

Geology of High Point State Park



Sussex County, New Jersey



Department of Environmental Protection
Land Use Management
New Jersey Geological Survey



STATE OF NEW JERSEY

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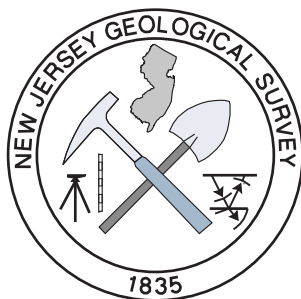
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Cover Photo: High Point Monument
looking northeast across Lake Marcia.
Photograph by Ron Witte, 2002.

New Jersey Geological Survey

Geology of High Point State Park,
Sussex County, New Jersey
and
Field Trip Guide

by
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and
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INTRODUCTION

High Point State Park affords its visitors an exceptional opportunity to learn about New Jersey's geology and its role in shaping the landscape. The park (fig. 1) lies on Kittatinny Mountain in the glaciated part of the Ridge and Valley physiographic province in northern New Jersey. It consists of about 20 square miles of hilly forest, rocky ridge crests, and wetlands. Rock outcrops, smoothed by glacial erosion, are very abundant along the main ridge line of the mountain, but in the western part of the park, bedrock exposures are sparse because the rock surface is covered by thick glacial sediment. In this area, the many wetlands, oval-shaped hills, and rolling nature of the landscape are all products of the last ice age.

Kittatinny Mountain forms a prominent northeast-trending ridge extending from Pennsylvania to the Shawangunk Mountains in New York. In places its continuity is broken by wind gaps, such as Culvers Gap, and water gaps, such as Delaware Water Gap. The High Point Monument, which lies at the north end of the park on the summit of Kittatinny Mountain, marks the highest point in New Jersey at 1803 feet above sea level. Kittatinny Valley lies east of the park and it in turn is bordered on its eastern side by a rugged upland called the New Jersey Highlands. Wallpack Valley, Wallpack Ridge, Minisink Valley, and the Pocono Plateau are found to the west.

Shale, siltstone, sandstone, quartzite, and conglomerate form the bedrock formations in High Point State Park. These sedimentary rocks are 460 to 400 million years old, and consist of material originally eroded from ancient lands and deposited as sediment in streams and seas that once covered the area. These loose materials were subsequently buried by younger sediments, and over millions of years they eventually changed to solid rock. Repeated uplift and subsequent erosion has exposed these rocks. The strong northeast-trending ridge-and-valley topography in the High Point area developed slowly, largely controlled by the structure of the underlying rocks and their varying resistance to erosion. Kittatinny Mountain, which is largely underlain by quartzite and

quartz-pebble conglomerate, very tough rocks resistant to erosion, forms the highest land; whereas softer rock underlies the valleys.

During the past two million years, continental ice sheets from the north modified the landscape by deeply scouring valleys, wearing down and smoothing bedrock ridges, hills and slopes, and carrying away soil and loose rock.

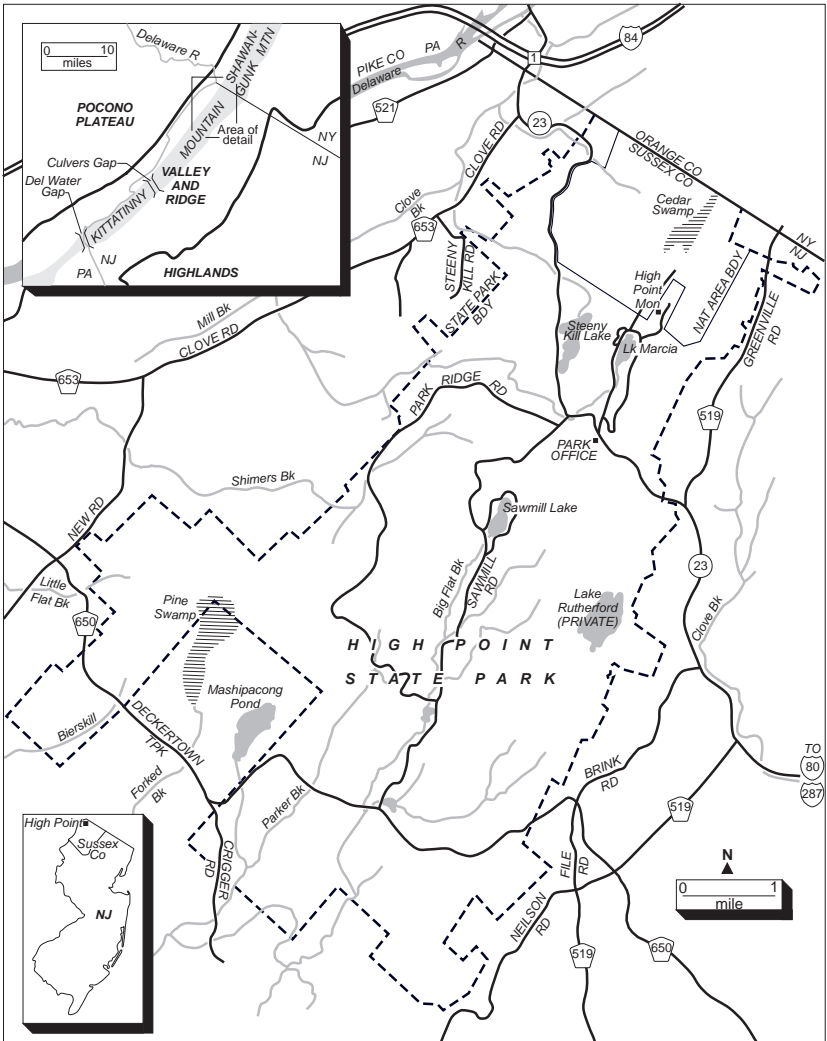


Figure 1. High Point State Park and vicinity in northern New Jersey.

BEDROCK GEOLOGY

Rock Formations

High Point State Park is underlain by three sedimentary bedrock formations that trend northeast to southwest (fig. 2).

From oldest to youngest they are: 1) the Martinsburg Formation,

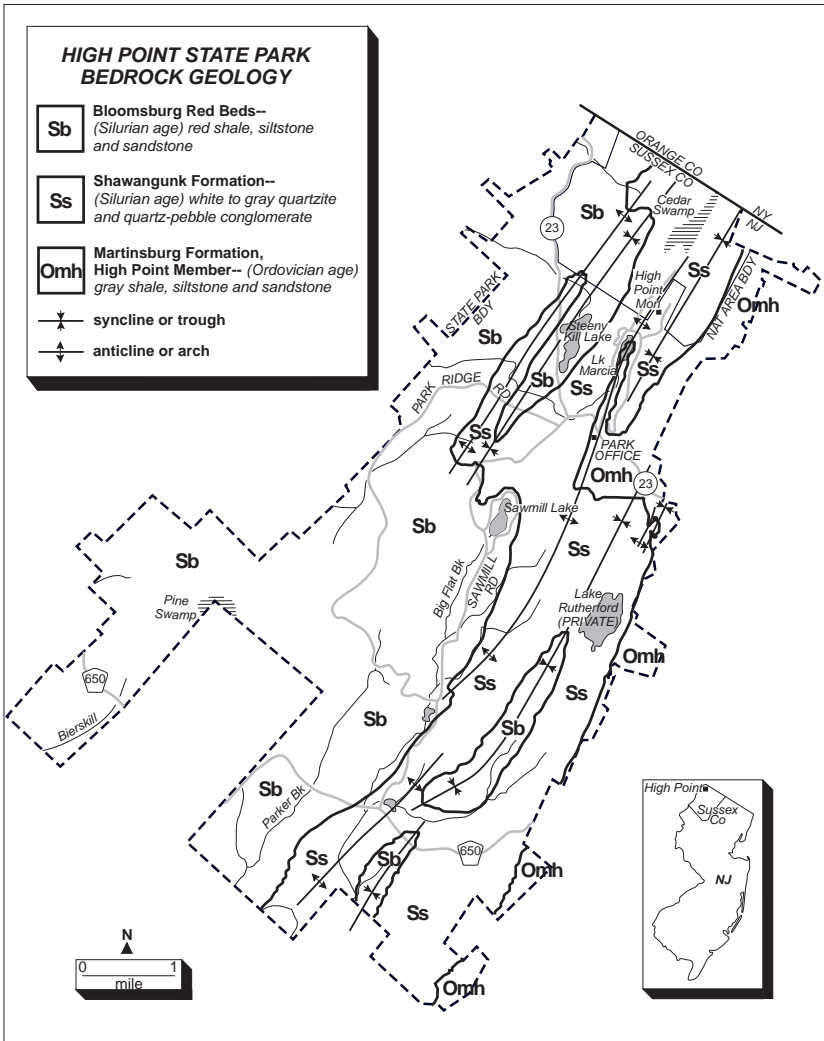


Figure 2. Bedrock geologic map of High Point State Park.

2) the Shawangunk Formation, and 3) the Bloomsburg Red Beds (back cover). The Martinsburg Formation underlies large parts of Kittatinny Valley and a small area at Lake Marcia (fig. 1). The Shawangunk Formation forms the higher ridges on Kittatinny Mountain, whereas the Bloomsburg Red Beds underlie its western flank.

The Martinsburg Formation is Middle and late Ordovician in age and records a history of sedimentation in a deep ocean basin about 462 to 450 million years ago. Martinsburg sediments consist of sand, silt and clay that were eroded from higher areas along an ancient continental margin and carried downslope by density currents to deeper parts of the ocean. Sediments deposited in this manner are called turbidites. Each turbidite may contain five different layers and each layer is defined by sediment grain size and sedimentary structures (fig. 3). The layers range from several inches to more than ten feet thick. In New Jersey, turbidite sequences generally contain only the upper three finer grained layers (fig. 3, layers C, D, and E) because the lower two were eroded or deposited farther up the continental slope.

The Martinsburg is divided into the Bushkill, Ramseyburg, and the High Point Members. The Bushkill Member is the oldest, consisting of about 1,500 feet of black shale that was formed from clay deposited in the deepest parts of the ocean basin. Overlying the Bushkill Member and younger than it are the interlayered shales, siltstones and minor sandstones of the Ramseyburg Member. This layering and overall increase in grain size shows that these sediments were laid down in a slightly shallower ocean closer to their source. The Ramseyburg ranges from 2,400 to 5,000 feet in thickness in New Jersey and is about 3,500 feet thick near the park. The High Point Member is

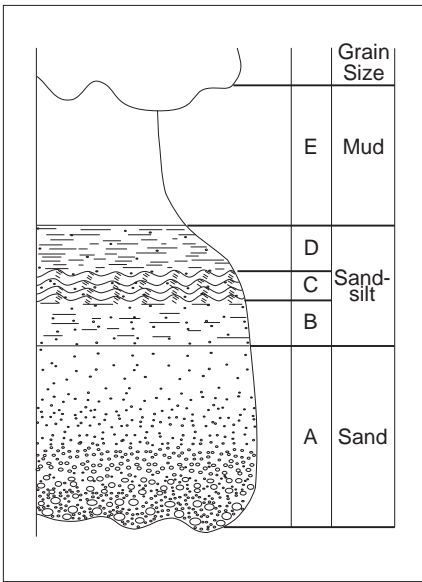


Figure 3. This diagram portrays the five parts of a classic turbidite. Not all parts are present every time. The most common turbidite in this part of New Jersey lacks part A and sometimes B. The remaining parts, C, D, and E have a combined thickness of several inches.

as much as 4,500 feet thick, and is the youngest and only member in the park. It consists of alternating thin sandstone, siltstone, and shale. The sandstone layers are typically coarse at their base and finer-grained near their top, a feature called graded bedding. These layers are as much as 6 feet thick and make up the coarsest part of the turbidite sequence (fig. 3). Pebbles of shale in their base show that the currents that carried them were powerful enough to rip up and erode some underlying sediment.

The upper surface of the Martinsburg Formation is marked by the Taconic Unconformity, a period of 20 to 30 million years during which the upper part of the formation was uplifted and stripped by erosion. The Shawangunk Formation was deposited on this surface; a slight angular difference in bedding orientation between the two formations defines the unconformity (fig. 4).

