter continental crust in a process known as subduction, and the volcanic island arc accreted to the continent. The mica-rich shale, subjected to the intense heat of the earth's mantle, was recrystallized and transformed into the schist I hold today, plucked out of the sands of Coney Island.

Most of New York City is built on three layers of strata known as Manhattan Schist, Inwood Marble, and Fordham Gneiss. The exception is Staten

Island, where a northeast-trending ridge of Serpentinite erupts to the surface in the island's middle, peaking at 540-foot-tall Todt Hill, the highest point in New York City. Schist forms the spine of Manhattan from the Henry Hudson Bridge on its north end to the Battery on its southern tip; it dips abruptly several hundred feet below ground at Washington Square, and makes a gradual ascent beginning at Chambers Street. These dips and rises account for the gap between "midtown" and "downtown" in the Manhattan skyline, since tall buildings had to be anchored on solid bedrock, and not on the glacial till that fills the valleys. The contemporaneous Inwood Marble, metamorphosed from limestone, forms beds 150 to 500 feet thick beneath the Harlem River and adjacent regions known to geologists as Inwood Lowland; it underlies the East River and the Harlem Lowland and above ground forms a ridge from Dyckman Street on the upper west side northward to Marble Hill. The billion-year-old Fordham Gneiss erupts to the surface in the Bronx, forming the Riverdale and Grand Concourse ridges. The three strata of schist,

