Chapter 3:
Geology and Topography of Dutchess County, NY

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INTRODUCTION

The topography, settlement patterns, and mineral resources of Dutchess County are all influenced by the underlying geology. For example, the highest mountains contain the hardest rocks, communities in the county are generally located in areas of sand and gravel because of the relatively level terrain and abundant water supplies they contain, and construction aggregates are mined where suitable deposits are found. Understanding geologic materials and processes is essential to sound resource management because the geology affects the

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quality and quantity of groundwater resources, the migration of pollutants, potential hazards to inhabitants, drainage patterns, mineral resources, and soil characteristics.

Geology is the study of the earth, including all materials found at and below the earth's surface. Geologists analyze the composition, origin, and ongoing changes in the rocks and sediments that compose the earth. The natural processes that shape the land – uplift, erosion, deposition of sediments, and faulting – are as vigorous today as they were in the past. These processes have resulted in a continual recycling of materials formed over the past 4.6 billion years of Earth's history. Here in Dutchess County we can see the effects of this **rock cycle** in the ancient gneisses exposed in Stissing Mountain and the Hudson Highlands, in the **schists** and **marbles** of the Harlem Valley, in the **sandstone** and **shale** that underlie Rhinebeck, and in the glacial deposits found throughout the county.

The geologic structure of Dutchess County is complex. Its history extends over one and a half billion years and has included several periods of major mountain building, ocean invasion and retreat, and **glaciation**. These events are part of the dynamic evolution of the earth's crust. However, there are also large gaps in the record of the geological history of the county; vast segments of time are unaccounted for within its borders due to erosion or simply lack of deposition. Today's topography is the result of the interaction between internal forces that uplift the land and external elements (weather, water, gravity, and human efforts) that continually erode it away.

GEOLOGIC HISTORY

All of the rocks in Dutchess County were formed during the Precambrian Eon (pre-Archaean, Achaean, and Proterozoic time intervals in Figure 3.1), and the Cambrian and Ordovician periods of the early Paleozoic Era, or between about 1,500 million years and 400 million years ago. Detailed descriptions of the rocks of Dutchess County are given in the *Bedrock Formations* section of this chapter.

EON	ERA	PERIOD	MILLIONS OF YEARS AGO
Phanerozoic	Cenozoic	Quaternary	1.6
		Tertiary	66
	Mesozoic	Cretaceous	138
		Jurassic	205
		Triassic	240
	Paleozoic	Permian	290
		Pennsylvanian	330
		Mississippian	360
		Devonian	410
		Silurian	435
		Ordovician	500
		Cambrian	570
Proterozoic	Late Proterozoic Middle Proterozoic Early Proterozoic		2500
Archean	Late Archean Middle Archean Early Archean		3800?
Pre-Archean			

Figure 3.1: Geologic time scale (US Geological Survey, 2010)

The oldest rocks in the county were deposited as sediments one and a half billion (1,500,000,000) years ago. One billion (1,000,000,000) years ago these sediments were caught in a collision between ancestral North America and another continent (perhaps an ancestral version of Europe or Africa, Figure 3.2). The collision, resulting in a mountain-building event that is referred to as the **Grenville Orogeny**, caused the sediments to be deformed, heated, and changed into the high-grade metamorphic rock known as **gneiss**. In places, the sediments were heated to the point of melting and an igneous rock known as **granite** was formed. The resulting mixture of granite and gneiss, designated p**Є**g on Map 3.1, is very resistant to erosion and forms the bedrock of the Hudson Highlands in the southern portion of the county and throughout neighboring Putnam County.

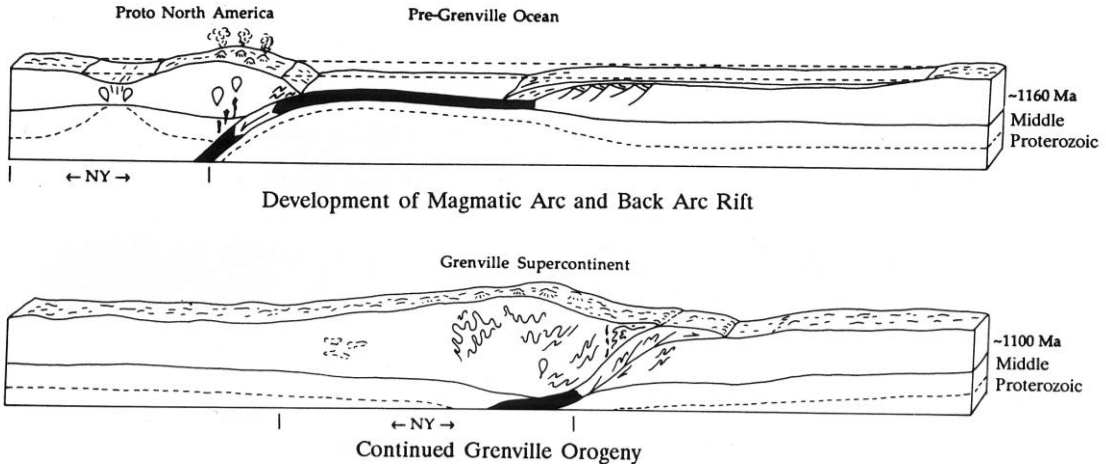

Figure 3.2: Diagram of Grenville Orogeny (from Isachsen et al., 1991).

Half a billion (500,000,00) years ago, the Grenville Supercontinent formed by the Grenville Orogeny broke apart nearly along the trace of the present Atlantic coast, forming a proto-Atlantic Ocean called the Iapetus Ocean (Figure 3.3). (In Greek mythology Iapetus was the father of Atlas, for whom the Atlantic Ocean is named.) The edge of the North American continent was near the present location of Dutchess County, and as sea level rose and fell, different kinds of sediments were deposited depending on the depth of the water.

Before the sea inundated the region, coarse sands and gravels were deposited on the land. After the area was inundated, but while sea level was still relatively low, the Dutchess County area was covered by shallow waters at the edge of the sea, and **limestones** rich in the carbonate minerals calcite and dolomite were deposited in coral reefs and carbonate banks much like the Bahamas today.