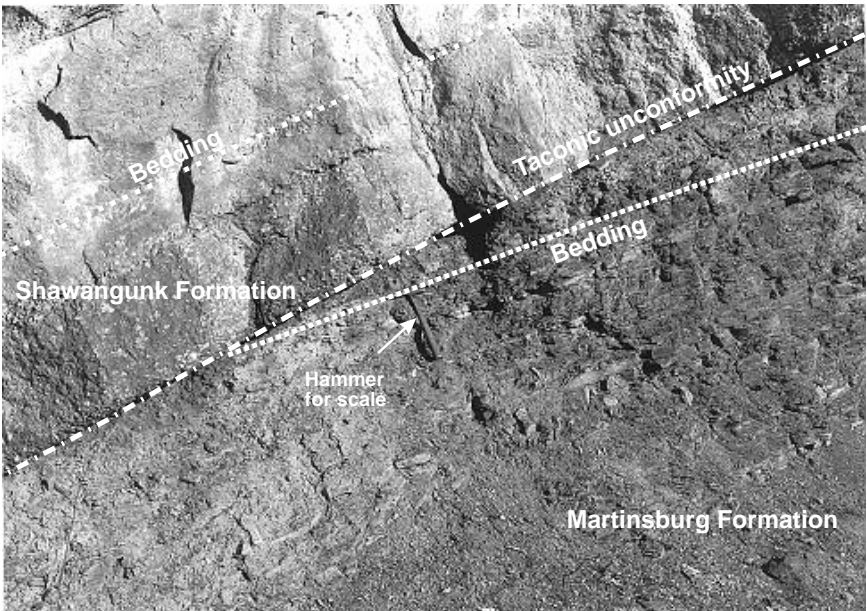


Figure 4. Photograph of the Taconic Unconformity, exposed during the construction of Interstate 84, just north of the Park in New York. View is toward north. Photo taken by Jack Epstein, U.S. Geological Survey.

The Shawangunk Formation is of Middle Silurian age (approximately 425 million years ago), about 1,400 feet thick and consists of interlayered pebble conglomerate, quartzite, and some shale. The conglomerate mostly contains rounded pebbles of quartz with lesser chert and shale in a matrix of quartz sandstone. Sediment

grain size becomes finer upward over several layers, forming repeating sequences of conglomerate that change from sandstone, to siltstone and finally to shale. This grain-size composition of the Shawangunk and its sedimentary structures (fig. 5) show that these materials were deposited by braided streams in alluvial fans. A braided stream flows in several dividing and reuniting channels that resemble a hair braid. Alluvial fans are large cone-shaped

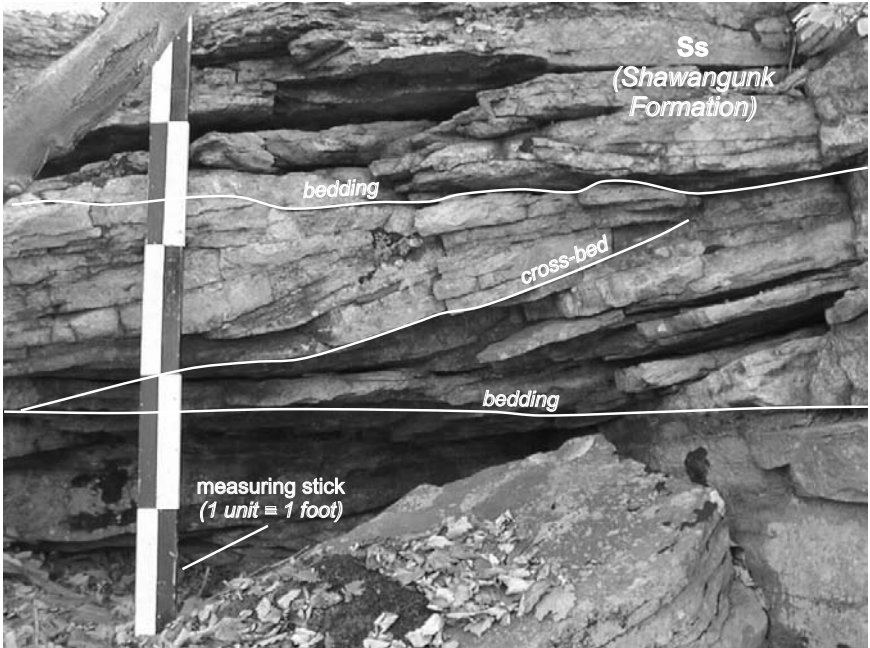


Figure 5. Photograph of cross-bedding in the Shawangunk Formation at Stop 1. View is toward north. The regional bedding surfaces are outlined and labelled. The cross-bed is clearly outlined in the rock by the more steeply inclined surfaces.

deposits laid down by rivers flowing out from mountainous areas onto low level plains. Most of the Shawangunk sediments were carried far out on the plain and away from the mountains. The cross-bed orientations in the Shawangunk Formation (fig. 5) show that the ancient rivers flowed in a northwesterly direction. This demonstrates that a mountain range to the east was the source of the Shawangunk sediments. Later, and after deep burial by younger materials, a silica-rich fluid cemented the sand and gravel, forming the rock that makes up the Shawangunk Formation. This tough cement also makes the rock very resistant to weathering and erosion.

The Bloomsburg Red Beds are of Late Silurian age and conformably overlie the Shawangunk Formation. The Red Beds are about 1400 feet thick, consisting of repetitively layered sediments 3 to 9 feet thick. Each sequence of layers typically has three parts. The lower part consists of gray to red, cross-bedded sandstone containing pebbles. It gradually changes into the middle part consisting of very thinly layered, finer-grained sandstone or siltstone that locally contains trace fossils. Cross-bedding in the sandstone layers shows that water currents flowed back and forth, suggesting that the Bloomsburg sediments were deposited under tidal conditions along the coast of a large inland sea. The upper part consists of red shale containing mud cracks, root traces, and evidence of soil formation. These features show that the sediment was exposed during short periods when sea level was lowered and the shoreline retreated seaward. The cycles of sedimentation show that sea level rose and fell many times during deposition of the Bloomsburg Red Beds.

Regionally, fossil shells and marine animal burrows in the formation also show a change in depositional environment proceeding from continental, to nearshore, to offshore oceanic environments. Younger, carbonate rock, which lies outside the park, conformably overlies the Bloomsburg Red Beds, indicating a change to clear, warm shallow seas.

Structure of the Rocks

Compressional or pushing forces caused by the collision of continental plates hundreds of millions of years ago formed folds, faults, joints, and cleavage in the rocks that underlie the park.

Folds form by compressive force, similar to pushing two ends of a piece of paper together. The arches and troughs that form are called anticlines and synclines respectively. Fold magnitude varies in each formation, but in the park it is on the order of several hundred feet (fig. 6). Generally, folds cannot be seen at an individual bedrock outcrop. One needs to walk across the rock and note the slow change in the dip of the beds from southeast to northwest.

A fault is a fracture or group of fractures in rock where one side has moved past the other. Such breaks form when rock is squeezed or pulled apart. An offset of sedimentary layering marks the location of a fault and helps to determine the rock's movement direction. Faults that parallel layering are harder to discern. A fault commonly exhibits linear grooves that show the direction of

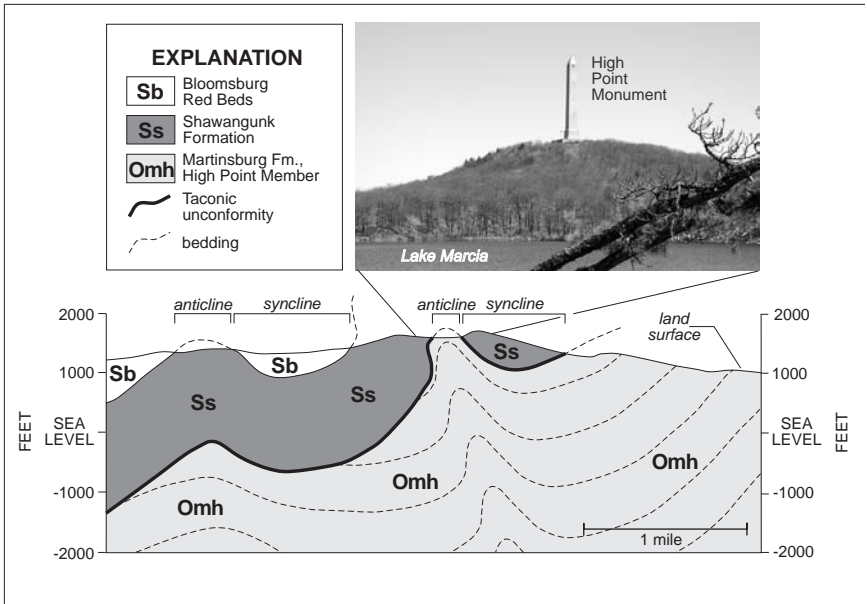


Figure 6. Regional crosssection through Lake Marcia from the northwest (left) to the southeast (right). The view, taken from the Lake Marcia beach, faces north toward the monument.

motion. These grooves form where bumps on the fault surface slide past and gouge the opposing rock surface. Quartz veins are also common in faults and their alignment is similar to that of the grooves described above. Faults cut the three rock formations in the park; all are small, have minor offsets, and are no longer active. They are most common in the brittle rocks of the Shawangunk Formation.

Joints are the most common structural feature in rocks (fig. 7). They are fractures, but unlike faults, they show no evidence of movement parallel to their common surface. Joints form where pulling or pushing forces caused the rock to break. Joints may cut across a whole outcrop or only an individual bed, and they commonly form in parallel or subparallel arrays called joint sets. Several different sets may occur in large areas, and they record the regional stresses that caused the fracturing. Ground water moves chiefly through fractures such as joints, so joint analysis helps us to understand ground-water flow.

Fine-grained rocks such as shale and slate split along closely spaced parallel planes called cleavage. Cleavage forms under compressive pressure in rocks enriched in clay minerals. Fine-

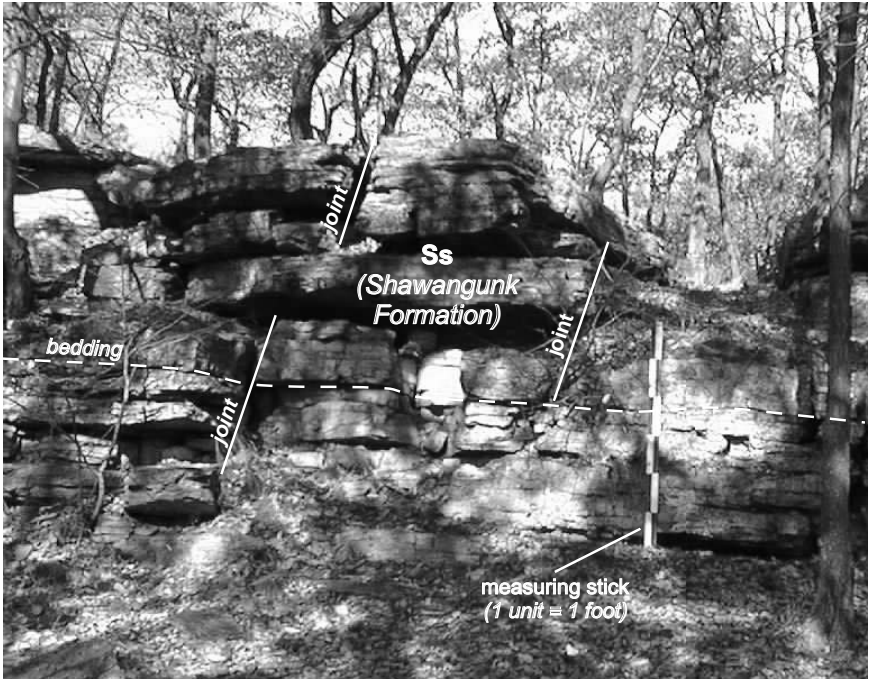


Figure 7. Photograph of subvertical joints in a south-facing outcrop of the Shawangunk Formation. Bedding is dipping slightly to the east (right).

grained rocks develop cleavage more readily than coarse-grained rocks because they contain more clay. This allows the rock to be split into flat products like chalk boards. The Martinsburg shales exhibit the best-formed cleavage in this region and they have been used for roofing slate and paving stone. Slate is shale in which the cleavage is highly developed. Therefore, the “shales” of the Martinsburg are better termed slates. Siltstones and sandstones in the Martinsburg also exhibit cleavage, but it is generally not as extensive and less closely spaced (fig. 8). Poorly developed cleavage occurs locally in the Bloomsburg Red Beds and the Shawangunk Formation.