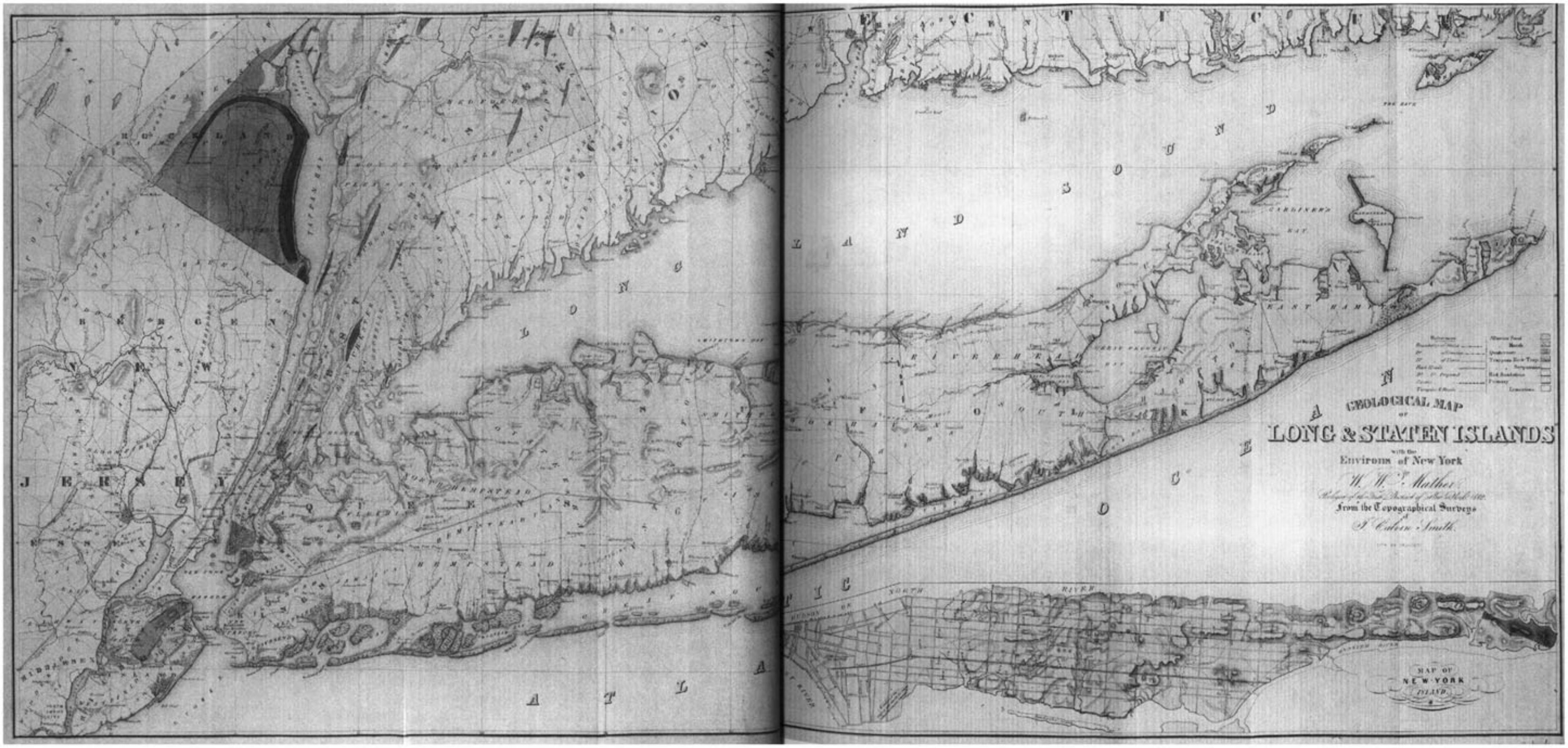

Fig. 1.1. W. W. Mather, Geological map of Long and Staten Islands with the environs of New York, 1842. (Courtesy of The Lionel Pincus and Princess Firyal Map Division, The New York Public Library, Astor, Lenox and Tilden Foundations.)

Table 1.1 Geologic Time Chart

(with selected major geologic events from southeastern New York and vicinity)

Era Periods (Epochs)	Years (Ma)	Selected Major Events
Cenozoic		
(Holocene)	0.1	Rising sea forms Hudson Estuary, Long Island Sound, and other bays. Barrier islands form and migrate.
(Pleistocene)	1.6	Melting of last glaciers forms large lakes.
		Drainage from Great Lakes overflows into Hudson Valley.
		Dam at The Narrows suddenly breached and flood waters erode Hudson shelf valley.
		Repeated continental glaciation with five (?) glaciers flowing from NW and NE form moraine ridges on Long Island.
(Pliocene)	6.2	Regional uplift, tilting and erosion of coastal-plain strata; sea level drops. Depression eroded that later becomes Long Island Sound.
(Miocene)	26.2	Fans spread E and SE from Appalachians and push back sea. Last widespread marine unit in coastal-plain strata.
Mesozoic	66.5	
(Cretaceous)	96	Passive eastern margin of North American plate subsides and sediments (the coastal-plain strata) accumulate.
	131	(Passive-margin sequence II).
(Jurassic)	190	Baltimore Canyon Trough forms and fills with 8,000 feet of pre-Cretaceous sediments.
		Atlantic Ocean starts to open.
		Newark basins deformed, arched, eroded.
	200	Continued filling of subsiding Newark basins and mafic igneous activity both extrusive and intrusive.
(Triassic)		Newark basins form and fill with nonmarine sediments.
Paleozoic	245	
(Permian)		Pre-Newark erosion surface formed.
	260	Appalachian Orogeny. (Terminal stage.) Folding, overthrusting, and metamorphism of Rhode Island coal basins; granites intruded.
(Carboniferous)	320	Faulting, folding, and metamorphism in New York City area. Southeastern New York undergoes continued uplift and erosion.
(Devonian)	365	Acadian Orogeny. Deep burial of sedimentary strata.
		Faulting, folding, and metamorphism in New York City area.
		Peekskill Granite and Acadian granites intruded.
(Ordovician)	440	Taconic Orogeny. Intense deformation and metamorphism.
		Ultramafic rocks (oceanic lithosphere) sliced off and transported above deposits of continental shelf.
	450	Cortlandt Complex and related rocks intrude Taconian suture zone. (Cameron's Line). Arc-continent collision.
		Great overthrusting from ocean toward continent. Taconic deep-water strata thrust above shallow-water strata.
(Cambrian)	510	(Passive-margin sequence I).
		Shallow-water clastics and carbonates accumulate in west of basin (= Sauk Sequence; protoliths of the Lowerre Quartzite, Inwood Marble, part of Manhattan Schist Formation).
		Deep-water terrigenous silts form to east.
		(= Taconic Sequence; protoliths of Hartland Formation, parts of Manhattan Schist Fm.).
Proterozoic		
	570	Period of uplift and erosion followed by subsidence of margin.
(Z)	600	Rifting with rift sediments, volcanism, and intrusive activity. (Ned Mountain, Pound Ridge, and Yonkers gneiss protoliths).
(Y)	1100	Grenville Orogeny. Sediments and volcanics deposited, compressive deformation, intrusive activity, and granulite facies metamorphism. (Fordham Gneiss, Hudson Highlands, and related rocks.)
Archeozoic		
	2600	No record in New York.
	4600	Solar system (including Earth) forms.

marble, and gneiss are complexly interfolded. Each layer tells its own story from which we can reconstruct the geological map of New York City, one that delineates a continental mosaic of ever-shifting boundaries.