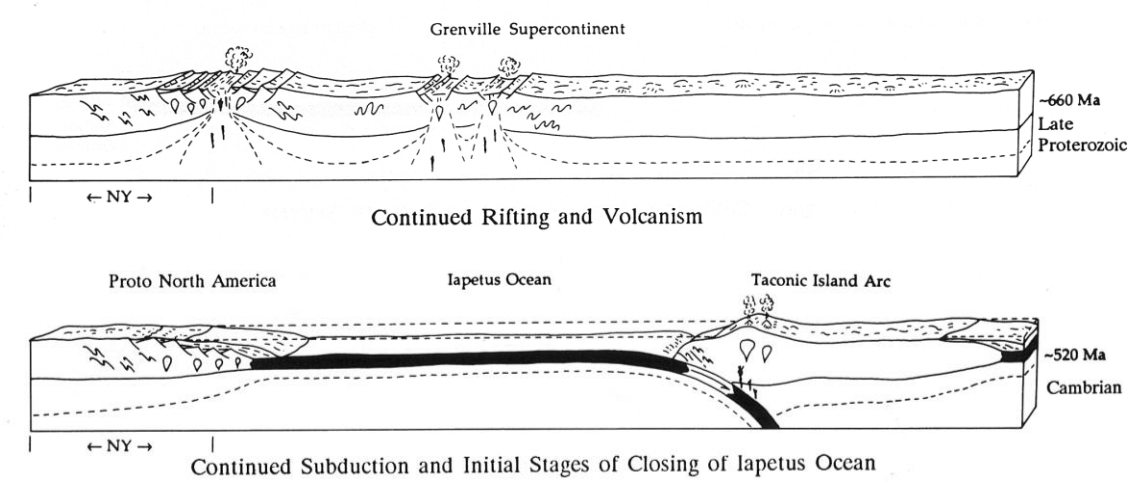

Figure 3.3: Diagram of rifting of the Grenville Supercontinent and formation of the Iapetus Ocean (from Isachsen et al. 1991).

At times when sea level was high, Dutchess County was covered by deeper water, and fine-grained black shales were formed, representing deposition in deep ocean waters of the abyssal plain (the deepest and flattest part of the ocean basins). These shales underlie much of the county, but since they are relatively soft they are not often seen at the surface. Both the limestones and shales are **autochthonous**, meaning that they were formed in their present location.

About 450 million (450,000,000) years ago the Iapetus Ocean began to close, and the east coast of North America began to feel the effects of a collision of continental plates that would continue in two major pulses over the next 200 million (200,000,000) years. During the initial stages of the collision (known as the **Taconic Orogeny**, Figure 3.4), interbedded **sandstones** and shales were deposited by submarine landslides along the continental shelf and slope. Later, large masses of sandstone and shale deposited in the open ocean at or just beyond the edge of the continental shelf were pushed from an area far to the south and east up and over the autochthonous shales and limestones of Dutchess County in a process known as **thrust faulting**. The **Taconic Allochthon** (allochthon means formed far away and transported to the present site), which was created by this thrust faulting, formed a high range of mountains (the ancestral Taconic Mountains) in the vicinity of the present New York-Connecticut border. The thrust faults that bound the allochthon are shown in Figure 3.10.

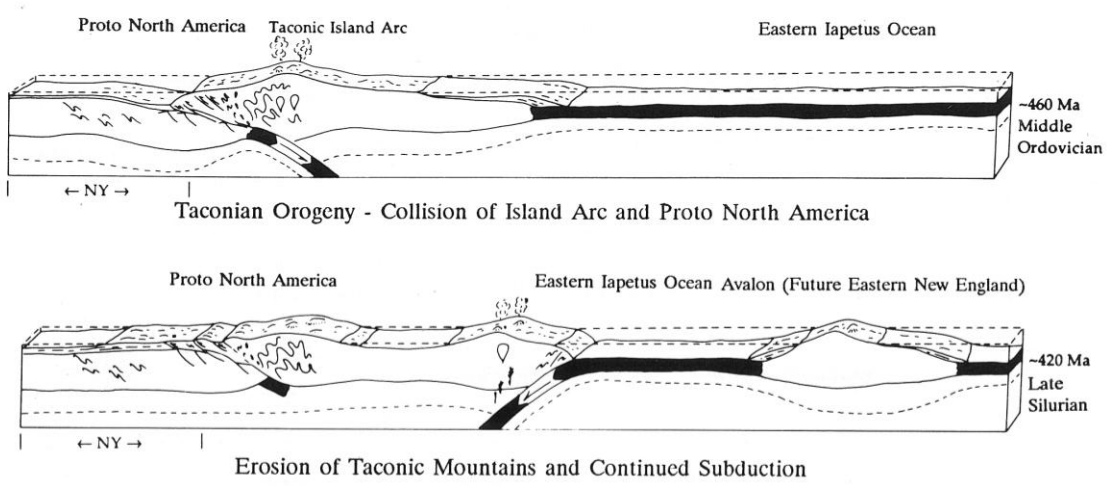

Figure 3.4: Diagram of Taconic Orogeny and erosion of the Taconic Mountains (from Isachsen et al., 1991).

In front of and just below the advancing allochthon, a mixture of different materials, including both allochthonous and autochthonous rocks, was deposited. The result was a chaotic mixture, known as **melange,** composed of large blocks of many different kinds of rock in a matrix of autochthonous shale.

The mountain building of the Taconic Orogeny squeezed and heated rocks caught within the collision zone causing them to be changed or "metamorphosed." The limestones in the western part of the county were metamorphosed to become the marbles today found in the Harlem Valley. Shales in the northwest part of the county were gradually metamorphosed to become **schists** and gneisses in the vicinity of Pawling. The intensity of metamorphism of the rocks increases from northwest to southeast with low-grade metamorphism in the northwestern part of the county (mostly shale), medium-grade metamorphism in the central part of the county, (mostly schist), and high-grade metamorphism in the southeastern part of the county (gneiss).

Several episodes of continental collision after the Taconic Orogeny resulted in the formation of a supercontinent called Pangea. Pangea broke apart during the Mesozoic Era, and subsequent drifting of landmasses has created the configuration of continents we see today. These tectonic events affected the rest of North America, but did not affect Dutchess County. While the county once lay at the margin of the North American tectonic plate, the edge of the plate is now located far to the east, in the middle of the Atlantic Ocean. As a result, our region has been very quiet tectonically for the past 300 million years, as North America has drifted westward from Europe and Africa. During this time, the area has been subject to erosion and development of the topographic features we see today.