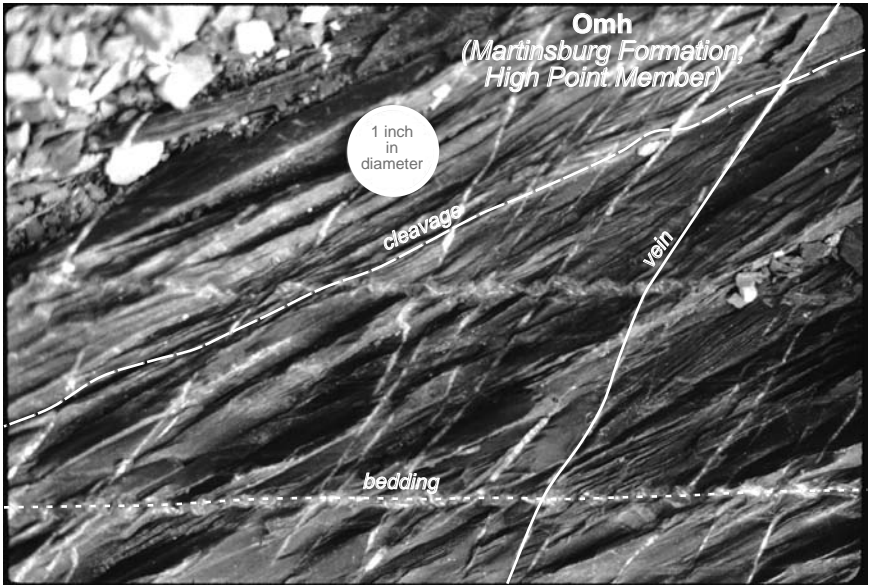


Figure 8. Photograph of cleavage in the slaty member of the Martinsburg Formation looking south (east to the left). Very closely spaced cleavage surfaces, almost paper thin, can be seen dipping to the east. Subvertical veins, formerly open fractures, are filled by quartz, a whiteish mineral.

Tectonic History

Kittatinny Mountain is part of the Appalachians, a long mountain chain that stretches from Alabama to Newfoundland. Its history includes three periods of continental stretching and collision that all involved folding and faulting. In northwestern New Jersey most of the folds, faults, joints and cleavage formed during three periods of mountain building. About 650 million years ago, during the Late Proterozoic, the granite and gneiss now making up the New Jersey Highlands were part of an ancient continent called Rodinia. About 540 million years ago, powerful tectonic forces began pulling the landmass apart. As the continental crust thinned and stretched, elongate rift valleys were formed. As time went on, the rifts widened and deepened, and flooded with sea water, eventually forming new oceanic basins. Finally, tectonic activity along the coast subsided. Carbonate sediments were deposited along an eastward facing shoreline of a warm shallow sea until about 480 million years ago. During this time, about 3000 feet of material accumulated; it now makes up the carbonate rock that underlies

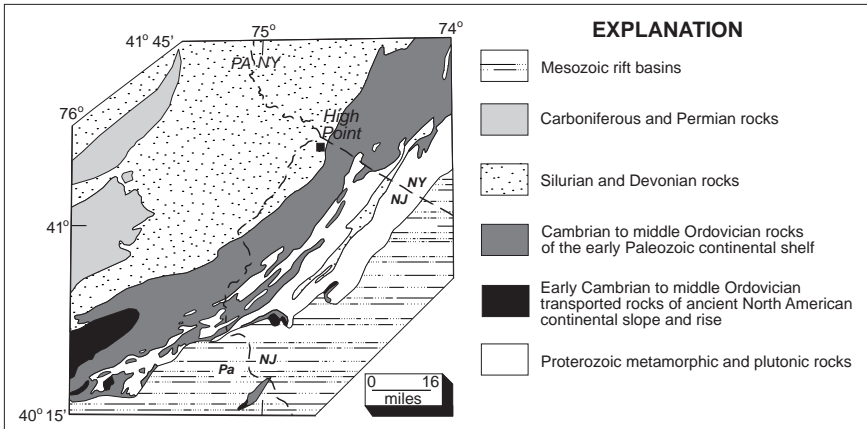


Figure 9. Regional geologic map of the area surrounding High Point State Park.

part of Kittatinny Valley.

About 460 million years ago the ocean basin began to close and a period of mountain building, called the Taconic Orogeny, began. During its initial stages, the North American plate collided with several smaller plates. This collision caused uplift and erosion of the carbonate rocks. A downwarping followed that submerged the land beneath the sea. Folding, faulting and a westward pushing and stacking of the rocks and sediments in the collision zone formed a mountain chain. Over time the mountains were lowered by erosion, the weathering products of clay, silt, and sand were carried westward by rivers and ocean currents to a deep ocean basin. These materials thickened, compacted and became the shale, siltstone and sandstone of the Martinsburg Formation.

Following deposition of the Martinsburg sediments, the entire region was again uplifted and the landmass again slowly eroded. This period lasted about 25 million years and marks the Taconic Unconformity, a regional surface that displays evidence of extensive erosion. Eventually, a westward facing coastal plain formed at the base of the mountains that became covered by stream deposits. These deposits make up the Shawangunk Formation. As sea level rose slightly, sediments laid down in muddy tidal flats and shallow marine waters that now make up the Bloomsburg Red Beds were deposited on the Shawangunk sediments. As the continental margin further subsided, seas eventually covered the Bloomsburg Red Beds. Carbonate materials were deposited in this calm shallow-marine environment. These carbonate rocks now lie just west of the park.

Between 410 and 380 million years ago a second period of mountain building occurred. This event, called the Acadian Orogeny, also involved several smaller continental plates colliding with the North American plate. This orogeny, responsible for New England's major structural features, is not represented in the rocks in High Point State Park. A third period, called the Alleghany Orogeny, occurred between 330 and 250 million years ago. Intense folding and faulting of the park's rocks mark this collision of the North American continent with the African continent.

EVOLUTION OF REGIONAL LANDFORMS

The landscape around High Point State Park was shaped by many geologic processes acting throughout millions to tens of millions of years. These processes included uplift and subsidence of the earth's crust, physical and chemical weathering, erosion by streams, and mass wasting. Some geologists believe that the present landscape had its beginnings in Permian or Triassic time when a large river system flowed westward toward the continental interior (the area now drained by the Mississippi River and its tributaries). When continental rifting opened the Atlantic Ocean more than 200 million years ago, in late Triassic time, newly formed streams along the coast worked their way inland and captured parts of the inland drainage. As time passed, streams flowing over weaker rock cut valleys faster and deeper than those flowing over tough, harder rock. Because belts of rock trend northeastward in northwestern New Jersey, drainage developed along northeast- to southwest-trending belts of weaker rock. In some places, hard, resistant rocks were weakened by faults or numerous joints. Streams cut through these resistant ridges at their weakened points and formed features like Delaware Water Gap and Culvers Gap.

Other geologists think that the ancestral Appalachian Mountains were worn low and subsequently covered by a thick layer of coastal plain sediments more than 100 million years ago during the Mesozoic Era. Newly formed streams, which flowed southeastward following the seaward slope of the land, cut their drainage inland from the Atlantic Ocean. Following a lengthy period of erosion, the underlying folded and faulted rocks of the Appalachians were exposed and streams began to adjust to the rock's structure. Water gaps were eroded in places where southeast flowing rivers first encountered the resistant rocks that make up the modern uplands such as Kittatinny Mountain.

The principal landscape features of the park probably formed during the late Tertiary period (10 to 25 million years ago). During this time, erosion and valley cutting accelerated when sea level fell due to the growth of the Antarctic ice sheet, and possible uplift of the earth's crust. Rejuvenated streams eroded the old land surface, deepening valleys and water gaps and further adjusting their courses along belts of weak rock. It was probably during this time that a stream flowing in what is now *Culvers Gap* was intercepted and captured by a tributary of the Delaware River.

THE ICE AGE

Regional History

During the Pleistocene Epoch (2 million to 10 thousand years ago) ice sheets advanced over northern New Jersey at least three times (fig. 10). From oldest to youngest, these glaciations are named the pre-Illinoian, Illinoian, and late Wisconsinan. Glaciers are large bodies of ice that form over long periods from the gradual buildup of

compacted and recrystallized snow. Eventually, the ice becomes thick enough to flow under the stress of its own weight. Ice sheets are thick glaciers that cover large parts of continents. In North America the Laurentide and Cordilleran ice sheets grew to enormous sizes. It is estimated that their centers were as much as 10,000 feet thick. At High Point, the ice may have been 2000 feet thick when the North American ice sheets were at their maximum size.

The North American ice sheets were centered in the subarctic regions of Canada and grew and spread outward during periods when the northern hemisphere was

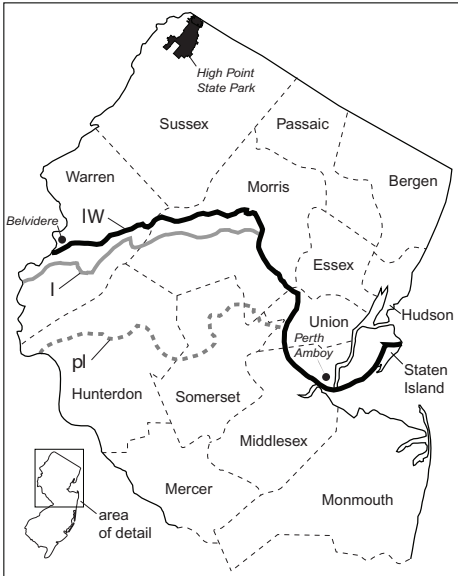


Figure 10. Limits of glaciations in New Jersey. The trace of the lw limit generally marks the Terminal Moraine. Key: IW - late Wisconsinan, I - Illinoian, and pl - pre-Illinoian.

colder than it is now. Current ideas are that small changes in the earth's orbit, tilt of its axis, direction of ocean currents and storms, and volcanic dust in the atmosphere may have all contributed to global cooling. The geologic record shows that the growth and decay of continental ice sheets in the northern hemisphere was cyclic. In New Jersey, the climate varied from arctic or boreal during glacial periods to temperate or subtropical during interglacial periods. Today we are considered to be in an interglacial stage.

A precise age of the oldest glacial deposits is uncertain. Their extensive weathering and poor preservation suggest they were laid down more than 800,000 years ago. Later, during the Illinoian stage about 150,000 years ago, an ice sheet again covered northern New Jersey. Most recently, New Jersey was glaciated during the late Wisconsinan substage, about 20,000 years ago.

Each ice sheet modified the landscape. Valleys underlain by weak rock were widened and deepened; bedrock ridges, hills, and slopes were slightly worn down and streamlined, and most surface materials were eroded. Rocks, gravel, sand, silt, and clay entrained in the ice sheets were deposited as till, an unsorted mixture of clay- to boulder-sized material. This material was laid down on the bedrock surface in sheets, in streamlined hills called drumlins, and in ridges laid down along the former edge of the ice sheet called moraines. Stratified sediment consisting of sorted and layered gravel, sand, and silt was deposited by glacial meltwater streams in valleys that drained away from the glacier and in glacial lakes. The harsh, cold climate immediately south of the ice sheets enhanced erosion of surficial sediment by mass wasting, and accelerated the physical weathering of bedrock, largely by frost shattering. In contrast, temperate and subtropical climates during interglacial periods lessened rates of physical weathering, but increased rates of chemical weathering, which led to the formation of thick decomposed bedrock.

