Bedrocks of the Newark Basin--Sediments and Volcanics

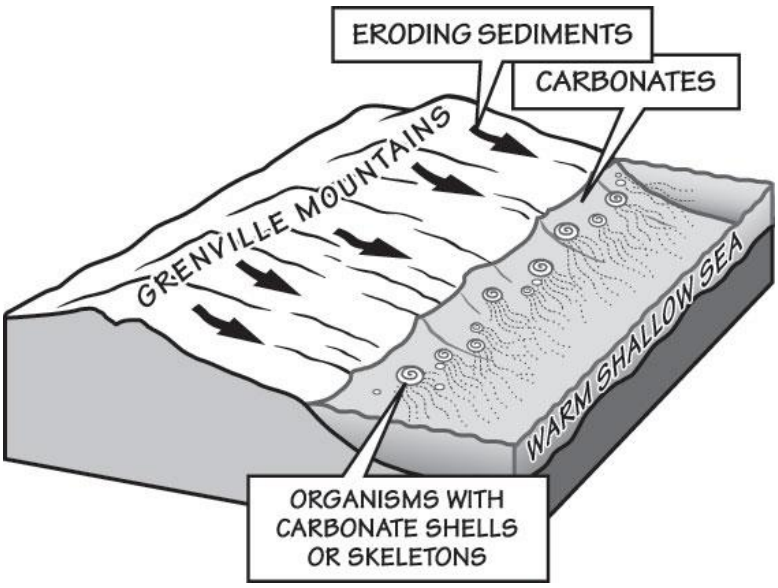
1. The Beginnings

The oldest rocks beneath what became the Hackensack River and surrounding area began to form about 1 billion years ago when collisions between ancient continents created a mountain chain that stretched from what is now Canada to Mexico. These Grenville Mountains show evidence of intense heat and pressure in the metamorphosed sedimentary rocks with igneous intrusions. Today they are exposed in the Ramapo Mountains of NJ, as well as in the Hudson Highlands, and the Fordham Gneiss in the Manhattan Prong in NY. They form the basement of the crust beneath the Hackensack River basin.

Exposures of Grenville-age rocks are found up and down the East Coast and Canada. NOTE: Figures, unless otherwise noted, from [The Teacher-Friendly Guide to the Earth Science of the Northeastern US](#)—illustrations by J. Houghton.

2. Erosion and New Mountain Building

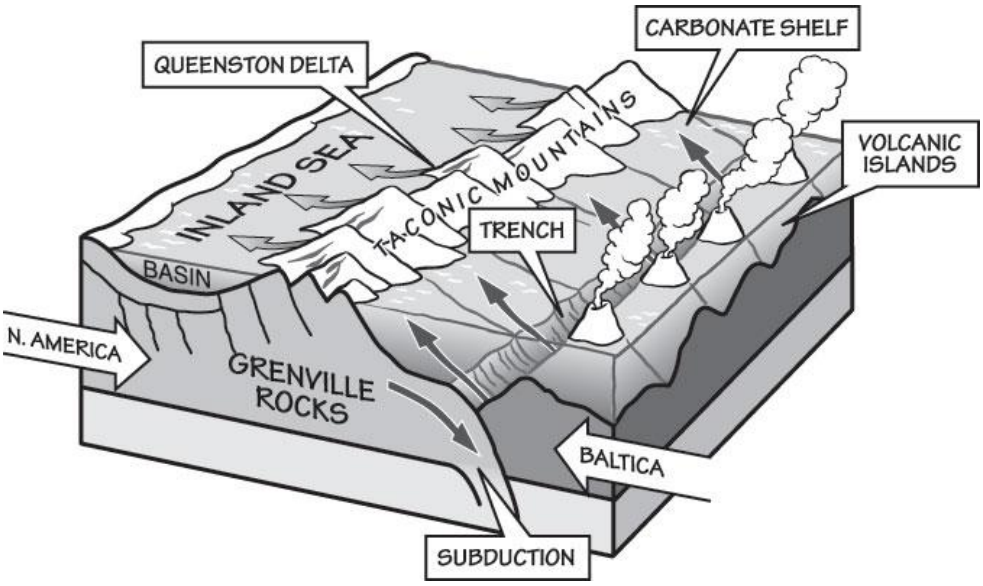
When the Grenville Mountains existed, what was to become North America was located across the Equator, with what is now the East Coast then facing southward. The rocks were slowly eroded into what is called the Iapetus or Proto-Atlantic Ocean. Sediments of sand, clay, and carbonates were deposited on a broad, flat continental margin.