The latest notable geologic force to influence Dutchess County was the advance of the massive Laurentide ice sheet southward out of Canada, which extended as far south as Long Island approximately 20,000 years ago (Figure 3.5). The retreat of the ice sheet left behind the surficial deposits of the county and the topography that we see today.

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Figure 3.5: Over the last 2.75 million years, continental ice sheets have repeatedly waxed and waned in the northern hemisphere. The most recent ice sheet, called the Laurentide ice sheet, peaked around 20,000 years ago and extended as far south as Long Island in New York State. (from Tasa Graphic Arts, Inc.)

As the Laurentide Ice Sheet retreated, it left behind sediment ridges that dammed glacial meltwater to form lakes. The largest of these lakes occupied the Hudson River valley and was called Lake Albany (Figure 3.6). It gradually lengthened as the ice margin retreated northward, eventually merging with a precursor of Lake Champlain called glacial Lake Vermont (Rayburn et al., 2005). A much larger lake, Lake Iroquois, to the west of Lake Albany formed in the area where Lake Ontario exists today. At around 13,000 years ago, the ice dam separating the two lakes was breached, leading Lake Iroquois to catastrophically drain through Lake Albany to the south, breaching the moraine dam that impounded Lake Albany and scouring out the lake sediments within the Hudson Valley (Donnelly et al., 2005).

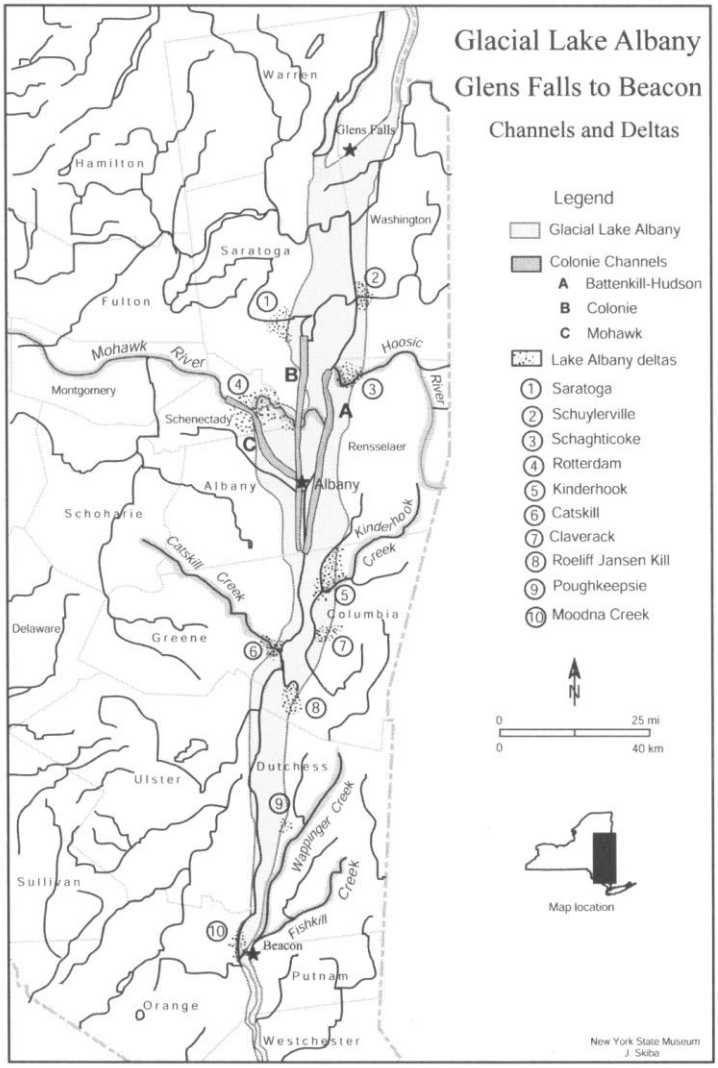

Figure 3.6 – Extent of glacial Lake Albany in the Hudson Valley (from Cadwell et al., 2003).

BEDROCK FORMATIONS

Dutchess County contains rocks from all three of the major rock groups: metamorphic, sedimentary, and igneous. **Metamorphic rocks** are those that have been changed in texture and composition by heat, pressure, or chemically active solutions deep within the earth but without melting. In contrast, **igneous rocks** are formed from the solidification of molten material, either at Earth's surface (volcanic rocks), or deep in Earth's interior (plutonic rocks). **Sedimentary rocks** are formed at or near the earth's surface by depositional and

biological processes. **Clastic sedimentary rocks** are composed of rock fragments and clay minerals that have been cemented together and include shale and sandstone. **Carbonate rocks** (sedimentary rocks composed of calcium carbonate) may be formed by biological or processes, such as the formation of coral reefs, or by physical processes, such as the precipitation of carbonate minerals out of saturated sea water. Carbonates that contain a significant component of calcium-magnesium carbonate are labeled "dolomite" or "dolostone." For a more in-depth treatment of these concepts see: http://geomaps.wr.usgs.gov/parks/rxmin/rock.html.

The **bedrock** of Dutchess County includes all of the solid rocks found in road cuts, valleys, and mountaintops. It can be divided into two basic groups: 1) older, highly altered (metamorphosed) former sedimentary and igneous rocks found primarily in the Hudson Highlands and in scattered outcrops elsewhere in the county, and 2) younger, slightly- to highly-metamorphosed sedimentary rocks found throughout the rest of the county. As mentioned in the geologic history section, the degree of **metamorphism** in the younger rocks increases from the northwest (Red Hook and Rhinebeck) to the southeast (Dover and Pawling). The rocks with the highest metamorphic grade (most altered) are found in the uplands east of the Harlem Valley. A simplified view of the bedrock types found in Dutchess County is shown in Map 3.1.

It is common for geologists to attach proper names to each distinctive geological unit. For example, there are many carbonates in the world, but only one Wappinger Group. The names come from localities were the unit was first or best described. There are many exposures of the Wappinger Group throughout the county, but the formation was first described in and around the Town of Wappinger.

Bedrock formations of Dutchess County are described in the following sections (detailed descriptions of the geologic units in New York are cataloged by the US Geological Survey).