The boundary where North America's eastern edge fused with the volcanic island arc is an extensive thrust fault zone known as Cameron's Line, which trends southwest to northeast from Staten Island into western Connecticut. East of Cameron's Line, in western Connecticut and southeastern New York, lies the Hartland Formation, first mapped by geologist Charles Merguerian of Hofstra University in 1983. This strata was metamorphosed from shale, graywacke, and volcanic rock that had formed in deep ocean water during the early Paleozoic period. West of Cameron's Line lies the Manhattan Prong, composed of metamorphosed rocks of shallow water origin—Fordham Gneiss, Inwood Marble, Manhattan Schist, and Lowerre Quartzite (metamorphosed sandstone). The east-west division is hardly a neat one. A recent map of Manhattan drawn by Charles Merguerian and his son Mickey Merguerian of Duke Geological Laboratory depict the deep-water schist unit of the Hartland Formation as the bedrock of Manhattan south of Eightieth Street. Cameron's Line zigs and zags across Central Park. The presence of the Hartland Formation in Manhattan tells the story of a violent east-to-west overthrusting of the older schist unit onto younger schist strata during the Taconic orogeny, or mountain-building episode. Prior to Merguerian's discovery, all of the schist on Manhattan was designated as "Manhattan Schist"; now, Manhattan Schist refers to the younger layer to distinguish it from the older Hartland Schist.[2] The schist, marble, and gneiss strata of Manhattan are by no means arranged in simple layers like the leaves of a book; over hundreds of millions of years, they were intensely folded, pushed up into mountains, eroded and weathered, buried under thousands of feet of sediment, and exposed by glacial scouring.

On Staten Island, the serpentinite formation was originally formed 450 million years ago in deep water, probably at an oceanic trench, and is considered an igneous rock (derived from the earth's mantle). During the Taconic orogeny, a sliver of this deep oceanic strata was broken off and thrust westward over existing continental bedrock. Millions of years later, during the ice age, glaciation scoured and sculpted the strata into roche moutonee outcrops, a geological term that describes the rounded shape (*moutonee* is French for sheep).[3]

Cameron's Line marks the "suture" boundary where the North American plate on its eastern edge collided with the oceanic plate. It testifies to great earth-moving forces that are hardly dormant. Indeed, a number of faults crisscross Manhattan. One northwest-trending fault underlies 125th Street. South of 125th Street two more faults slice through the island, one at 14th Street; north of 125th Street five additional faults veer northwestward, as mapped by Charles Merguerian in water tunnels between 1983 and 1985. These northwest-trending faults transect the northeast-trending faults, cutting up Manhattan into blocks that are by no means stable. Climbing down into the water tunnel beneath Amsterdam Avenue at 125th Street, Merguerian was startled to find a ninety-degree rotation of "highly fractured Manhattan Schist," indicating strike-slip motion along the 125th Street fault. In fact, Merguerian