Local History

High Point State Park lies entirely within the limit of the last glaciation and only glacial deposits (fig. 11) and erosional features associated with the late Wisconsinan ice sheet are preserved here. Older glacial deposits and features were buried beneath younger glacial sediment or were eroded during the last glaciation. The late Wisconsinan advance of ice into northwestern New Jersey consisted of ice lobes initially moving southwestward down Minisink and Kittatinny Valleys. In time, the ice became thick enough to flow over Kittatinny Mountain and, turning south, it flowed across the

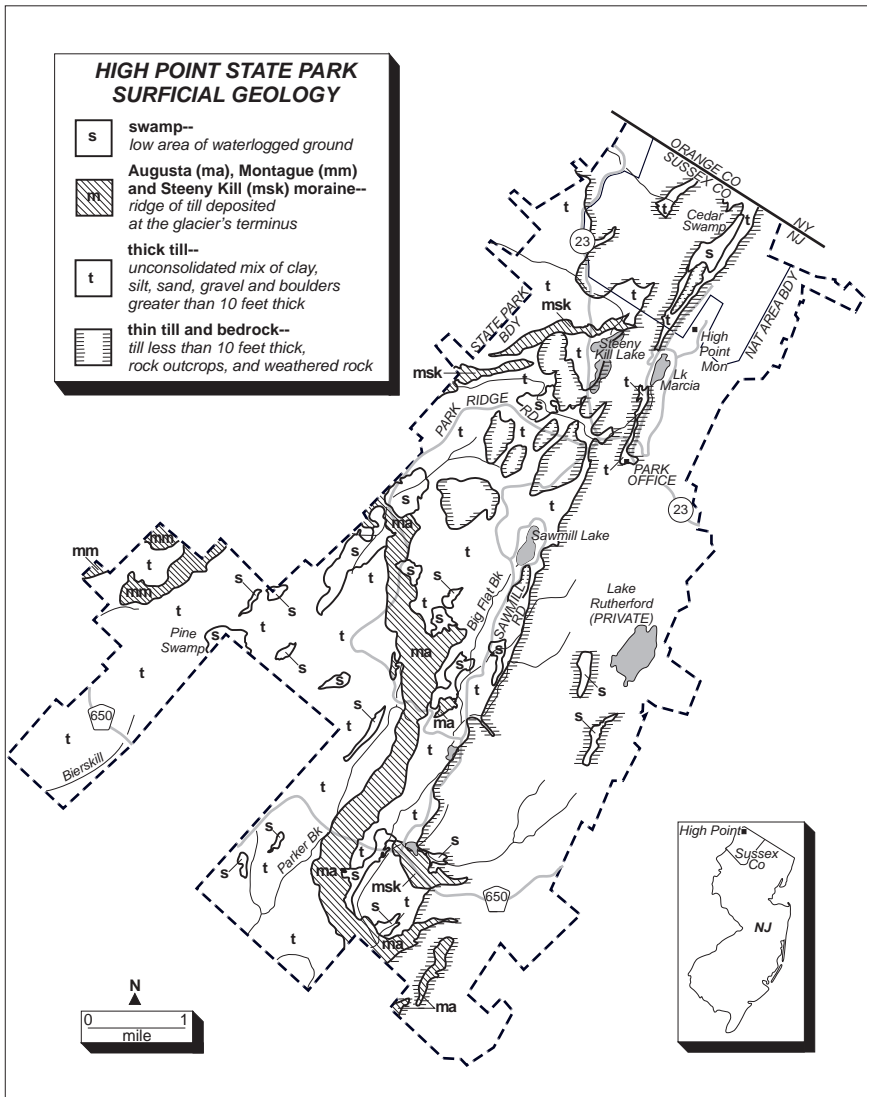


Figure 11. Surficial geologic map of High Point State Park.

region's southwesterly topographic grain. The Terminal Moraine, which lies 30 miles south of the park (fig. 10), marks the farthest advance of the ice sheet. However, in a few valleys, sublobes of the glacier extended as much as a mile south of the Terminal Moraine. During deglaciation, the edge of the ice sheet thinned and its flow became more controlled by the southwesterly trend of the larger valleys. The Kittatinny and Minisink Valley ice lobes retreated

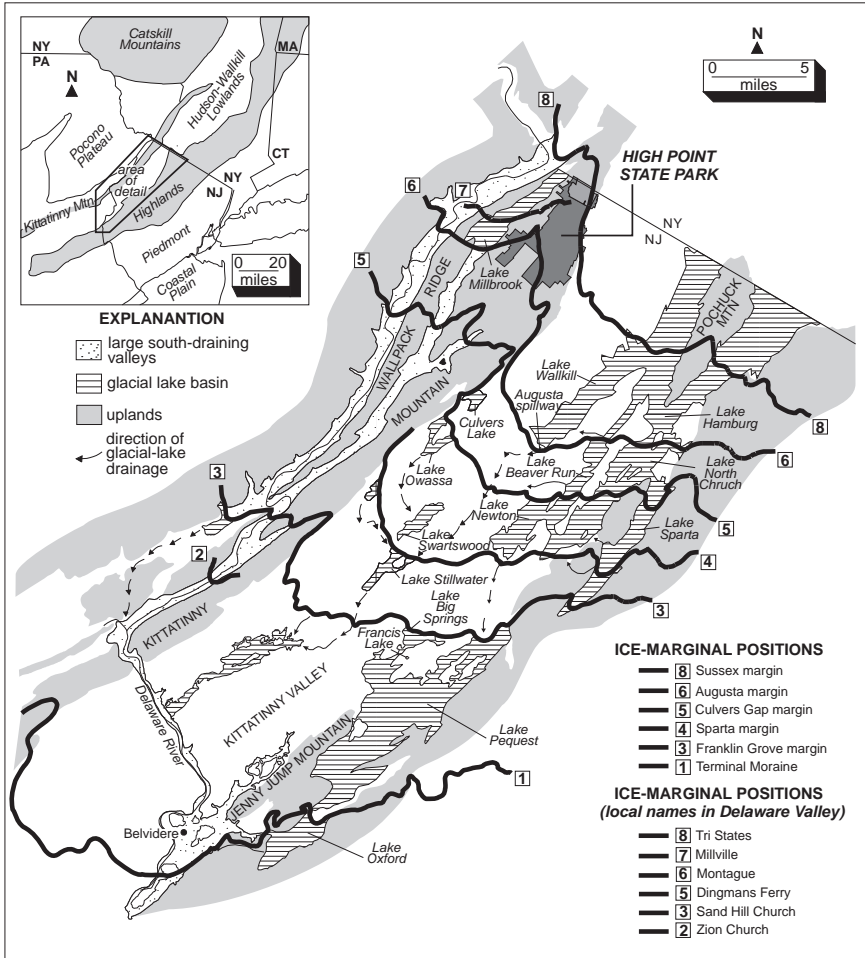


Figure 12. Ice margins of late Wisconsinan age showing successive positions of the ice front as it retreated northeastward, location of large glacial lakes, and extensive valley-outwash deposits in northwestern New Jersey.

gradually to the northeast. However, at times the edge of the ice lobes remained stationary, and in a few instances readvanced southward a few miles (fig. 12). Deglaciation was probably triggered by warming temperatures that melted ice at the glacier margin faster than it was replaced by flowing ice, and by a decrease in the formation of new glacier ice due to reduced precipitation on the ice sheet. During periods when the glacier margin remained stationary, sand and gravel laid down by meltwater streams built up at and beyond the glacier margin in stream valleys and glacial lakes in

Minisink, Wallpack, and Kittatinny Valleys (fig. 12). Additionally, end moraines were deposited at the glacier's terminus.

Both the ice-marginal parts of the meltwater deposits and end moraines mark the former edge of the ice sheet. Mapping these ice-recessional positions enables geologists to reconstruct the geometry and retreat history of the ice sheet. The Augusta margin, which runs through High Point (fig. 12), is delineated by the Augusta and Montague moraines. The continuity of the moraines, and the size and extent of meltwater deposits laid down in nearby valleys south of the Augusta margin show that the glacier's terminus maintained a nearly constant position for more than a hundred years.

Erosion by Ice

Features carved in bedrock by moving glacial ice are numerous in the park. They include striations, crescentic marks, polished bedrock, and plucked outcrops. Striations are linear scratches and grooves cut in bedrock by overriding ice that show the direction of glacial movement. They formed in places where hard stones, frozen to the bottom of the glacier, scraped across the underlying bedrock. Striations are also found on stones that have been glacially transported. Crescentic marks, which include gouges, fractures, and chatter marks, are cracks and chips in the rock surface made when stones at the glacier's base exerted great pressure on the underlying rock. Striations and crescentic marks in the park show that the glacier flowed S70°W to due west. These features were made near the edge of the Kittatinny Valley ice lobe when the front of the ice was retreating. It is likely that southerly-oriented striations, made earlier when the ice was much thicker and its margin far south of High Point, were subsequently removed by glacial erosion.

Other forms of glacial erosion include polishing and plucking. Polishing occurred where sand and silt, frozen to the glacier's base, slid over rock. Like sandpaper smoothing a piece of rough wood, the rock surface becomes highly smoothed and polished. Plucking occurred where rock fragments, fractured and loosened from pressure exerted by the weight of the overriding glacier, were broken off. Generally, the fragments, some as big as boulders, are removed from the downstream side of the outcrop. In extreme cases, the processes of abrasion and plucking can impart a whaleback shape to an outcrop, also called a *roche moutonnée*.

Glacial Deposits

All of the deposits in the park laid down directly by or from glacial ice are called till. Till, a nonsorted mixture of clay to bouldery-sized material, covers the bedrock surface in most places, except the rocky crest of Kittatinny Mountain and a few steep hillslopes. Where it is thin, the underlying bedrock topography shows through. Thicker till subdues and buries this irregular surface, and in many places completely hides it. Till in the park is typically a compact, yellowish-brown, brown, or light olive brown silty sand consisting of a mixture of quartz sand, rock fragments, feldspar, silt, and clay. Subangular to subrounded stones of quartz-pebble conglomerate, quartzite, red sandstone, gray sandstone, and red shale may make up as much as 20 percent of the deposit by volume. Many of these are striated. This material is called lodgement till and was deposited



basal till ①: poorly sorted, nonstratified mix of clay- to boulder-sized material.



planar beds ③ of stratified gravel and sand: deposit of a glacial meltwater stream.

- ① basal till
- ② flowtill
- ③ planar beds of gravel and sand
- ④ inclined beds of sand and some gravel
- ⑤ laminated beds of silt, clay, and very fine sand

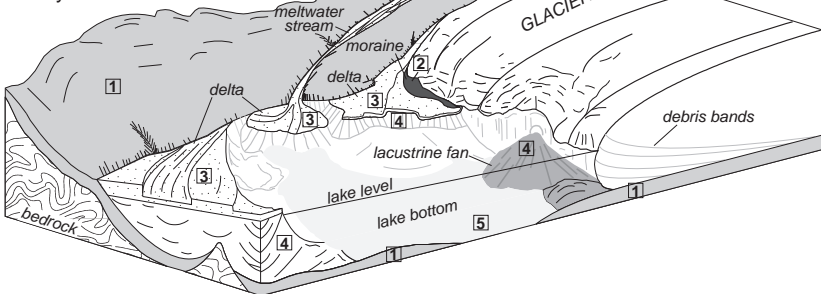


Figure 13. Block diagram showing the depositional setting of glacial sediments with photo insets of till and outwash.

at the glacier's base (fig. 13). Overlying this lower compact till is a thin, discontinuous, loose, poorly sorted silty sand and sand containing as much as 35 percent pebbles, cobbles, boulders, and lenses of sorted sand, gravel, and silt. Overall, stones are typically more angular than those in the underlying till. This material is debris that was released from the glacier by melting at the glacier's terminus. It may have been let down slowly by melting ice or flowed off the ice onto adjacent land. This material is called ablation till and flow till respectively (fig. 13). Frost heaving, burrowing animals and insects, and root growth have also altered the upper few feet of till making it less compact, and reorienting its stones.

A glacial erratic is a rock, commonly a boulder, that was picked up and carried by the glacier and deposited some distance from its source, often many miles. Most erratics show evidence of glacial erosion by their subrounded shape, flattened sides, and striated or polished surfaces. They are found throughout the park and were largely plucked from nearby outcrops on Kittatinny Mountain and in Kittatinny Valley. A few are larger than 10 feet in diameter. The most remarkable are the Martinsburg sandstone boulders that were carried up and out of Kittatinny Valley to the top of Kittatinny Mountain. There they rest, as much as 900 feet above the valley floor.