Older metamorphic rocks of the County (map symbol pЄg)

The oldest rocks in Dutchess County are in the Hudson Highlands, an upland area composed primarily of various **gneisses** (metamorphic rocks made up of discrete bands of

light and dark minerals). These rocks (p**Є**g on Map 3.1), which were formed more than one billion years ago during the Grenville Orogeny (Isachsen et al, 1991), are most common along the southern border of Dutchess County, between the Hudson River and the western border of the town of Pawling. The second largest occurrence of these rocks underlies a group of prominent hills, the Housatonic Highlands, east of Dover Plains. Isolated, uprooted blocks of gneiss also crop out at Todd Hill along the Taconic Parkway in the town of LaGrange, Corbin Hill north of the Village of Pawling, Stissing Mountain in the Town of Pine Plains, and in a series of small fault slivers between the City of Beacon and the Town of Fishkill.

Most of the gneiss consists of light and dark colored minerals arranged in layers with a banded, streaky, or speckled appearance. Gneisses containing light colored minerals such as quartz, feldspar, and muscovite (white mica) predominate. Various types of gneisses containing dark minerals such as hornblende, garnet, and biotite (black mica) also occur. Extensive outcrops of gneiss are generally more resistant to weathering than sedimentary rocks. As a result, gneiss outcrop areas are usually part of more rugged terrain and exist at higher elevations. Granitic gneiss, which occurs at North Beacon Mountain, is the most durable of these types and is sometimes quarried for crushed stone and building stone.

Younger sedimentary/metamorphic rocks (map symbols Є and O)

The younger sequence of bedrock units in the county includes:

1. Carbonate rocks of the **Wappinger Group** (**OЄw** on Map 3.1) and its metamorphic equivalent, the Stockbridge marble)
2. **Poughquag quartzite** (Єp), a body of sandstone known from its extensive outcrops near the hamlet of Poughquag
3. Metamorphosed clastic sedimentary rocks (now schists) of the **Taconic Sequence** (**Єt**), which were deposited at a point several hundred kilometers east of North America and were subsequently shoved over younger rocks to their present position. The Taconic sequence is very similar to the clastic rocks that it rests upon (Osh) which were deposited in about the location we find them now. The Osh rocks are **autochthonous** shales, whereas the Taconic sequence is **allochthonous** shales.

4. Relatively unaltered to moderately metamorphosed autochthonous clastic sedimentary rocks, including the **Poughkeepsie** (or **Taconic**) **Melange** (**Otm**) and the **Austin Glen greywacke** (**Oag**)

Carbonate rocks

Carbonate rocks are formed primarily from the precipitation of calcium and magnesium carbonate in seawater, commonly through the action of algae and other organisms like corals and mollusks. The Wappinger Group, found in the central and western part of the county, consists of Cambrian- and Ordovician-age carbonate **strata** (rocks composed of layered sediments). Its metamorphic equivalent, the Stockbridge marble, underlies the Harlem Valley. Outcrops of carbonate rocks are found scattered throughout the southern, central, and eastern parts of the county. In the southeast, carbonate rocks form valleys, as the marble is softer and more susceptible to erosion than the surrounding metamorphic rocks. Elsewhere, the carbonates form small ridges, as they are relatively harder than the adjacent unmetamorphosed clastic rocks. Some of these rocks can be seen south of Poughkeepsie in road cuts along Route 9 near the Galleria and South Hills Malls, and along the river in the large quarry operating at Clinton Point.

Carbonate rocks are economically important in Dutchess County as a source of construction aggregate. One of the largest quarries in New York State is located in the Town of Poughkeepsie at Clinton Point. Glimpses of the carbonate rocks and the quarry operations can be seen from the Metro-North train between Poughkeepsie and New Hamburg. The carbonate rock of this quarry has an average magnesium carbonate content of about 40 percent. For this reason it is classified not as a limestone, but as a dolostone, which is slightly harder than limestone. The rock is blasted, crushed, and sorted to sizes ranging from large individual rock fragments (riprap) weighing up to 15 tons each, to sand used in the production of asphaltic paving and the manufacturing of concrete blocks. Most of the production from the quarry is shipped by barge to New York City. Carbonate rocks are also mined in the Town of Pleasant Valley to produce construction aggregate. During World War II, marble in the Town of Dover was mined to recover magnesium for the war effort.

The metamorphism of the Wappinger Group generally increases in intensity from the northwest to the southeast. In the town of Milan and the valley of the Wappinger Creek, the original bedding (layering) is readily visible because the rocks are relatively unaltered. Farther east, in the Harlem Valley, the formation has been metamorphosed into marble and the beds are severely folded. The marble in the southeastern part of the county has been deformed several times by plastic flow so that it appears to wrap around stronger rocks. South of Pawling, masses of schist (a metamorphic rock made of parallel layers of mica and other minerals) have been folded and shoved into the carbonate, appearing as inclusions.

It is difficult to determine the exact thickness of the carbonate rocks because of the amount of faulting and metamorphism that have occurred. However, these rocks are believed to be approximately 1,000 feet thick in the western part of the county, and to thicken to the east. A thickness of 2,800 feet has been measured near Stissing Mountain (Knopf, 1962), and they are estimated to be nearly 4,000 feet thick in the Harlem Valley (Isachsen et al., 1991).

Carbonate rocks are susceptible to internal erosion by the movement of groundwater along fractures and faults. Groundwater dissolves carbonate deposits, producing solution channels and voids; these openings provide storage cavities for groundwater supplies. This stored water can easily be polluted by contamination sources, such as septic tanks, where there are not enough sediment deposits on top of the carbonate bedrock to filter the waste materials. Although cave-ins may occur elsewhere in carbonate rocks, they are rare in Dutchess County.

Clastic Rocks

Clastic sedimentary rocks were formed by the compaction and cementing together of muds and sands at shallow depths beneath the Earth's surface. All of the clastic rocks of Dutchess County were originally formed in an ocean; however, much of the Catskill Mountains, to the west, is composed of clastic rocks formed on land.

There are two distinct groups of clastic rocks in the county. These are: the Poughquag quartzite, found in close proximity to the Wappinger Group carbonate rocks, and shales and clay-rich sandstones (and their metamorphic equivalents) found throughout the county.

Poughquag Quartzite

The Poughquag quartzite (**Є**p on the map) is a very hard, compact, white to gray sandstone with a quartz content greater than 90 percent. Very clean sandstones (almost pure quartz) are typically believed to be former beach deposits; winnowing by waves removed clays and other minerals. The quartzite is so hard that Native Americans mined it for stone tools and points. Although it is relatively thin (less than 50 feet), equivalent sedimentary layers extend across the United States as far west as Nevada.