The Grenville Mountains gradually eroded over millions of years, depositing sediments on either side of the range, becoming layered with carbonate rocks that were forming in the proto-Atlantic Ocean along the margin of the continent.

Today, these rocks are preserved in the sandstones, shales, limestones, and marbles overlying the metamorphic rocks in the Ramapo Highlands and to its west in the Ridge and Valley Province.

During the Ordovician Period (about 470 million years ago,) the Iapetus Ocean began to close as the proto-North American and proto-Europe (Baltica) plates approached each other. Folding, faulting, uplift, and intrusions caused new mountains to arise—the ancestors of the Taconics. To the east, an off-shore trench separated the Grenville rocks from a chain of volcanic islands. To the west, a large inland sea formed. Sediments eroded from the ancient Taconics formed the Queensland Delta rocks of New York and Pennsylvania. Rocks of this episode are not found in the Hackensack River basin, but are on its boundary, especially on the east in Manhattan and Westchester.



Volcanic islands formed where the plates were forced together as the Iapetus Ocean closed. The compression crumpled the crust to form the Taconic Mountains and a shallow inland sea.

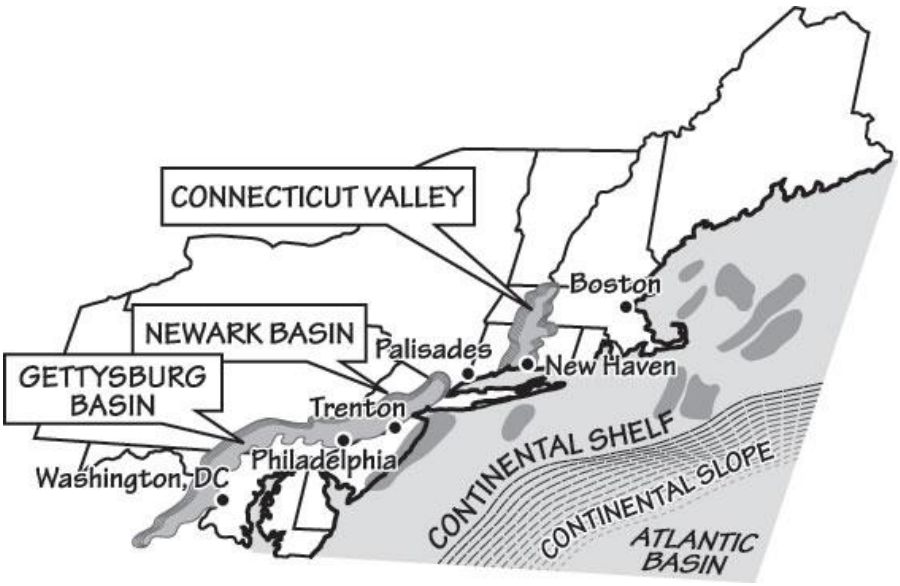
3. Closing of the Iapetus Ocean and More Mountain-Building

Ancient Africa and North America continued to move slowly toward each other, and approximately 250 million years ago, collided to form the Appalachian Mountains. This was part of the processes that formed the supercontinent of Pangaea. This chain originally extended from what is now Alabama through Maine into Canada, and continued into what are now the Caledonia Mountains of Greenland and northwestern Europe. This was part of the processes that formed the supercontinent of Pangaea.

One stage in the formation of Pangaea—Reconstruction of continental locations during the Late Pennsylvanian (306 million years ago.)