Glacial Landforms

Landforms in the park that were created by the glacier include drumlins, end moraines, and kettles. Drumlins are oval-shaped hills consisting of till that were deposited at the glacier's base. Most drumlins are in the western part of the park in places where till is thick. Their long direction is parallel to the direction of former glacier flow and they formed where the glacier streamlined loose surficial material or molded till at its base. Drumlins in the park trend due south to south 13° west, a more southerly direction than shown by nearby striations. This suggests that the drumlins formed when ice was much thicker, and its flow not as controlled by topography as it was when the striations were made. End moraines are bouldery, cross-valley ridges that mark the former lobate edge of the ice sheet. They consist of till with lenses of silt, sand, and gravel and exhibit ridge-and-kettle, and knob-and-kettle topography. In the park the moraines are named the Augusta, Montague, and Steeny Kill Lake (fig. 11). Kettles are depressions in the land that formed by the melting of stagnant ice blocks that were partly or completely buried in glacial material and then left

behind by the retreating ice sheet. Pine Swamp and the many depressions on the Augusta moraine are good examples.

POSTGLACIAL HISTORY

Ice retreated from New Jersey about 17,000 years ago. During the few thousand years following deglaciation, the harsh climate and sparse vegetation enhanced erosion of the land. Unconsolidated, water-saturated surficial materials were easily moved downhill by the constant pull of gravity. Disintegration of rock outcrops by frost shattering formed extensive accumulations of rock debris, called talus, at the base of cliffs on Kittatinny Mountain. Boulder fields formed at the base of slopes where rocks, transported by soil creep, came to rest. Other fields were formed where meltwater carried away the finer-grained material from till leaving behind the heavier stones. A few others may have been deposited directly by the glacier. In places boulders stand upright and some form crude stone circles. These may have been formed by frost heave, and possibly tree growth.

Stream deposits, called alluvium, consist of sand and gravel laid down in channels, and finer sediment laid down on narrow flood plains. Many modern streams in High Point flow along channels originally cut by glacial meltwater. In a few places, such as the ravine northwest of Steeny Kill Lake (Plate 1), these channels are as much as 60 feet deep. Alluvial fans formed where tributaries entered larger valleys and deposited their heavier loads. Their composition is highly variable, chiefly derived from local surficial materials laid down by intermittent and perennial streams. Most are entrenched by modern streams. This suggests they are probably of late Wisconsinan and early Holocene age and formed when rigorous climate, sparse vegetation, and abundant sediment favored their formation.

Swamps and bogs contain sediment and organic material that can be used to reconstruct past climates. Because their materials were laid down layer upon layer, they may preserve a record from the end of the Ice Age to the present. Pollen and other plant material retrieved from swamps may be identified and provide dates used to interpret past climate. Several studies of bogs and swamps in northwestern New Jersey and northeastern Pennsylvania have established a dated pollen stratigraphy that nearly goes back to the onset of deglaciation. The pollen records the transition from tundra with sparse vegetation, to an open parkland of sedge and grass with scattered stands of spruce and fir. From about 14,000

to 11,000 years ago a dense closed boreal forest developed that consisted largely of spruce and fir blanketing the uplands. This was followed by a period (11, 000 to 9,700 years ago) when pine became dominant. About 9,400 years ago oak became dominant and displaced the conifers, signaling the change from a boreal to a temperate climate.

Mastodon remains, excavated from Shotwell Pond in Stokes State Forest show the presence of these large mammals on Kittatinny Mountain during the close of the Ice Age. They disappeared from this area about 12,000 years ago, presumably because of a rapid change in climate and food source.

ECONOMIC RESOURCES

There has been limited economic use of the park's bedrock materials. Minor lead and zinc deposits occur in quartz veins that crosscut bedding in the Shawangunk Formation. The remnants of a formerly active small mine are found in the southern end of the park. A small shaft and dump piles are all that remain. The park obtains material for road and trail maintenance from two small borrow pits in the High Point Member of the Martinsburg Formation. Southeast of the park, near the village of Newton, the Bushkill Member of the Martinsburg Formation was formerly quarried for roofing slate and flagstone.

GEOLOGIC TOUR OF THE PARK

The following section is a self-guided geologic tour of High Point State Park. All locations are shown on Plate 1 and in smaller maps in this section. For each stop a brief description of the local geology is given. These sites were chosen because they illustrate the park's geology and are easily accessible. Most of them are near roads, or well-marked trails. Please take only photographs and leave only footprints so that others may also enjoy the park in its natural state. Please note that some park roads may be closed during winter. More information about the geology at these stops is found in the previous part of this booklet.

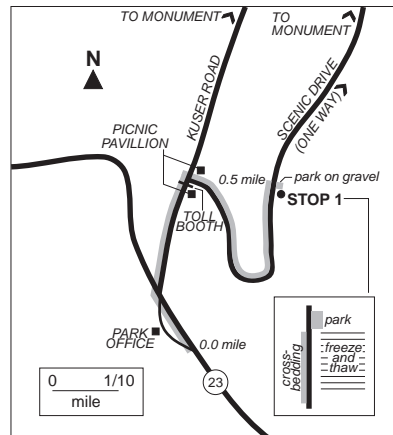
Interval/Cumulative mileage

- 0.0 mile/0.0 mile** **Begin at NJ State Route 23 and High Point State Park Office driveway exit.**
- 0.0 mi/0.0 mi** **Turn left onto NJ 23. Bear right immediately, enter High Point State Park.**
- 0.2 mi/0.2 mi** **Toll booth. Turn right immediately onto Scenic Drive (one way).**
- 0.3 mi/0.5 mi** **Stop 1. Park on small gravel pad on right.**

Stop 1

Location - Port Jervis South quadrangle, main ridge of Kittatinny Mountain, 1500 feet north of Route 23, east side of Scenic Drive.

Geology - *Surficial* - freeze-and-thaw weathering, erratics, glacial scour, striations, and crescentic marks. *Bedrock* - Shawangunk Formation, cross-bedding, and joints.



Explanation - The overall streamlined and smoothed rock surface, faint striations, and crescentic marks are products of glacial erosion. The scratches and crescent-shaped marks on the outcrop east of Scenic Drive, show that the ice sheet (Kittatinny Valley lobe) flowed S 70° W. Several angular to subangular boulders of conglomerate, glacially transported from nearby locations, lie on the scoured rock surface. The many-sided pattern outlined by vegetation on the rock surface (fig. 14) follows joints and fractures in the bedrock. These features gradually widen over time by the action of freezing water, and root growth, eventually they fill with rock fragments that form a thin soil. The expansion of ice also breaks the rock apart along bedding surfaces as shown by the upward movement and change in position of some joint blocks (figure 14).



Figure 14. Stop 1: Outcrop of the Shawangunk Formation showing many joints and joint-block boulders.

The Shawangunk Formation here consists of thin-to- thick layers of quartzite and conglomerate that slope gently to the southeast, forming the eastern limb of an anticline. Cross-bedding, visible on parts of the outcrop, consists of thin, stacked, and curved layers (fig. 5). The orientation of cross bedding shows the ancient river that laid down these deposits flowed in a northwesterly direction. Excellent examples of cross-beds are exposed on the northwest side of Scenic Drive on the slope just below the road surface.

Other Occurrences - Evidence of glacial scour, striations, and crescentic marks are found throughout the park where bedrock is exposed. In some places weathering has roughened the rock surface, obscuring these markings. The effects of such weathering may be seen wherever bedrock is exposed, and cross-bedding can generally be observed at most of the Shawangunk outcrops, and in the turbidite sequences in the Martinsburg Formation.

0.0 mi/0.5 mi
0.4 mi/0.9 mi

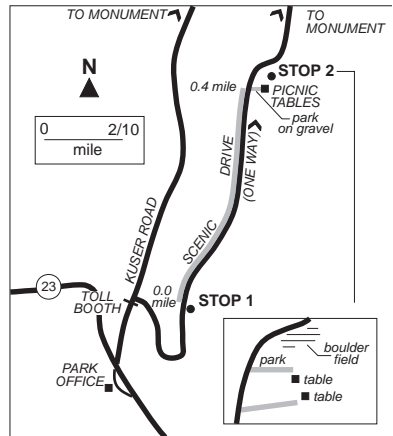
From Stop 1, continue on Scenic Drive.
Stop 2. Park on right on gravel road leading to picnic tables.

Stop 2

Location - Port Jervis South quadrangle, main ridge of Kittatinny Mountain, 4000 feet north of Route 23, east side of Scenic Drive.

Geology - *Surficial* - Small boulder field, and mechanical weathering.
Bedrock - Shawangunk Formation.

Explanation - The small, oval-shaped boulder field was produced by freezing and thawing. Most of the boulders were dislodged from adjacent outcrops of the Shawangunk Formation, and fell directly downslope where they were further moved by creep. Over time they accumulated at the base of the slope. Parts of the boulder field are collapsed. This shows that some of the boulders may have previously fallen onto a small block of remnant ice. Some boulders form crude stone circles, and many have been reoriented to a near-vertical position (tombstone orientation), presumably by frost heave and tree growth. Many have also been split apart by root growth and by the expansion of freezing water (fig. 15).



The Shawangunk Formation here dips southeastward and forms the eastern limb of the same anticline seen at Stop 1. The northwest-dipping limb of the anticline lies on the west side of Lake Marcia (fig. 6). The fold's core contains the Martinsburg Formation,



Figure 15. Stop 2: Split boulder showing the effects of freeze and thaw along a fracture.

which crops out on the eastern side of the parking lot and along the service road leading to the lake.

Other occurrences - Boulder fields are found throughout the park in three settings. The first is in hollows, swales, and saddles along the main outcrop belt of the Shawangunk Formation. Here they typically lie below large outcrops or above bedrock that lies very close to the surface. Boulders in this setting are generally angular in shape, and may be as much as 25 feet long. The second place is in areas of thick till, boulder fields form massive, oval-shaped accumulations that lie near the base of hillslopes, and more rarely they occur on broad uplands where they may have been deposited by the glacier. Boulders in this setting generally have a subrounded shape, their corners worn down during glacial transport. Sorting is common and many boulders form crude stone circles. The third location where bouldery accumulations are found is in small upland valleys and elongated fields along hillslopes formed in places where meltwater washed over the till leaving the heavier stones behind.

Bedrock is folded throughout the park (fig. 2), but such folds are not easily observed because of their large size. They are best noted when passing through the park in a northwest-southeast direction,

across the trend of the mountain.

0.0 mi/0.9 mi

From Stop 2, continue on Scenic Drive.

0.3 mi/1.2 mi

Turn right onto Monument Drive.

0.4 mi/1.6 mi

High Point Monument parking area.

Park and walk to Stops 3 and 4.

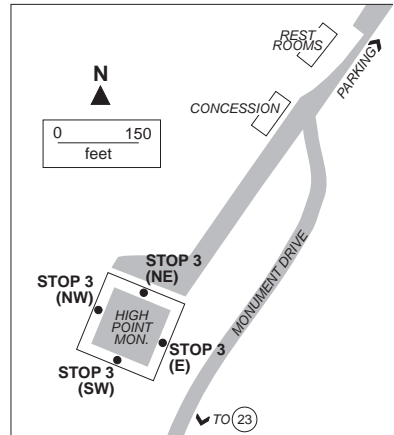
Stop 3

Location - Port Jervis South quadrangle, Kittatinny Mountain, High Point Monument.

Geology - Panoramic view of New Jersey Highlands, Kittatinny Valley, Kittatinny Mountain, Shawangunk Mountains, Catskill Mountains, Minisink Valley, Pocono Plateau.

Explanation

View to the southwest along the curving ridge line of Kittatinny Mountain (fig. 16).



The large, high ridge that forms the spine of Kittatinny Mountain is underlain by tough quartzite and conglomerate of the Shawangunk Formation. The lower area west of the ridge is underlain by less resistant red shale and sandstone of the Bloomsburg Red Beds, and several of the smaller hills in this area are drumlins. Because the Shawangunk Formation is highly resistant to weathering and erosion, it stands out in greater relief than the area on its flanks, which is underlain by softer rocks. The small notch near the ridge's midpoint is Culvers Gap, which was cut by an ancestral stream of the Raritan or Delaware Rivers.

View to the east across Kittatinny Valley.