Shales and clay-rich sandstones

Most of Dutchess County is occupied by what were originally shales and clay-rich sandstones (map units **Є**t-allochthonous Taconic sequence, **O**sh-autochthonous shales, and **O**ag-Austin Glen formation) (Figure 3.7). These are found throughout the county, extending into Columbia County to the north, and Orange and Ulster counties to the west. Like the carbonates, the intensity of metamorphism increases from the northwestern part of the county to the southeast. These rocks were originally formed in relatively deep water, during or after the Taconic Orogeny (see *Geologic History* section), as muds derived from land settled in ocean water.

Figure 3.7: Excellent exposure of relatively unaltered sandstone and shale of the Austin Glen formation (map unit Oag) along Route 199, between Route 9G and the Hudson River

A distinct subset of these rocks is the Poughkeepsie or Taconic Melange (map unit **O**tm). This unit formed as the westward-moving allochthons slid into a deep basin lying in the approximate position of the Hudson River, forming a jumbled mix of sandstone blocks in a matrix of mud. Good exposures of the melange are seen in Kaal Rock Park, at the eastern end of the Mid-Hudson Bridge (Figure 3.8). The melange also underlies much of the bank of the Hudson River from Poughkeepsie to Hyde Park.

Figure 3.8: Sandstone blocks in Taconic melange; Kaal Rock Park (Jeff Walker)

The mineral composition and structure of the shale and sandstone units change from the northwest to the southeast. Quartz and mica are found chiefly in the northwest and central parts of Dutchess County. Feldspar is an additional component in the southeast. Bedding plane openings that serve as channels for the storage and movement of groundwater are apparent between the Fishkill Creek and Wappinger Creek valleys. Also between the two creeks, slaty cleavage (a texture produced by rock compression) has resulted in numerous small, closely spaced parallel fractures within the rock. Such cleavage is absent and the rocks are more massive in the southeastern part of the county. Garnet has been mined in the Harlem Valley, as described below. Because these garnet-bearing rocks are relatively soft, they are not used commercially except locally as fill.

A variety of names have been applied to the clay-rich rocks in the county, which may have formed at different times and in different geologic settings. The lack of well-preserved fossils or other diagnostic features, combined with the complex deformation to which they have been subjected, has resulted in less certainty as to the correlation amongst the various named units. Generally, the rocks located in the higher elevations east of the Taconic Parkway are allochthonous (moved), whereas those west of the Parkway are autochthonous (in-place).

STRUCTURAL GEOLOGY

Although sedimentary rocks are generally formed in horizontal layers, parallel to the Earth's surface, today we find them oriented in many directions. Their present configuration is the

result of multiple mountain-building events, as described in the section on *Geologic History*. Additional signs of mountain building are found in folds and faults that can be observed in road cuts throughout the county (Figure 3.9). Similar, but larger-scale features can be inferred from the distribution of different types of bedrock. For example, higher-grade metamorphic schists overlie lower-grade slates in the eastern part of the county. Although the contacts between these contrasting rock types are only exposed in a few places, they are inferred to be low-angle thrust faults (faults that allow one rock unit to ride up and over another rock unit, a movement that occurs during the compression associated with mountain building).

Figure 3.9: Folding in the Austin Glen Formation, Noxon Road (Jeff Walker)

The distribution of rock units generally forms a northeast to southwest pattern across the county, as depicted in Map 3.1. Areas of similar bedrock types are inferred to be bounded by faults that separate them from areas of differing bedrock types. No doubt there are many faults within the blocks of similar rock types, but it is difficult to identify them because of the soil and vegetative cover.

The fracturing and crushing that occurs along faults creates channels that can carry large volumes of groundwater. These channels may be enlarged in carbonate rocks as a result of dissolution from acidic waters. As a result, wells drilled into fault and fracture zones may yield large quantities of water.