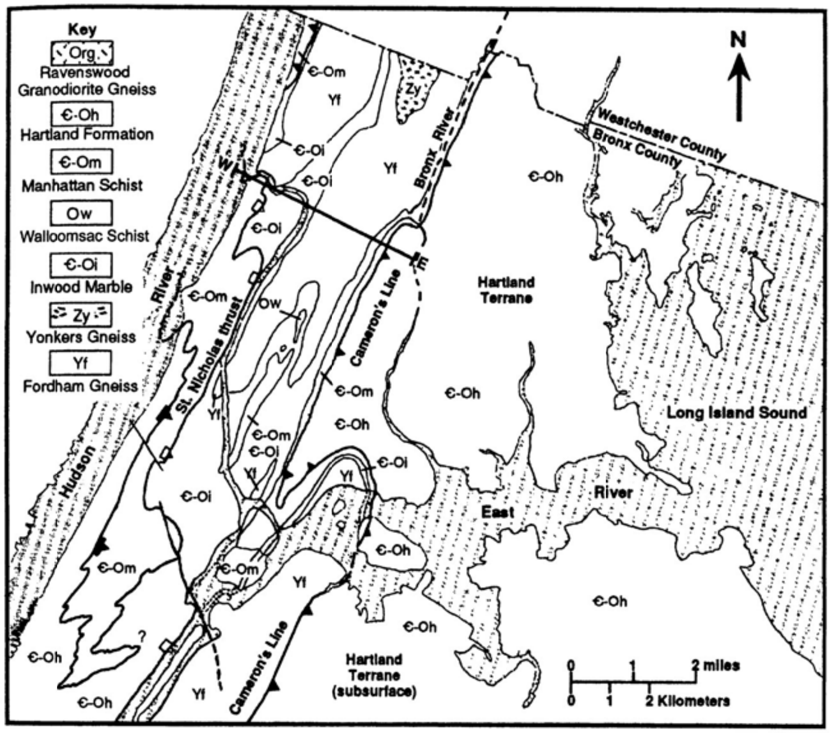

Fig. 1.2. Geological map of northern segment of New York City, including portions of Manhattan, Queens, and the Bronx. (Courtesy of Charles Merguerian, Hofstra University, 2004.)

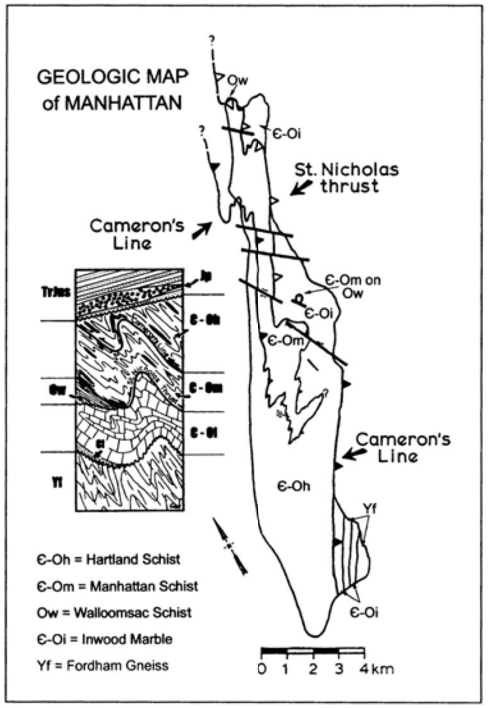

Fig. 1.3. Bedrock map of Manhattan showing the three schist units. (Charles Merguerian, Hofstra University, and Mickey Merguerian, Duke Geological Laboratory, 2004.)

notes, a magnitude 4.0 earthquake on October 19, 1985, centered in Westchester County (known as the Ardsley quake), "was related to episodic slip along a fault with a northwest trend." The last earthquake before that was in 1884—a magnitude 5.0 centered offshore to the south of Brooklyn, and felt as far away as Philadelphia and Hartford. Could it happen again? Absolutely, Merguerian assures us, and with far more damage, considering the extensive construction over landfill that has taken place in the last few decades in New York City.[4] After conducting extensive mapping of the new Queens water tunnel between 1998 and 2000, Mergeurian concluded:

> Ground-breaking rupture and seismic activity cannot and certainly should not be ruled out for this region. Because large magnitude earthquakes have struck NYC in 1737, 1783, and 1884, this new data identifies a potential failure surface along which earthquake energy could be released. Given the population, cultural development, infrastructure, and financial investment concentrated in New York City, the specter of a massive earthquake must be considered in revising existing building code designs and emergency preparedness procedures. Unfortunately, despite the scientific community's pleas for action, severely limited emergency planning exists at the present time. Clearly, this should be changed, as pre-emptive urban seismic planning is an absolute necessity in New York City.[5]