4. Breakup of Pangaea, Formation of Rift Valleys, and Igneous Activity

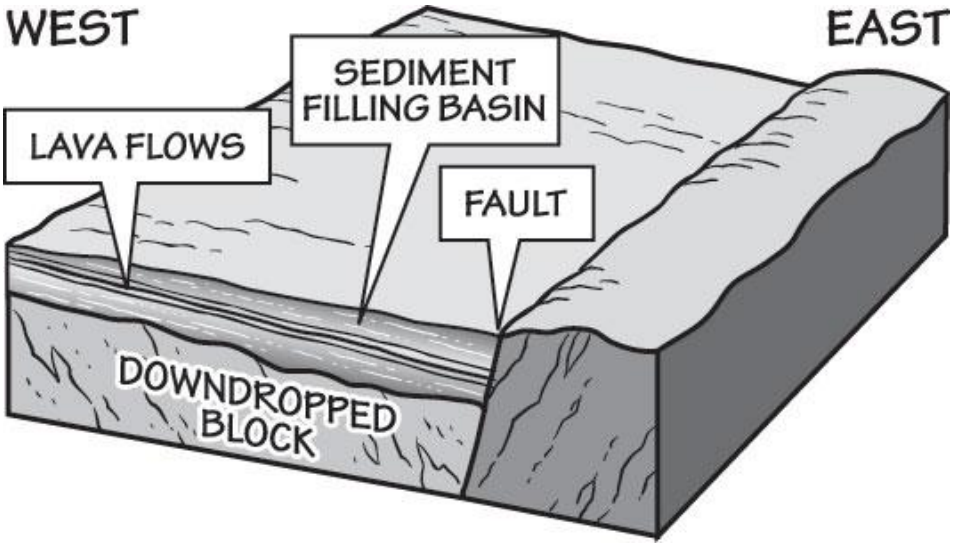
Pangaea existed for more than 100 million years, but gradually shifts in the direction of crustal plate movements produced great stresses that were released by rifting—faults that created basins as the continents moved apart. One excellent modern analog is the East African Rift Valley. What was to become the Hackensack River basin was part of one of numerous basins that formed along the East Coast from Canada to Alabama. For tens of millions of years in the late Triassic and early Jurassic, the boundary faults separated the basins from the developing Atlantic Ocean.



Three of the sedimentary basins that formed along what became the East Coast. The Hackensack River lies in what is called the Newark Basin, one of a series formed by rifting along the East Coast.

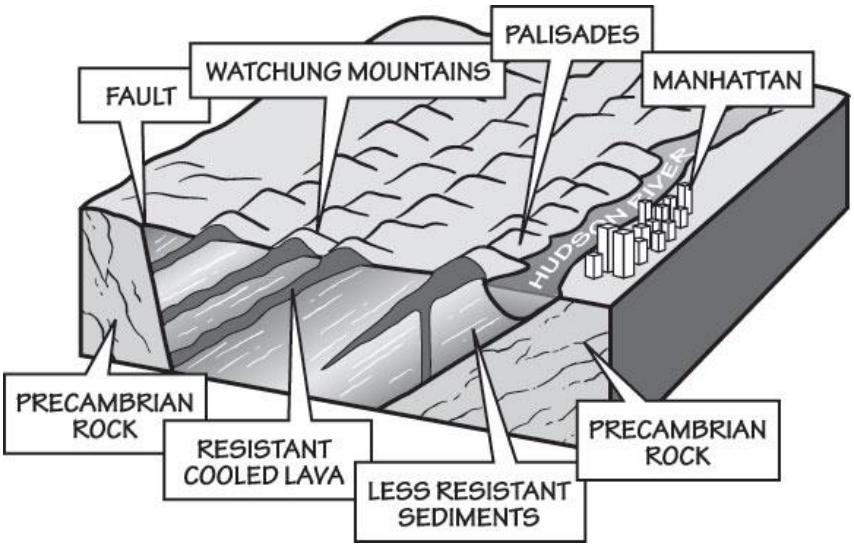
Sediments from the earlier highlands were eroded and deposited in such non-marine environments as streams, sedimentary fans, and lakes. The reddish-brown color of the sandstones and shales provide evidence of the surface origin of these sediments, as do such trace fossils as dinosaur footprints and worm burrows. Cyclical patterns in the rock layers indicate that the lake depths varied depending on climate changes, and occasionally dried out completely.