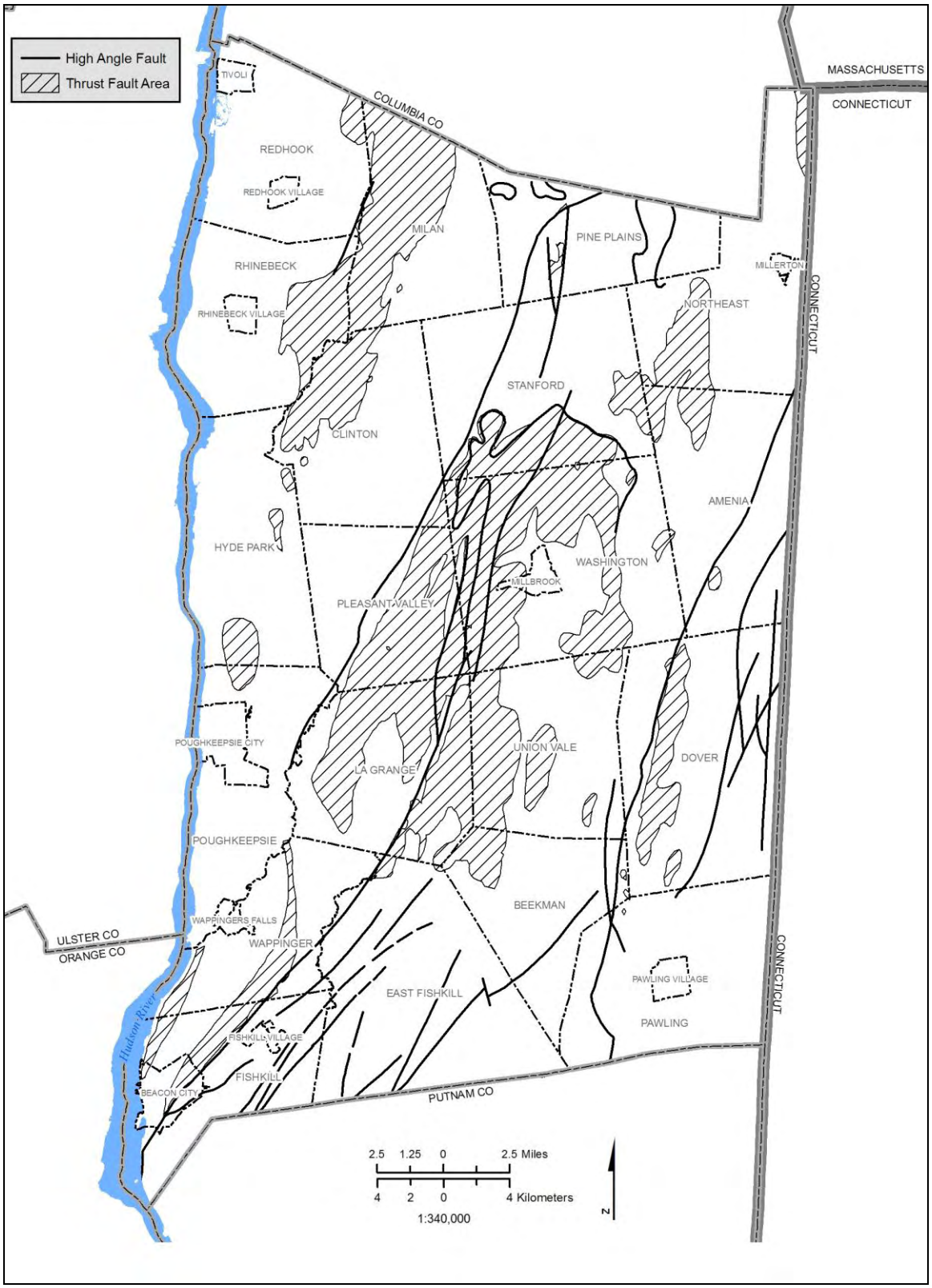

Figure 3.10: Map of faults within Dutchess County

The faults in the region are very old and considered to be inactive. They were formed more than 200 million years ago and have experienced little or no activity since then. Consequently, the county has historically had very few, mostly small, earthquakes.

The tectonic history of the Taconic Orogeny has resulted in a complex structural picture for Dutchess County. A schematic cross section approximately along the line of Route 55 is shown in Figure 3.11. Formation names and symbols are the same as in Map 3.1. The map and the cross section indicate a number of faults where rock masses have moved in relation to one another during the long geologic history of the area.

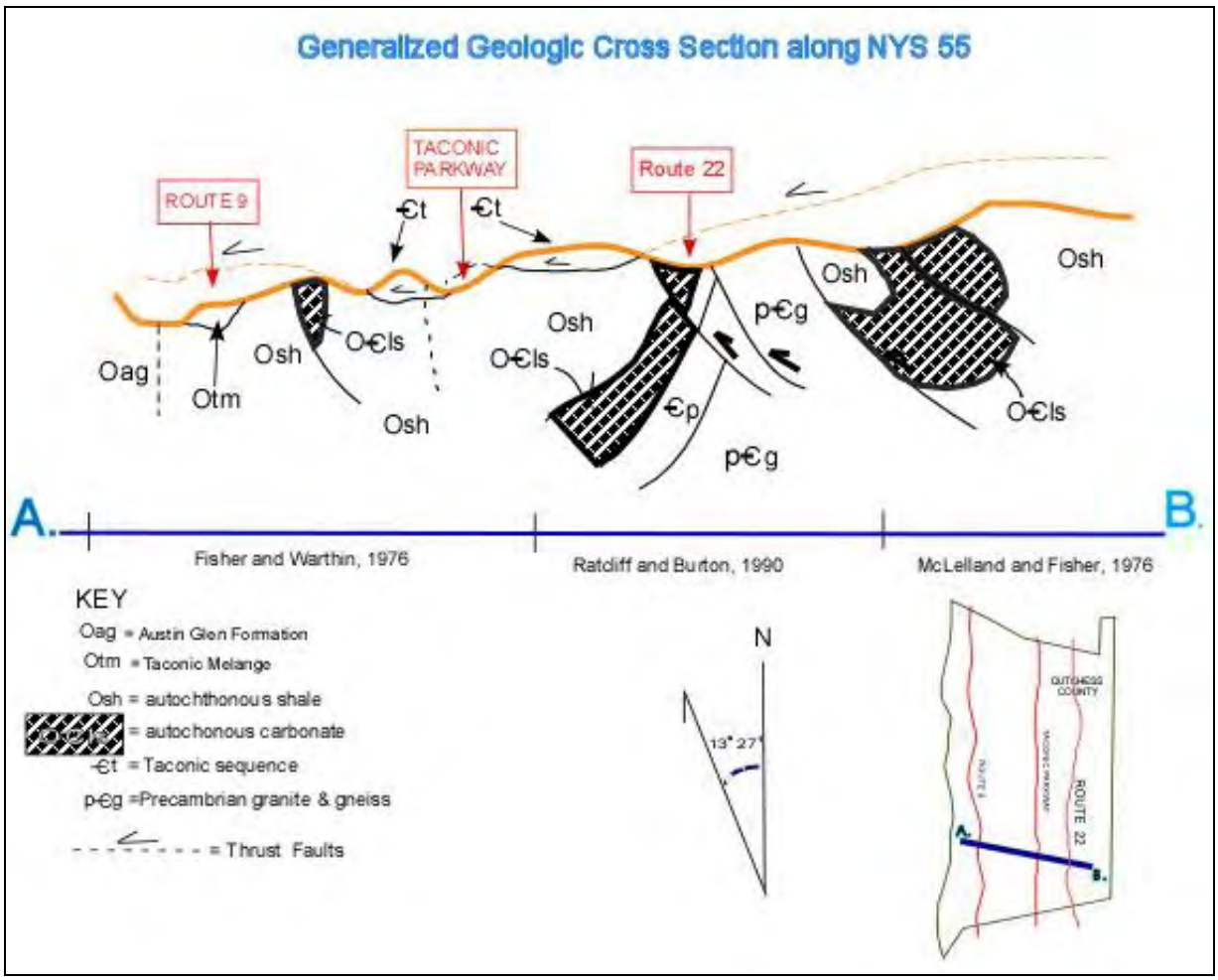

Figure 3.11: Generalized geologic cross-section along Route 55 (interpreted by Jeff Walker; drafted by John DeGilio).