New York City is located, after all, at a site where continental plates collided and broke apart—cataclysmic events written in the rocks. According to plate tectonic theory, the earth's surface is composed of crustal blocks, or plates, that "float" on a deeper layer of plastic rock acting like a conveyor belt. The continental and oceanic plates are continually moving around, crashing into each other (what geologists call "docking") or rifting. Half a billion years ago, the North American continent was tipped over on its eastern side and bisected by the equator, placing the New York region in a subtropical zone south of the equator. The continent then was much smaller in area, and New York was part of the submerged continental shelf. Between roughly 450 and 250 million years ago, a series of continental collisions known collectively as the Appalachian orogeny culminated in the creation of the supercontinent Pangaea. The first of these mountain-building episodes, the Taconic orogeny, pushed up the Taconic mountains in eastern New York as North America collided with an offshore volcanic island arc. During this event, marine shales and limestones metamorphosed, or melted and recrystallized, into Manhattan Schist and Inwood Marble. The same event thrust a layer of billion-year-old Fordham Gneiss (metamorphosed during the earlier Grenville orogeny) onto the schist and marble strata, forming what geologists call the Manhattan Prong, an ancient ridge that extends from New England to its southernmost point beneath Manhattan. The second event, the Acadian orogeny that took place between 375 and 335 million years ago, pushed up alpine mountains in New England. Sediments that flushed westward from these mountains buried the eroded stumps of the Taconics and created the Catskill Delta. The climax event, the Alleghenian orogeny of 250 million years ago, was a huge continent-continent collision that uplifted colossal mountains. The Appalachians formed the backbone of Pangaea, comprised of the earth's continents like pieces of a jigsaw puzzle. It stood its ground for 50 million years.

During this period, the mountains were being steadily eroded, their sediments flushed by streams and rivers into alluvial fans and lakes. Over time, the sediments cemented into layers of sandstone and siltstone, forming the great Permo-Triassic red beds such as those in the Connecticut River Valley and New Jersey's Newark Basin. The superabundance of oxygen in the earth's atmosphere at that time oxidized the sediments, in effect rusting them.

Two hundred million years ago, the earth began to move again. A plume of molten rock from the earth's mantle erupted with such cataclysmic force that it tore a gash in the crust. Rifting, volcanic eruptions, floods, and crustal slumping marked the breakup of Pangaea, as North America pulled away from Africa. The earth's crust was being stretched and splintered into fault blocks, which dropped down, creating basins. The basins, or rift valleys, filled with sediments and sank further, in the process tilting up ranges like the Watchung of New Jersey, west of the Newark Basin. (You can see the same basin-and-range conformation in northwest Africa, like two matching pieces in a geological puzzle.) Lava erupted and flowed through rift valleys, hardening into basalt that capped the redbeds. Where the lava intruded instead of flowing over the layers, it hardened to form blocks of dolerite encased in sandstone. Over time, the rock layers were tilted and exposed, and the sandstone envelope eroded, leaving great vertical blocks of diabase sill that extend in a 1,000-foot bed from Haverstraw, New Jersey, to Staten Island. The dramatic maroon columns of the Palisades, 400-foot-tall cliffs overlooking the west side of the Hudson River, testify to the great forces that broke apart Pangaea.

On Coney Island, a walk on the jetties here offers a chance to touch the three strata of New York City's bedrock: Manhattan Schist, Inwood Marble, and Fordham Gneiss. The whitish marble blocks are granular like sugar, many streaked with yellow and red derived from iron minerals. If you look closely, you may discern the original limestone layers of the metamorphosed rock. Both the schist and gneiss glint with mineral grains such as biotite mica. Schist is a coarse, flaky rock that separates easily along cleavage planes and may show a wavy structure. Gneiss is a denser rock, with buff bands of feldspar crystals alternating with charcoal bands of biotite mica. Both schist and gneiss may be veined with quartz and studded with garnet.

Holding a rock that I know has been pushed deep within the earth's crust and thrust high in an ancient mountain, I am humbled by the forces that

shape our planet. Plate tectonics yields a moving map of the world, a dizzying dance of the continents. One can never be sure where "here" is: this rock was not formed "here" but "there," when eastern North America was south of the equator, and the continent was flirting with Africa. It could not have been formed without being subjected to the intense pressure and heat of the lower crust, and it got there only by sliding down into it, as the heavier oceanic crust was subducted beneath the lighter continental crust. This picture of the earth consuming itself revives the ancient myth that depicts the world as a snake swallowing its tail. Envision thick sea-bottom sediments compressing into shale, sliding into the earth's mantle, metamorphosing into schist. When North America bumped into Africa, the schist strata were folded and uptilted into jagged mountains. As these mountains eroded, the weight of their sediments ultimately buried their own roots. They were inundated by a sea, exposed again when the sea regressed, and eventually became the bedrock of the archipelago that forms New York City. And I hold this rock in my hand, turning it in the light, only because humans—who settled here in the last instant of time—blasted it out of the bedrock when they wanted a subway, and transported it here when they wanted seawalls and jetties to protect their homes from the eroding onslaught of the ocean on the land they had reclaimed from the sea.