The uplands visible across Kittatinny Valley include Pochuck Mountain, Mount Adam, Mount Eve, and the New Jersey Highlands. These areas are all chiefly underlain by granite and gneiss, rocks

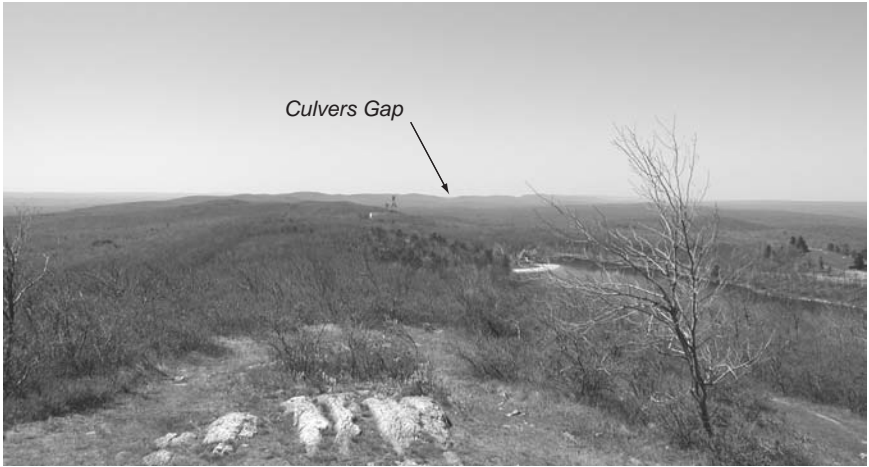


Figure 16. Stop 3: Vista from High Point Monument looking southwestward along the curving ridgeline of Kittatinny Mountain. The small notch along the midline of the ridge is Culvers Gap.

that are more than 570 million years. Kittatinny Valley forms the broad lowland between the Highlands and Kittatinny Mountain. Its upper part is drained by the Wallkill River, which flows northward and empties into the Hudson River just south of Kingston, New York. Its lower part is drained by the Pequest River and Paulins Kill, which flows southwest to the Delaware River. The valley is underlain by slate and sandstone of the Martinsburg Formation and limestone and dolomite of the Kittatinny Supergroup. The higher ridges and hills in the valley are underlain by slate and sandstone, which are more resistant to weathering than limestone and dolomite. Overall, the rocks that underlie Kittatinny Valley are much less resistant to weathering and erosion than the rocks that underlie the New Jersey Highlands and Kittatinny Mountain.

View to the northeast along the curving ridge line of Kittatinny Mountain.

The broad upland at northeast end of ridge is the Shawangunk Mountains. The Catskill Mountains, which can be seen only on a very clear day, form a high, jagged upland west of the Shawangunks.

View northwest across Minisink Valley to the Pocono Plateau.

The uneven upland in the distance is the Pocono Plateau, an area underlain by gently-northwest-dipping, limestone, shale, and sandstone. Extensive erosion of these rocks over millions of years has created a rugged landscape that remains largely uncultivated. The Delaware River drains southeastward from the Pocono Plateau to the towns of Matamoras, Pennsylvania, and Port Jervis, New York. Here the river enters Minisink Valley, makes a right-angle turn and continues its course to the southwest.

Stop 4

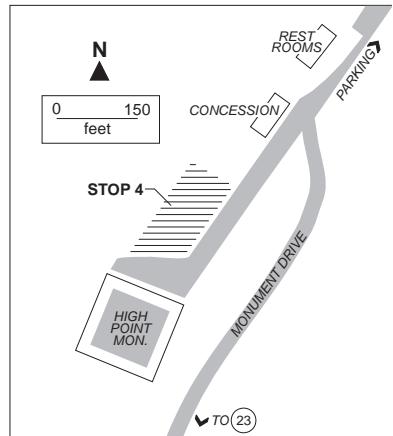
Location - Port Jervis South quadrangle, Kittatinny Mountain, northeast side of High Point Monument.

Geology - Surficial - Glacial erosion, striations, crescentic marks, polishing, roche moutonnées, and plucking. **Bedrock** - Shawangunk Formation.

Explanation - Excellent examples of striations can be seen on the glacially polished rock surface (fig.

17) northeast of the monument. They consist of straight scratches and larger grooves that show the glacier flowed south 85° west to due west. Crescentic marks (fig. 18) are also well developed; they show a similar direction of ice flow. The westerly direction of ice flow exhibited here shows that these glacial markings were made near the glacier margin where ice flow was controlled by the lobate geometry of the Kittatinny Valley lobe.

In places weathering has obliterated the striations and roughened the polished rock surface. This suggests that these features were once covered by thin till, which may have lessened the effects of weathering. Later, the till was stripped by erosion. When viewed from a distance the rock outcrops have a streamlined and asymmetrical,



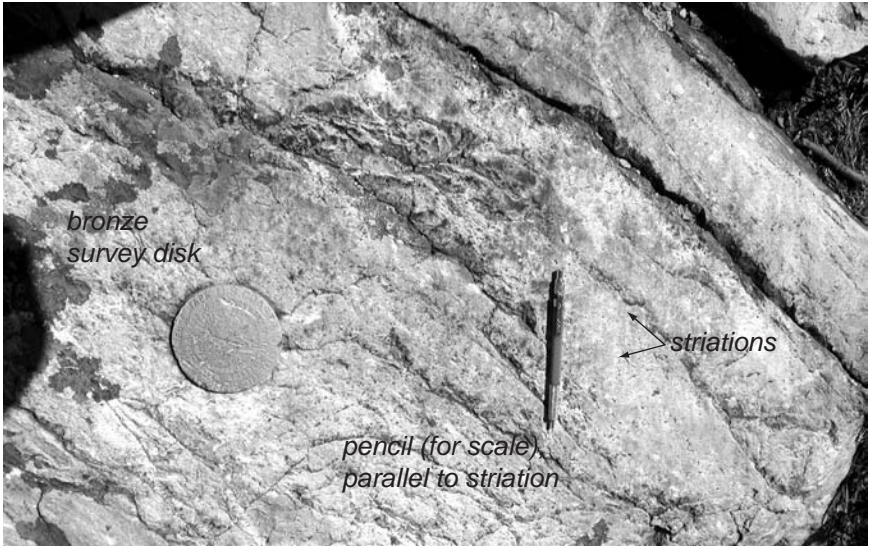


Figure 17. Stop 4: Striations on the Shawangunk formation just north of the monument. They show that ice flowed westward (toward top of photo) across Kittatinny mountain.

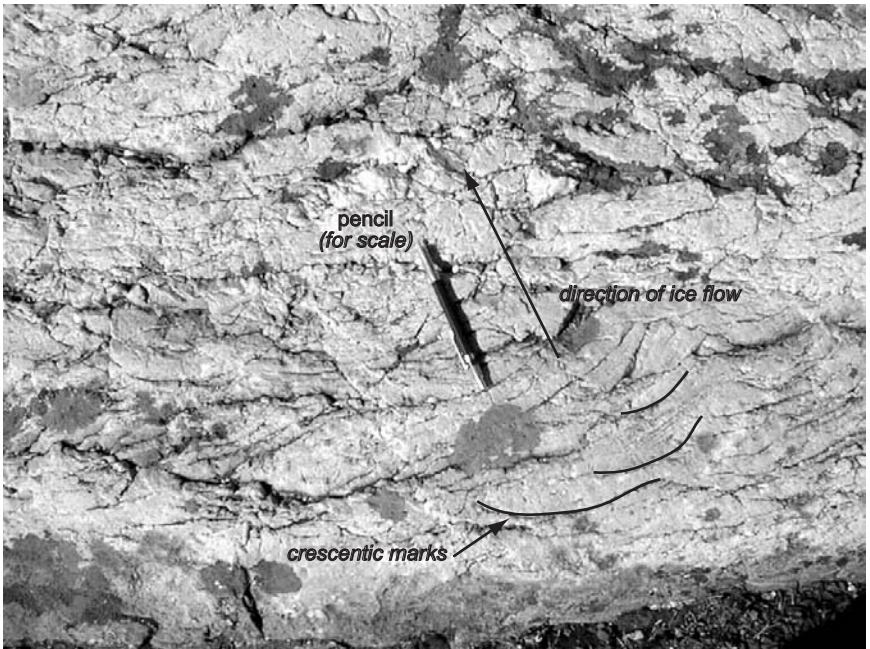


Figure 18. Stop 4: Crescentic marks (a few highlighted on photo) on the Shawangunk Formation just north of the monument. They show a similar direction of glacial flow as nearby striations.

smoothed shape. On the downstream side (west and southwest), rock has been removed by glacial plucking and quarrying. On the upstream side (east and northeast sides), rock has been removed by abrasion. This gives the outcrop a characteristic sheepback or whaleback shape called a *roche moutonnée*.

The Shawangunk Formation here dips southeastward and forms the eastern limb of an arch or anticline, the same one as that described at Stops 1 and 2. The steeper dip of the rock layers, the white quartz veins that cut across the bedding, and some small faults show that the rock here has been more strongly deformed than those at the previous stops.

Other occurrences - Most rock outcrops in the park show the effects of glacial erosion. Striations and crescentic marks are best preserved where the rock retains its glacial polish. Quartz veins and small faults are found in the beds that were tightly bent during folding and in beds that were overturned.

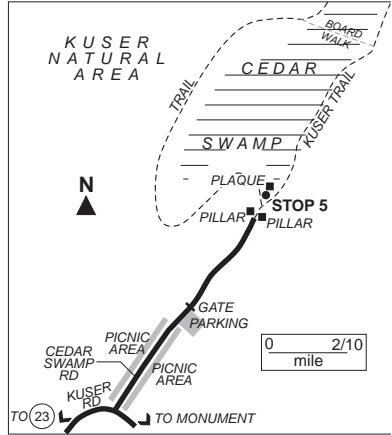
- | | |
|----------------------|--|
| 0.0 mi/1.6 mi | From Stops 3 and 4, exit parking area via Monument Drive. |
| 0.5 mi/2.1 mi | Turn right, follow sign to Dryden Kuser Natural Area. |
| 0.3 mi/2.4 mi | Gate. Park on paved area on right. Walk to Stop 5. |

Stop 5

Location - Port Jarvis South quadrangle, Cedar Swamp, Dryden Natural Area. Park in area near locked gate. Proceed northeast about 1200 feet along abandoned road to plaque just beyond pillars. Here Kuser Trail may be traveled to bypass the swamp, or for a shorter route follow the boardwalk cutoff. The abandoned road cuts through an area of thin till and bedrock outcrop. Many of the outcrops exhibit evidence of glacial erosion in their overall streamlined form and lightly weathered surfaces. The base of the steep slope east of the road and swamp is covered by a thin narrow apron of talus.

Geology - *Surficial* - Swamp deposits, till, talus. *Bedrock* - Numerous outcrops of Shawangunk Formation.

Explanation - Cedar Swamp occupies a north-draining valley eroded by glacial ice along the hinge line of an anticlinal axis in the Shawangunk Formation. During retreat of the last ice sheet about 18,000 years ago, a small glacial lake flooded this valley, its waters draining westward across a low bedrock-floored outlet. Further glacial retreat uncovered a lower outlet north of the area now marked by the New Jersey - New York State line. During this time, the lake drained northeastward over a plug of thick till. Its water level lowered by as much as 20 feet, but it did not completely drain. The lake persisted well into recent time before decayed vegetation filled it in, forming a swamp. The bouldery area along the swamp's modern outlet is called a lag deposit. It was formed by the small stream that drained the lake, which eroded the fine-grained sediment from the till it was flowing over, leaving behind the heavier stones.



The lower part of the slope on the east side of the swamp consists of a thin layer of till. In a few places, bedrock is very close to the surface, as shown by irregular areas of angular boulders. Large outcrops of Shawangunk Formation form the upper part of the slope. These rocks dip to the southeast, and below them lies a narrow apron of conglomerate and quartzite talus. Bedding on the lower part of the hillslope dips northwestward, which shows that the talus apron conceals an anticlinal fold axis.