Important features of the cross section include remnants of the Taconic Allochthon (labeled ϵt in Figure 3.11), which underlie topographic highs in the central part of the county. These remnants are floored by relatively low-angle thrust faults active during the Taconic Orogeny. Also shown are relatively high-angle reverse faults, another type of faulting typical of the compressional forces active during mountain building events. These faults bring very old Precambrian gneisses and their Paleozoic cover rocks, including the Poughquag quartzite (ϵp), Wappinger Group limestones (Oϵw), and autochthonous shales (Osh), to the surface at various places across the county. Some of these faults may have originally formed as extensional fractures known as normal faults during the initial breakup of North America 500 million years ago, and may have been reactivated during the Taconic Orogeny (400 million years ago) as reverse faults. During the breakup of Pangea (200 million years ago) they may have become normal faults once again (Isachsen, et al., 1991). The location of and sense of motion on the faults is largely conjectural since the faults themselves are rarely exposed at the surface.

In addition to faults, the cross-section in Figure 3.11 shows several large folds that bend the autochthonous rock into downwarps known as **synclines**. Finally, the cross section suggests an interesting topographic inversion whereby the limestones are ridge-forming units in the western part of the county because the limestone is more resistant to erosion than the surrounding shales, and valley-forming units to the east where the situation is reversed. In the humid northeast United States it is more common for limestones to floor valleys because they are more susceptible to weathering and erosion than other rock types.

SURFICIAL DEPOSITS

Unconsolidated materials overlie the bedrock in most parts of the county. These include glacial deposits formed during by the Laurentide ice sheet during the last Ice Age as well as more recent stream deposits. Many of the surficial geologic deposits have been altered to produce soils, which are discussed in NRI Chapter 4: Soils.

The sedimentary deposits (Map 3.2) produced by the advance and retreat of ice sheets vary depending on whether the deposits were formed under the ice sheet or adjacent to it as

climate warmed and the ice margin retreated northward (Figure 3.12). Rocks embedded in the bottom of ice sheets were pushed over the underlying landscape, scratching bedrock surfaces and creating particles that range in size from large boulders (erratics) to fine clay. Resulting glacial deposits are classified into three main categories: 1) till, 2) outwash, and 3) clay. Unlike the bedrock, the processes that formed Dutchess County's glacial deposits can be observed today in association with modern glaciers, streams, and lakes.

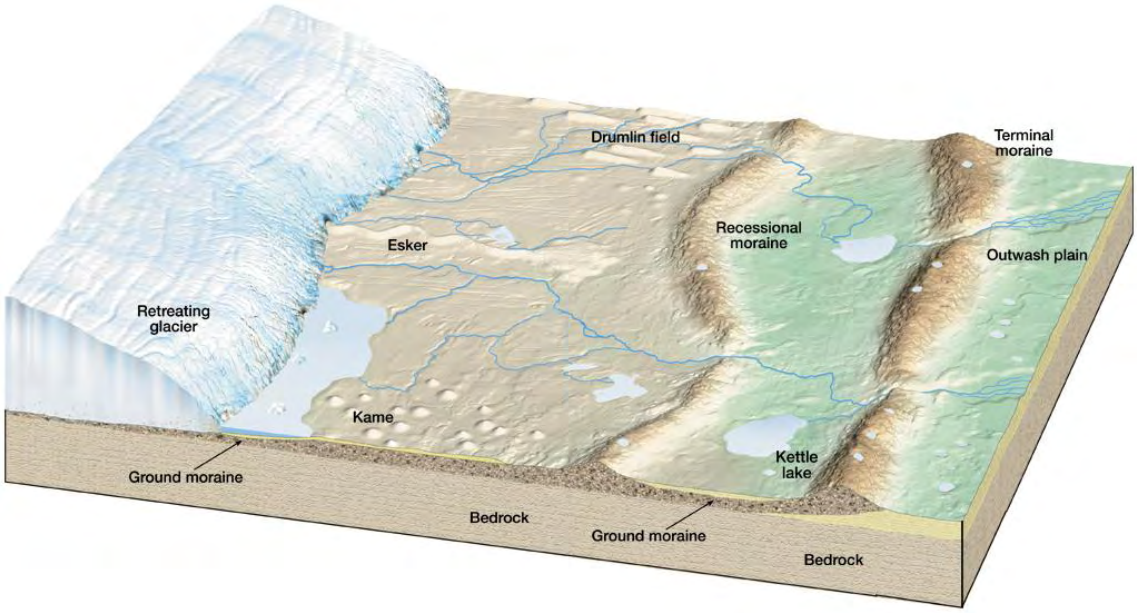

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Figure 3.12: Deposits left behind by continental ice sheets vary depending on whether they were formed underneath the ice sheet, adjacent to it, or in front of it. Additional controls on deposit type include whether the sediments were deposited by the ice directly or by meltwater streams. (from Tasa Graphic Arts, Inc.)

Till

Unsorted mixtures of fine material, sand, and larger cobble-sized rocks make up glacial **till** found throughout the county (Figure 3.13). This material blankets the hills of the county and underlies the other glacial deposits in the valleys. It was deposited directly from the melting ice without further modification by moving water. In some areas, till was pushed up into linear ridges (moraines, Figure 3.12) by the episodic re-advance of the ice sheet.

Figure 3.13: Glacial till. Note the mixture of grain sizes from large rocks to fine sands, silts, and clays that indicate no reworking by water. (from http://nesoil.com/images/tillcut.htm, 2010).

Outwash

Meltwater issuing from the edge of a glacier can transport large volumes of debris, much as modern streams do during flooding. The coarser-grained fraction of the stream load is deposited where the flow velocity of the stream ebbs because it enters a lake or flood plain. In contrast, fine-grained sediments are carried far away. The resulting glacial **outwash** is relatively free of very large boulders and fine silts and clays.

During the retreat of the Laurentide ice sheet, sands and gravels were deposited in deltas where meltwater streams issuing from the front of the ice sheet entered glacial lakes and dropped their coarse-grained loads. These deposits are characterized by stratification (layering) that is inclined at 5 to 30 degrees from horizontal (Murray, 1976; Figure 3.14).

Figure 3.14: Delta foreset beds (from http://academic.emporia.edu/aberjame/ice/lec06/lec6.htm, 2010)

Outwash also fills many of the major valleys of the county, including those currently occupied by Wappinger Creek and the Tenmile River. Horizontally stratified sand and gravel were deposited on flood plains of the glacial predecessors of these modern streams. The layers within the outwash terraces reflect changes in grain size due to changes in stream flow volume and velocity.