To break out of the textbook terminology of New York's complex geology, I must walk the terrain and touch the rock. Manhattan is one of the best places to explore the island's rocky past.

Twenty thousand years ago, a glacier scoured the island's surface to expose beautiful outcrops of schist. Both Hartland and Manhattan schist can be seen in Central Park. Hartland schist is exposed in the southern part of the park, while Manhattan schist crops out in the northern end. A famous example of Hartland schist is Umpire Rock, a huge hump of rock located at the school playground in the west side of the park around Sixty-third Street. Two northeast-trending brittle faults cut through the rock, and on its northwest edge, northwest-trending glacial troughs bear witness to torrents of glacial meltwater that once gouged out channels and scoured the bedrock. Although most Manhattan Schist outcrops are exposed in the park's northern half, an example in the southern half can be seen just west of the Carousel off Sixty-fifth Street, distinguished from the gray-weathering Hartland Schist by its rustier coloring.

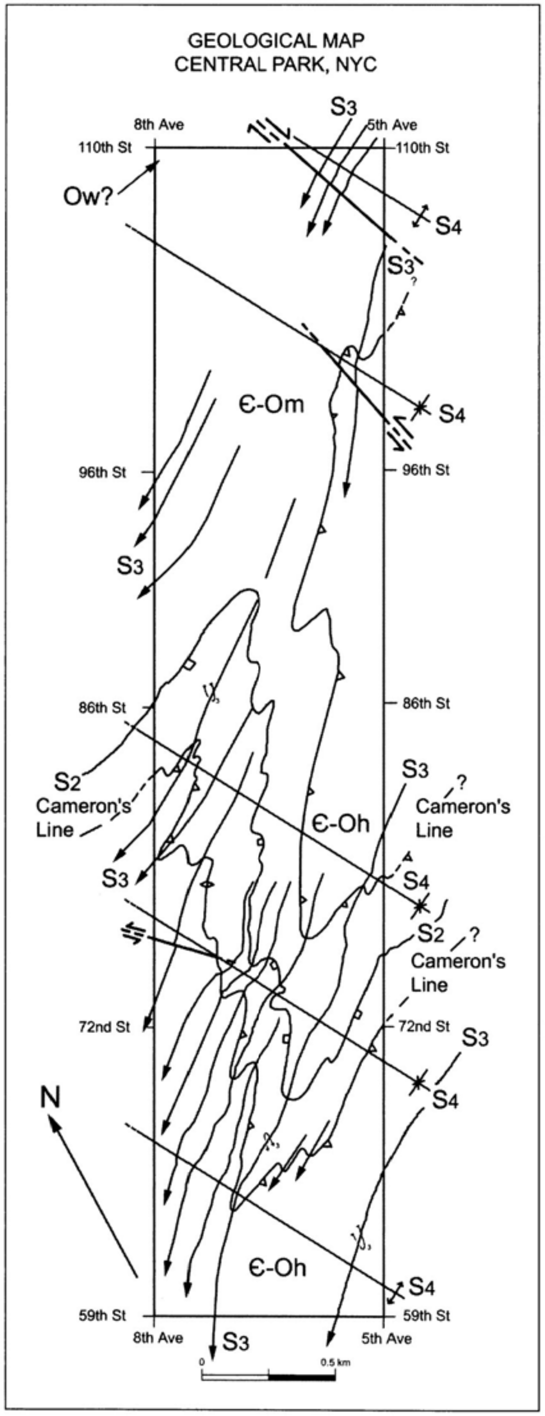

Fig. 1.4. Geological map of Central Park. (Merguerian and Merguerian 2004.)

One of the best places to see all three strata of New York City's bedrock is at the northern tip of Manhattan. Inwood Hill Park affords dramatic views of a ridge of Fordham Gneiss, just across Spuyten Duyvil Creek in the Bronx. Within the park, beautiful outcrops of Manhattan Schist are exposed, and just across the street from the park, Inwood Marble erupts to the surface. The park is located on a high schist ridge that rises 200 feet above the Hudson River on its west side, with the Harlem River to its east. The park may be reached by subway (the A train to 207th Street and Broadway), but a drive and walk allows me to experience the dips and rises of the ancient mountain terrain. Driving west on 181st Street, I turn north onto Broadway. On the west side, the forested ridge shadows the bustling neighborhood of densely built low-rise apartment buildings. Shoppers throng the hilly sidewalks of the main business district, and cars, trucks, and buses thread their way through the streets. Where Broadway crosses Dyckman Street, the terrain flattens out. This is the so-called Dyckman Street Gap, a lowland underlain by Inwood Marble. Typically, Inwood Marble — softer and more water soluble than schist — is the bedrock of the lowlands and river valleys of northern Manhattan and the Bronx.