Great forces caused deep rocks to melt and rise to or near the surface at times in the late Triassic and Jurassic. These did not form circular volcanoes, but rather came out in sinuous structures that are preserved as the Watchungs west of the Hackensack River valley. To the east, another flow never made it to the surface, but rather moved between sandstone and shale layers. Heat altered the sediments to form contact metamorphism zones above and below the igneous rocks, proving its intrusive nature. Later, erosion exposed this underground flow to create the Palisades along the Hudson River. This now forms the eastern edge of the Hackensack watershed.

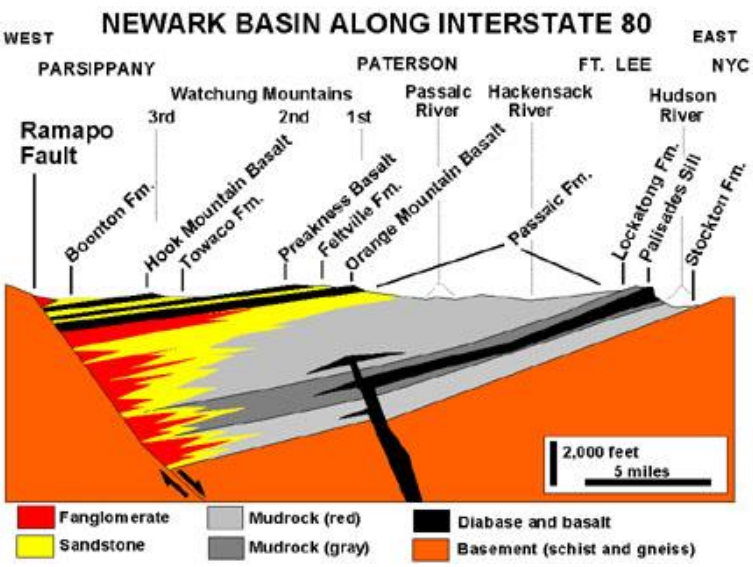


Erosion deposited sediments in lakes, streams, and subaerial fans within the Newark Basins and similar structures along the east Coast. Extrusive lava flows were buried by later deposition.

During the mid-Jurassic, tectonic activity—perhaps associated with the opening of the Atlantic Ocean far to the east, created stresses that tilted the region downward to the west. Less resistant sedimentary rocks were eroded away to form the continental shelf and slope. More resistant igneous rocks remained to form the relatively higher Watchungs and Palisades. Within what is now the Meadowlands, a smaller body was left as Laurel (Snake) Hill. This rifting to create the Newark Basin and ongoing erosion completed the events that formed the basic geology of the Hackensack River basin.



Generalized block diagram showing the rock structures creating the Hackensack Valley and environs.



Another cross-section showing the Newark Basin geology in more detail.
Source: http://3dparks.wr.usgs.gov/nyc/mesozoic/newarkbasin.htm

5. Origins of the Hackensack River Valley

Erosion over nearly 200 million years created the bedrock features seen today. Interestingly, it was not some ancestor of the modern Hackensack River that carried out much of the erosion, but rather an ancestor of the Hudson River. What is now the Hudson Valley west and north of what became New York City was then solid rocks. Near Sparkill, a few km north of what is now the NJ/NY state line, there is a gap in the Palisades. This may have been created as the ancestral Hudson found a weak zone through the igneous rocks and made a sharp turn toward the west.

The ancient river course can be traced southward in valleys cut into the sandstones and shales and now buried beneath later sediments. One of these lies beneath where the Meadowlands Sports Complex was built, and foundation supports had to reach different depths to find solid rock. The ancestral Hudson may have extended through the Newark Bay area, apparently turning eastward south of what is now Staten Island, where the Raritan River flows, and emptied into the Atlantic Ocean.

The modern Hudson River valley off New York City and Yonkers probably formed when a small stream slowly eroding northward along the east side of the Palisades broke through and provided a more direct route to the sea.