Figure 19 shows the change in forest cover around High Point from the close of the last ice age to the present; a period of 11,000 years. It is based on a pollen diagram of a core retrieved from Cedar Swamp. The lower part of the record shows that spruce and pine formed the dominant forest cover. The high percentage of spruce, which favors a climate much cooler than that now present at High Point, shows that the forest cover 10,000 years ago was similar to the present-day forests of northern Maine and southern Canada. Higher up in the record, a rise in the percentage of oak, accompanied by decreasing pine and disappearance of spruce, record the transition to a temperate forest of mixed hardwoods dominated by oak. The predominance of oak at the 14-foot depth (~7500 years ago) suggests

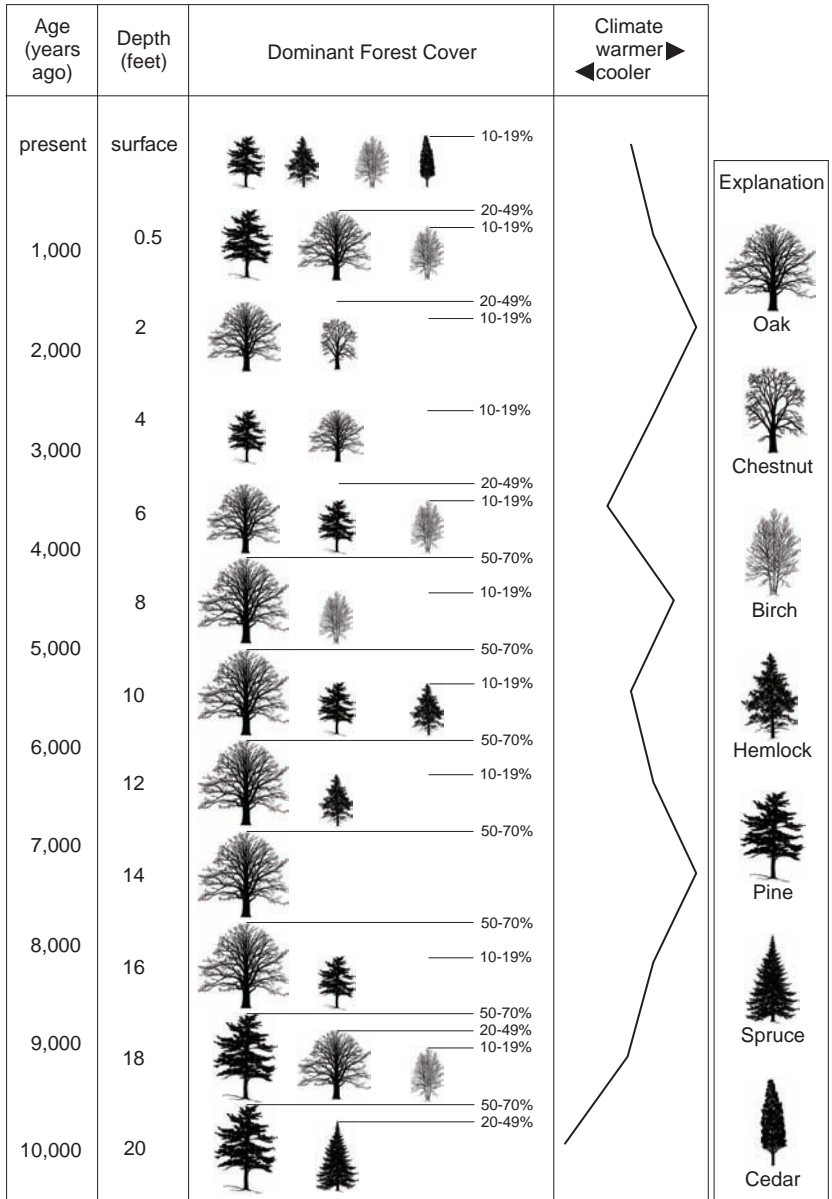


Figure 19. Step 5: Forest succession around Cedar Swamp, High Point State Park, during the last 10,000 years. Dominant trees and percentages are based on a percent-pollen diagram constructed by William A. Neiring, in *The Past and Present Vegetation Of High Point State Park, New Jersey* in *Ecological Monographs*, April, 1953, v. 23, p. 127-148. Relative climate change is estimated on the percentage of cold-tolerant vs. temperate-tolerant species of tree.

a warmer and dry climate, whereas the appearance of hemlock shortly thereafter records the change to a cooler and moister period during the middle part of the Holocene. The upper part of the diagram is marked by several climatic cycles. The co-dominance of oak and chestnut, both warmer-temperature-tolerant species, at the 2-foot level probably represents a warmer period, whereas the re-emergence of birch and hemlock may indicate a shift to cooler and possibly moister conditions. The upper part of the record also shows an increase in the diversity of codominant trees. This may be explained by the closing or filling of the lake basin by dead vegetation, thereby creating a more suitable habitat for cedar and other trees. Pollen collected near the swamp's surface also reflect deforestation by man during the 19th and 20th centuries.

Other occurrences - Swamps are found throughout the park and occupy various settings. The largest ones are in the western side of the park, in areas underlain by thick till. Smaller swamps occupy glacially-eroded valleys and small basins cut in bedrock. Most of these are in the eastern side of the park where the Shawangunk Formation forms the major ridges of Kittatinny Mountain. Elsewhere, small swamps have formed in small depressions that were formerly occupied by stagnant ice blocks. These features are called "kettles" and they are common on moraines.

Broad folds in bedrock occur throughout the park (fig. 2). They are best noted when traversing the park in a northwest-southeast direction, or across the trend of the mountain. When hiking, try to find places where the dip of the rock layers changes from northwest to southeast or southeast to northwest. Along this change in dip direction a fold axis exists.

- | | |
|----------------------|--|
| 0.0 mi/2.4 mi | From Stop 5 parking area, turn around and travel toward Monument Drive. |
| 0.3 mi/2.7 mi | Bear right at yield sign. Turn right immediately, follow sign to Interpretive Center. |
| 0.1 mi/2.8 mi | Monument Trail (red/green trail) on right. |
| 0.1 mi/2.9 mi | Circle Interpretive Center. Park in front. Walk to Stop 6. |

Stop 6

Location - Port Jervis South quadangle, intersection of Monument and Steeny Kill Lake trails, about 1.2 miles north of Route 23. Park in the driveway on the north side of the Interpretive Center near entrance to Monument Trail. Walk northeast on trail (red/green blazes) to Steeny Kill Lake trail (blue blazes)

Geology - *Surficial* - boulder fields, erratics, glacially-scoured rock. *Bedrock* - Shawangunk Formation, cross-bedding.

Explanation - The first 1000 feet of Monument Trail follows the rocky crest of a lower, secondary ridge on Kittatinny Mountain. Glacially-scoured Shawangunk crops out on the west side of the trail.

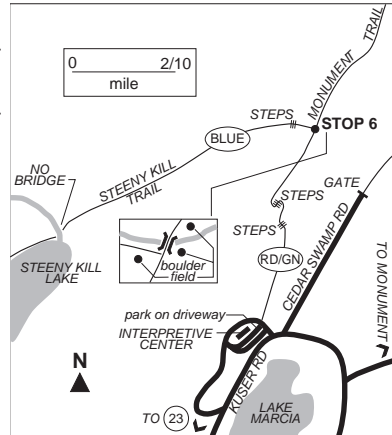


Figure 20. Stop 6: Quartz-pebble conglomerate erratic (Shawangunk Formation) along Monument Trail.

Glacial erosion has given these rocks an overall smoothed shape. About 400 feet from the trail's entrance lies a glacially-transported Shawangunk boulder (fig. 20). The steep hillslope above stop 6 is covered with many boulders. Some of these were derived from frost-shattered bedrock that lies just beneath the bouldery mantle. Other boulders, based on their subrounded shape, have been glacially transported. For those who are more adventurous, the Steeny Kill Lake Trail provides a moderate hike down to the Steeny Kill Lake moraine, ending on the north shore of the lake.

0.0 mi/2.9 mi

From Stop 6 parking area, exit and turn right.

0.1 mi/3.0 mi

Turn right at yield sign.

0.4 mi/3.4 mi

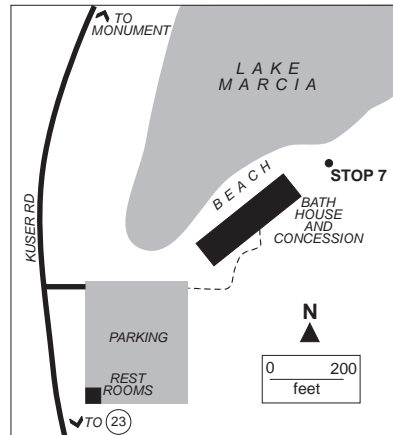
Turn left into beach parking area. Park and walk to Stop 7.

Stop 7

Location - Port Jervis South quadrangle, East shore of Lake Marcia.

Geology - *Surficial*-Talus. *Bedrock* - Shawangunk Formation.

Explanation - The rock rubble (talus) that borders the east shore of Lake Marcia consists of angular Shawangunk boulders that were dislodged from rock outcrops by frost shattering, and over time accumulated at the base of the hillslope.



This stop is just east of boundary between the Shawangunk and the Martinsburg Formations. The Martinsburg Formation forms the core of an arch or anticline, and the Shawangunk Formation overlies it. Erosion of the tougher rock of the Shawangunk Formation exposed the softer and more easily eroded Martinsburg Formation forming a small valley where the lake lies.

Other occurrences – Throughout the park, talus, made up chiefly of boulders from the Shawangunk Formation, blankets the base of cliffs and steep hillslopes.

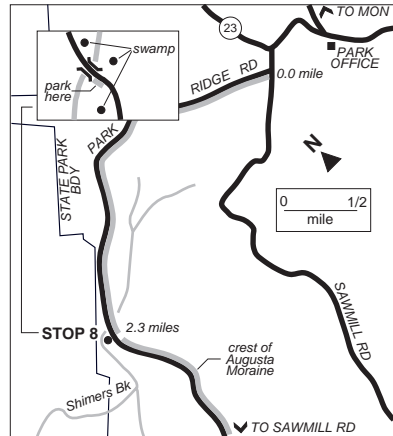
- | | |
|----------------------|--|
| 0.0 mi/3.4 mi | From Stop 7 parking area, exit and turn left. |
| 0.4 mi/3.8 mi | Toll booth. |
| 0.1 mi/3.9 mi | Bear right onto NJ 23, follow sign to Port Jervis. |
| 0.4 mi/4.3 mi | Turn left, follow sign to Sawmill and Park Ridge Roads. |
| 0.1 mi/4.4 mi | Turn right onto Park Ridge Road. |
| 2.3 mi/6.7 mi | Stop 8. Park on right beyond Shimers Brook bridge. |

Stop 8

Location - Port Jervis South quadrangle, Ridge Road.

Geology – *Surficial* -Recessional moraine, drumlins, and swamp deposits.

Explanation - In this part of the park, thick deposits of till cover the Bloomsburg Red Beds, masking the topography of the buried rock surface. This part of Kittatinny Mountain lies along a thick belt of glacial drift that extends northeastward from Culvers Gap to the New Jersey-New York boundary. Many of the hills in this belt are drumlins. They are elongated in a direction parallel to glacier flow and formed where the glacier streamlined pre-existing surficial material or molded till at its base. Drumlins in the park trend due south to south 15° west, a direction much more southerly than showed by nearby striations. This suggests the drumlins were made when the ice was much thicker, and its flow not as controlled by topography as it was when the striations were made.



The many swamps and poorly-drained areas are typical of constructional glaciated landscapes. Thick till deposited in drumlins, ground moraine, and recessional moraine has completely buried the preglacial surface concealing former stream courses. Upon deglaciation, surface water, which had formerly flowed off the mountain in a well defined network of streams, became trapped in the many depressions, lakes, and ponds that dotted parts of the mountain. As time passed, streams expanded their drainage areas slowly by headward erosion. Although more than 18,000 years have passed since the last ice sheet left, the land retains its glacial imprint.

South of stop 8, Park Ridge Road follows the crest of the Augusta moraine for about a mile. Morainal topography is well expressed along this stretch of the road. The two large swamps on either side of the moraine are former glacial lakes, now filled with sediment and decayed vegetation. The lakes formed when the glacier margin retreated northward from the Augusta and Montague moraines, ponding meltwater in the low area between the front of the ice sheet and the moraines. The low area between the two swamps is an erosional channel cut by meltwater that spilled over a low area on the moraine. This stream was too small to move the larger stones and a lag deposit formed.

Other occurrences - Recessional moraines are found throughout the park. They include the Augusta, Montague, and Steeny Kill Lake moraines (plate 1) and they represent places where the retreating margin of the ice sheet halted long enough to build a low ridge of till.