From Broadway I turn west at 207th Street, then north onto Seaman Avenue. At Isham Street I park the car and get out to walk around the marble outcrops of the pocket park across from the entrance of Inwood Hill Park. The sugary rock crops out in a sinuous ridge, its colors ranging from white to bluish-gray, weathering to brown. Pegs of quartzite (known by the French word *boudins* for their sausagelike shape) intrude segments of the rock, indicating intense metamorphism. I pick up a broken-off piece and run my thumb over the crumbly texture.

Crossing Seaman Avenue, I enter Inwood Hill Park. I never walk alone so I am joined by my constant walking companion, my husband, Joe Giunta. We follow the path that winds uphill toward Overlook Meadow. A glacial erratic placed on the path bears a plaque that testifies to the alleged sale of Manhattan to Peter Minuet on this spot, where a giant tulip tree once grew. This is known as the Shorakapok Rock, after the name the Lenapes called their village site. North of this rock, a large field slopes down to a tidal marsh that edges Spuyten Duyvil Creek, the waterway that snakes around the island's northern tip connecting the Harlem and Hudson rivers. Inwood Marble underlies this lowland, which once served as planting fields for the Lenapes and later for the Europeans when the area was still rural.

The path takes us up through increasingly dense oak-hickory woodland that has been uncut since the Revolutionary War. The straight massive trunks of tulip trees tower over the canopy, underlain by a rich understory of sassafras, witch hazel, and viburnum. Narrow overgrown trails descend from the main path toward kettle ponds, but their remoteness discourages us from exploring. As we ascend the western ridge, we stop to examine the massive schist outcrops. The wavy structure of one outcrop testifies to the rock's heating during metamorphosis. The outcrops glint with mica flakes and garnet crystals. Muscovite mica looks silvery gray, while biotite mica looks blackish. The schist strata also contain lenses of blackish amphibolite, a metamorphosed igneous rock formed in deep water before the Taconic Orogeny.

We ascend to Overlook Meadow, listening to the roar of cars on the Henry Hudson Parkway below. The forest opens into a clearing where we can look westward across the Hudson to the Palisades. A rusty chain-link fence has been partly peeled away to allow access to the schist ledge overlooking the river gorge. We step gingerly, for the ledge tilts down to a steep drop-off. It is a somewhat hazy day, but the Palisades' sheer maroon cliffs rise across the water, offering us a window into another geological era. Indeed, the Hudson marks the boundary between two geological eras: on its west side the Palisade cliffs date to the breakup of Pangaea that began 200 million years ago; on its east side, the schist ledge dates back 500 million years, when the continents began to clump and fuse into the supercontinent Pangaea. To take us back even further in time, we continue up the path to the northernmost end of the park, where the Henry Hudson Bridge crosses into the Bronx. Looking across Spuyten Duyvil Creek, we can see billion-year-old Fordham Gneiss snaking to the surface as Riverdale Ridge in the Bronx.

Back home, I take a sunset walk along the beach and contemplate what geologists of old called the "testimony of the rocks." Here on Coney Island in Cenozoic time, buildings cluster at the edge of sand and water, themselves made of rock and mineral, worn away by salt and wind and rain and pollution, in various stages of decay. Coney Island rusts; sand drifts under the boardwalk and shapes itself into incipient dunes until bulldozed flat again. The shifting tidal lines along the beach repeat, on a microscale, the shifting boundaries of continents. Mica dust leaves silvery traces like tidal shadows. The shore can teach us about the tenacity of life on the edge and its astounding capacity to transform itself and evolve new forms. Metamorphosis is the recurring theme of nature, whether of rocks or animals. In a few mineralized grains of sand, in a pebble or rock fragment, in the crushed mussel shells that litter the beach, in the barnacles that encrust the jetties, in the microscopic life of a small tide pool—the history of the evolving earth is telescoped.