6. The Ice Ages and Creation of the Hackensack River Valley

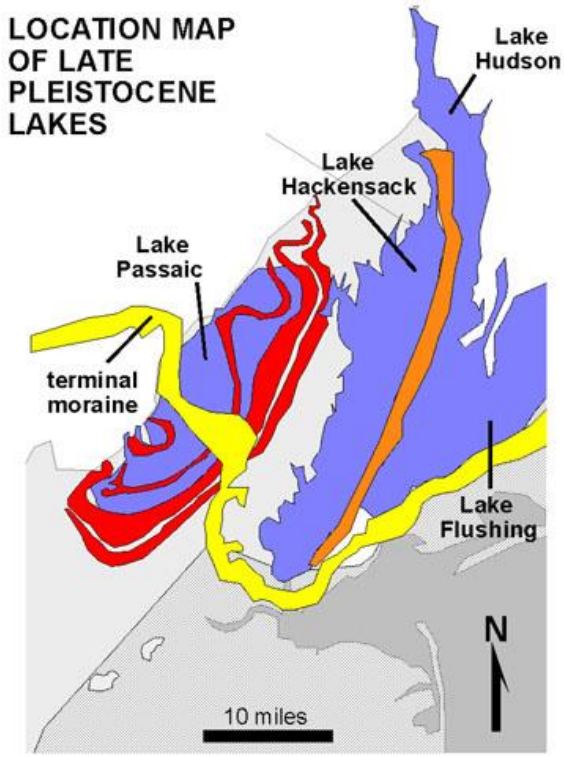
The final steps in forming the geologic setting involve the advances and retreats of great ice sheets during the Pleistocene Epoch and its subsequent disappearance. Several times during the past 100,000 years, cooling climates resulted in development of vast bodies of ice that moved out of Canada and covered much of North America. The most recent advance of these

ice sheets occurred about 18,000 years ago. Ice perhaps 1,000 feet thick covered what is now most of the New York metropolitan area.

As the glaciers advanced, they broke rocks off the bedrocks beneath them and carried the fragments ahead and within them. The furthest advance of the ice sheets are marked by terminal moraines. Two of these form Long Island, and extend westward across New Jersey. As the ice melted, fragments within the glaciers were dropped, creating the mix of boulders and smaller fragments found in the soils over much of the region.

The terminal moraines, the Watchungs, the Palisades, and other relatively high features created barriers that blocked melting glaciers from draining away. "Glacial Lakes" formed that lasted for thousands of years. Annuals patterns of deposition—smaller particles settling during the quiet of winter, larger particles during spring melts—produced layering in the glacial lake clays. These patterns are called varves, and counting them provides evidence of the length of time in which the glacial lake existed.

Glacial Lake Hackensack was about 45 miles long and 10 miles wide at its maximum extent. Counting the varves in the brick clay pits in Little Ferry showed the lake existed for more than 2,000 years.



Glacial Lake Hackensack and other features created during the last Ice Age.
Source: http://3dparks.wr.usgs.gov/nyc/images/fig144.jpg

At the maximum extent of the last Ice Age about 18,000 years ago, the Atlantic coast was about 75 miles to the southeast of where it is today. Sea level rose as the ice sheets

melted, covering lower-lying areas to create the modern shorelines. The New Jersey Meadowlands developed as sediments were deposited on top of the glacial lake sediments. Headwaters of the modern Hackensack lie in Rockland County, NY, west of the Palisades. Thus, the Hackensack flows through the former glacial lake bed and empties into Newark Bay. The Passaic River similarly flows through the remains of Glacial Lake Passaic and also joins Newark Bay not far to the west.

Before construction of the Oradell Reservoir Dam in the 1920s, the entire Hackensack was a fresh-water river flowing southward. But the dam divided the river system into two parts. The upper Hackensack is basically fresh water flowing through the reservoir system. Below the dam, the river became a tidal estuary with changing flows that created a brackish ecosystem.

Summary of events creating the Hackensack River Valley

- Grenville Orogeny (approx. 1 billion years ago, bya)
- Erosion into the Iapetus Sea
- Formation of offshore island arcs and proto-Taconic mountains (500 mya)
- Erosion into the late-Paleozoic inland sea
- Appalachian Orogeny and development of Pangaea (300 mya)
- Breakup of Pangaea, rifting to form the Newark Basin (200 mya)
- Deposition, volcanic extrusions and intrusions, tilting, and erosion
- Advance of continental ice sheets
- Melting of ice sheets, appearance and draining of Glacial Lake Hackensack
- Rise in sea level to create the Meadowlands

References:

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