- 0.0 mi/6.7 mi** **From Stop 8, continue south on Park Ridge Road.**
- 2.0 mi/8.7 mi** **Stop 9. Park on left before Parkers Brook bridge.**

Stop 9

Location - Port Jervis South quadrangle. Ridge Road, 3400 feet northwest of the intersection of Ridge and Sawmill Roads

Geology - *Surficial* - Meltwater channel, bouldery-lag deposits, and modern stream deposits.

Explanation - Many small valleys and ravines in the park were cut by streams discharging from the melting ice sheet. In many places, meltwater channels do not contain modern streams, and in other places the modern streams are underfit (too small to have eroded the valley in which they lie). Typically these channels are floored by bouldery lag deposits, and the modern alluvium only occupies a small part of the valley floor. In some places, bouldery terraces that are higher than the present floor of the channel show the former location of meltwater streams and the margin of the ice sheet. North of the Montague moraine, meltwater channels parallel the course of the moraine and they delineate the former positions of the glacier margin as it retreated northward. Meltwater streams also carried sediment from Kittatinny Mountain down to Flat Brook and Clove Brook valleys where the material was deposited in ice-contact deltas and outwash fans.

Other occurrences - Meltwater channels are found throughout the park in areas underlain by thick till, especially in front of the recessional moraines.

0.0 mi/8.7 mi

0.8 mi/9.5 mi

3.3 mi/12.8 mi

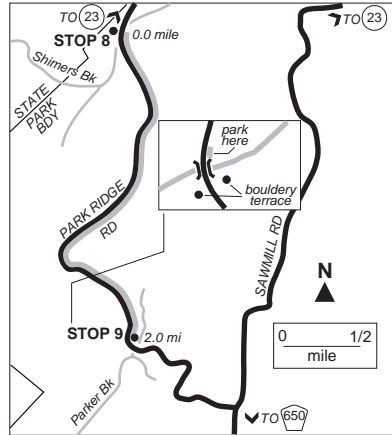
0.4 mi/13.2 mi

From Stop 9, continue on Ridge Road.

Turn left onto Sawmill Road.

Turn right onto NJ 23.

End at High Point State Park Office driveway.



Glossary

alluvial fan - A low, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a tributary stream at a marked flattening in gradient such as where a stream leaves a mountainous area and enters a plain.

anticline - A fold, generally convex upward, of which the core or central part contains older rocks.

bedding - The arrangement of a sedimentary rock in beds or layers of varying thickness and character.

bedrock - A general term for the consolidated (solid) rock that underlies soil or other unconsolidated surficial material.

boreal - Pertaining to the north, or located in northern regions.

braided stream - A stream that divides into or follows an interlacing or tangled network of several small branching and reuniting shallow channels separated from each other by branch islands or channel bars, resembling in plan the strands of a complex braid.

carbonate - A sediment formed by the organic or inorganic precipitation from aqueous solution of carbonates of calcium and magnesium or a rock consisting chiefly of carbonate minerals, such as limestone, or dolomite.

chert - A hard, very fine-grained, extremely dense, dull to glassy, crystalline sedimentary rock, consisting dominantly of interlocking crystals of quartz.

Cordilleran ice sheet - Pleistocene ice sheet in western North America that covered the northern parts of the Rocky Mountains, Cascade Mountains, and Coastal Ranges extending into Alaska.

conglomerate - A coarse-grained sedimentary rock, composed of rounded to sub-angular fragments larger than 2 mm in diameter (granules, pebbles, cobbles, boulders) set in a fine-grained mixture of sand or silt, and commonly cemented by calcium carbonate, iron oxide, silica, or hardened clay; the consolidated equivalent of gravel.

cross-bed - A single sedimentary layer, inclined at an angle to the main planes of bedding in a body of rock or unconsolidated deposit.

deglaciation - The uncovering of a land area from beneath a glacier or ice sheet by the withdrawal of ice due to shrinkage by melting and evaporation.

density current - A gravity-induced flow of one or more currents of varying densities over, through, or under another current.

dip - The angle that a structur-

al surface, that is, a bedding or fault plane, makes with a horizontal plane.

dolomite - A carbonate sedimentary rock of which more than 50 percent consists of calcium magnesium carbonate.

end moraine - A ridge-like accumulation of glacial drift formed at the margin of an actively flowing glacier.

formation - A body of rock identified by color, mineralogic composition, grain size and stratigraphic position that is mappable or traceable.

freeze and thaw - The mechanical weathering of rock caused by repeated cycles of freezing and thawing of water in pores, cracks, and other openings, usually at the surface.

gneiss - A coarse-grained, foliated metamorphic rock marked by bands of light-colored minerals such as quartz and feldspar that alternate with bands of dark-colored minerals.

granite - A light-colored, coarse-grained, intrusive igneous rock composed of quartz, feldspar, and mica.

Holocene - An epoch of Quaternary period ; 10,000 years ago to present time.

knob-and-kettle topography - An irregular landscape in which an assemblage of knolls, mounds, or ridges of glacial drift is interspersed with irregular depressions, pits, or kettles that are commonly

undrained and may contain swamps or ponds.

Laurentide ice sheet - Pleistocene ice sheet that covered most of northern North America east of the Rocky Mountains.

limestone - A sedimentary rock consisting chiefly of calcium carbonate, primarily in the form of the mineral calcite.

mass wasting - A general term for the dislodgement and downslope transport of soil and rock materials.

mastodon - One of a group of extinct, elephant-like mammals widely distributed in the Northern Hemisphere from about 34 million to 10,000 years ago.

mechanical weathering - The process by which a rock or mineral is broken down into smaller fragments without altering its chemical makeup; weathering that affects only physical characteristics.

member - A geologic unit of subordinate rank, comprising some specially developed part of a geologic formation.

Mesozoic - An era of geologic time, from the end of the Paleozoic to the beginning of the Cenozoic, or from about 225 to about 65 million years ago.

orogeny - The processes of mountain formation related to the convergence of crustal plates.

Permian - The last period of the Paleozoic era; thought to

have covered the span of time between 280 and 225 million years ago.

Pleistocene - An epoch of the Quaternary period, after the Pliocene of the Tertiary and before the Holocene; corresponding to the cyclic growth and decay of continental glaciers in the northern hemisphere. It began about two million years ago and lasted until the start of the Holocene some 10, 000 years ago. Also known as the Ice Age.

pollen - The multicelled sperm-carrying reproductive bodies of seed plants enclosed in a protective case (microspore wall). Fossil pollen consists entirely of the microspore wall .

Proterozoic - The more recent of two great divisions of the Precambrian from about 1200 to 550 million years ago

quartzite - A very hard slightly metamorphosed or unmetamorphosed sandstone, consisting chiefly of quartz grains that have been so completely recrystallized and solidly cemented with secondary silica that the rock breaks across or through the grains rather than around them.

rejuvenation - The action of stimulating a stream to renew erosive activity, as by uplift or by a drop of sea level.

ridge-and-kettle topography - An irregular landscape formed on end moraines in which an assemblage of oval-shaped knolls and mounds, or ridges of

glacial drift is interspersed with oval- to irregularly-shaped depressions, troughs, or kettles.

rift - A long, narrow continental trough or valley that is bounded by normal faults. It marks a zone along which the entire thickness of the lithosphere has ruptured under extension.

roche moutonnee - A small elongate protruding knob or hillock of bedrock, so sculptured by a large glacier as to have its long axis oriented in the direction of ice movement, an upstream (stoss or scour) side that is gently inclined, smoothly rounded, and striated, and a downstream (lee or pluck) side that is steep, and rough.

sandstone - A medium-grained sedimentary rock composed of abundant rounded or angular fragments of sand set in a fine-grained matrix (silt or clay) and more or less firmly united by a cementing material (commonly silica, iron oxide, or calcium carbonate); the consolidated equivalent of sand.

shale - A fine-grained sedimentary rock, formed by clay, silt, or mud. It is characterized by finely laminated structure that parallels bedding, along which the rock breaks readily into thin layers; the consolidated equivalent of mud.

siltstone - A fine-grained sedimentary rock formed by silt and having the texture and composition of shale but lacking its fine lamination.

surficial - Unconsolidated, residual, alluvial, or glacial deposits lying on bedrock or occurring on or near the Earth's surface.

syncline - A fold, generally concave upward, of which the core or central part contains younger rocks.

talus - Rock fragments of variable size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope.

tectonic - Said of or pertaining to the forces involved in, or the resulting structures of the outer part of the Earth related to the movement of its crustal plates.

terminal moraine - The end moraine that marks the farthest advance or maximum extent of a glacier.

topography - The general configuration of the Earth's surface, such as its mountains, valleys, and the shapes of landforms, that characterizes a given landscape.

Trace fossil - Fossilized track, trail, burrow, or tube resulting from the movement of an animal.

Triassic - The first period of the Mesozoic, thought to have covered the span of time between 225 and 190 million years ago.

tundra - A treeless, level or gently undulating plain characteristic of arctic and subarctic regions.

turbidite - A sediment or rock deposited from, or inferred to have been deposited from, a turbidity current.

weathering - The destructive process or group of processes by which rocks and minerals at or near the Earth's surface are broken down by physical disintegration and chemical decomposition, with little or no transport of the loosened or altered material.

Geologic Time Scale

Years Ago ¹	Eon	Era	Period	Epoch	Geology, Life, and Environment	
0 to 10,000	CENOZOIC	QUATERNARY		Holocene	Climate change from boreal (cold) to temperate (mild). Northern New Jersey glaciated at least 3 times.	Modern humans evolve.
10,000 to 1.8 million				Pleistocene		
1.8 to 66 million		TERTIARY		Pliocene	First large mammals appear. Abundant mammals; first hominids. Grasses and modern birds appear.	
				Miocene		
				Oligocene		
			Eocene			
			Paleocene			
66 to 146 million	MESOZOIC	CRETACEOUS		Late	Heyday of dinosaurs, pterosaurs and marine reptiles until their extinction at end of period. First flowering plants.	414.2 million-year gap estimated in geologic record at High Point State Park
146 to 200 million			JURASSIC			
				Middle		
200 to 251 million		TRIASSIC		Late	Age of dinosaurs begins. First mammals. Mollusks are dominant invertebrate.	
				Middle		
				Early		
251 to 299 million	PERMIAN		Late	Age of Amphibians. Pangea forms. Greatest mass extinction ever. Trilobites go extinct.		
			Early			
299 to 359 million	PENNSYLVANIAN ²		Late	Widespread coal swamps. First winged insects and reptiles.		
			Middle			
359 to 416 million	MISSISSIPPIAN ²		Late	Many ferns and amphibians.		
			Early			
416 to 444 million	DEVONIAN		Late	Age of Fishes. First shark. Many diverse land plants. Earliest amphibians, ferns and mosses.		
			Middle			
			Early			
444 to 488 million	SILURIAN		Late	Bloomsburg Red Beds Shawangunk Formation	First insects, jawed fish, vascular land plants.	
			Middle			
			Early			
488 to 542 million	ORDOVICIAN		Late	Martinsburg Formation • High Point Member • Ramseyburg Member • Bushkill Member	First corals, moss. Primitive fish, fungi and seaweed.	
			Middle			
			Early			
542 to 2500 million	CAMBRIAN		Late	Age of Trilobites. Cambrian explosion of life occurs. First vertebrates. Earliest fish. First shells appear.	Rocks of these ages are not found at (or near) the surface at High Point State Park. They may be at depth.	
			Middle			
			Early			
542 to 2500 million	PROTEROZOIC ³	Neoproterozoic Mesoproterozoic Paleoproterozoic			Cold climate with three episodes of glaciation in late Proterozoic. First soft-bodied invertebrates and colonial algae. Oxygen build-up in atmosphere during Mesoproterozoic.	
2500 to 4600 million	ARCHEAN ³	Neoarchean Mesoarchean Paleoarchean Eoarchean			Life appears. First bacteria and blue-green algae begin freeing oxygen to Earth's atmosphere. Earth molten. Sun and planets form.	

Lower limit of Eoarchean is not currently defined. Estimated to be 4600 million years.

Shading indicates that geologic deposits from these time periods are present at High Point State Park.

¹Gradstein, F.M. and others, 2004, A Geologic Time Scale: Cambridge University Press, 589 p.

²Pennsylvanian and Mississippian comprise the Carboniferous System.

³Also called Precambrian, a non-specific time term.