Lacustrine (lake) Clay

Finer silt- and clay-sized particles, winnowed from the sand and gravel fraction of stream loads, were carried farther downstream, eventually being deposited into local lakes and ponds. These deposits are very dense and uniform in grain-size, although some of the lake deposits are finely layered (varved), possibly reflecting seasonal changes in flow. The lake deposits are located in the lowest parts of the glacial terrain, and are commonly found above a thin layer of till and beneath glacial outwash or modern wetland soils.

Remnants of Lake Albany sediments can today be found along the river's edge on the lands of many of the large estates, such as the Franklin Delano Roosevelt home, the Vanderbilt Mansion, and Locust Grove. Additional lake sediments underlie the Vassar College farm, the Dutchess Plaza shopping center in the Town of Poughkeepsie, and the athletic fields of the Dutchess Day School in Millbrook.

MINERAL RESOURCES

Mineral resources have played an important role in the development of Dutchess County since its settlement. Many of the oldest buildings in the county (including the 1765 stone Clinton House and the 1767 brick Glebe House) were constructed of locally mined materials. Historically, significant resources have included: construction aggregate (crushed stone, sand, and gravel), metallic minerals, and non-metallic minerals.

Such resources can only be utilized where suitable deposits occur. Thus, gravel mines can only be located where there is a substantial reserve of gravel, and rock quarries must be situated where the bedrock has characteristics appropriate for the purpose to which it is to

be put. As a result, resource-rich towns such as Amenia and Fishkill have had a more active mining industry than resource-poor towns, such as Wappinger. Unfortunately, as residential development has spread across the county, land-use conflicts have arisen and many potentially valuable resources have been lost.

Construction Aggregate

Sand and Gravel

Sand and gravel are mined for construction aggregate throughout New York and are an important economic resource in Dutchess County. Significant sand and gravel reserves are found primarily along stream valleys, where glacial outwash is located. The valley of Wappinger Creek (in the central part of the county) and the Harlem Valley are notable for their thick outwash deposits. These relatively level gravel terraces are the greatest areas of land use conflict because they are also valuable as farmland and suitable for easy residential development.

The unconsolidated sand and gravel is extracted from open pits, processed on site, and shipped by truck to its point of use. These uses include: construction of septic systems, erosion and stormwater management projects, sand filters for purifying water, concrete for houses and roads, and ice-control sand for reducing hazardous winter driving conditions.

Crushed Stone

Rock aggregate, produced by crushing bedrock, is currently the leading mineral commodity in New York State. There are four active quarries in Dutchess County at this time. These are: the Clinton Point quarry (carbonate, Town of Poughkeepsie), Dutchess Quarry (carbonate, Pleasant Valley), the Thalle Industries quarry (gneiss, Fishkill), and the Wingdale Materials quarry (schist, Dover). Historical records indicate that numerous, small quarry operations produced crushed rock and building stone in the county. The Clinton Point (locally known as "Trap Rock") quarry was started in 1888 for this reason.

Much of the production from the quarries is used in highway construction. The non-carbonate aggregate is especially useful for creating relatively skid-resistant road surfaces.

Metallic Minerals

Iron

At one time, iron ore constituted the most valuable metallic mineral resource found in New York State. From the mid-1800s to the early 1900s the resource was very actively exploited, with approximately 40 iron mines in operation in the Hudson Highlands and Harlem Valley. The iron ore in the Harlem Valley was found in the metamorphic schists, near the contact with the marble. Bog iron was also a source of raw materials for Dutchess County iron works. This iron was precipitated in wetlands where iron-rich groundwater discharged to the oxygen-rich surface environment.

The burgeoning demand for iron and steel during the Second Industrial Revolution and advances in technology encouraged the exploitation of lower grade ores in Minnesota and the abandonment of the mines in Dutchess County and vicinity. Iron furnaces are still visible in the Harlem Valley, however, such as along Dover Furnace Road.

Silver and Lead

Reserves of other metallic minerals are lacking in the county. There have been historic reports of small silver and lead mines, but these were primarily prospects without significant economic production.

Non-metallic Minerals

Garnet

The aluminum-rich mineral garnet is found in high-grade metamorphic schists in the uplands adjacent to the Harlem Valley in the towns of Amenia, Dover, and Pawling. This very hard mineral is commonly used as an industrial abrasive. Garnet is recovered as a by-product of crushed stone production at the Wingdale Materials quarry in Dover. The sale of the garnet helps to offset the costs of operating this underground mine.

Clay

Hudson Valley brick manufacturers primarily used clay from relict glacial lake sediments located along riverbanks. Away from the rivers, clay-rich glacial till was also mined to create bricks. The largest brickyards were located in the Beacon area. The Dennings Point Brick

Works produced as many as 400,000 bricks a day in the late 19th century. The Brockway Brick Company had a yard north of Beacon. Another brickyard existed in the area presently occupied by the Dutchess Plaza shopping area in the Arlington neighborhood in the Town of Poughkeepsie. The brickyards closed in the early 20th century because of changing economic conditions.

DUTCHESS COUNTY TOPOGRAPHY

Topographic Relief

Most of Dutchess County is part of the Mid-Hudson Valley and therefore at relatively low elevations. Exceptions include the Hudson Highlands along the southern edge of the county, the Taconic Mountains in eastern Dutchess County, and Stissing Mountain in Pine Plains. While hilltop elevations in the lowlands are generally below 500 feet above sea level, some elevations in the highlands exceed 1,500 feet.

Topography is intimately related to the underlying geology. Much of the Mid-Hudson Valley is underlain by soft shale or carbonate bedrock, while the Hudson Highlands and the Taconic Hills are underlain by much harder granites, gneisses, schists, and other hard rocks. Carbonate rocks often form localized valleys in the eastern part of the county and ridges in the west. For example, the Harlem and Clove Valleys in the east, as well as the ridge beneath the Galleria Mall in Poughkeepsie, are all under underlain by carbonates. Major streams commonly occur over soft carbonate rocks in Dutchess County. Webatuck Creek, Wappinger Creek, and Fishkill Creek in southwestern Dutchess County all occur on carbonate bedrock.

Dutchess County has extensive low and relatively flat terrain (Map 3.3). These areas include the Fishkill Creek/Sprout Creek Valley in southwestern Dutchess, the Wappinger Creek Valley in west-central Dutchess, the Harlem Valley in eastern Dutchess, Clove Valley in Union Vale and Beekman, and the plain created by a glacial melt-water lake west of Red Hook and Rhinebeck. While the valley bottoms have low relief, adjacent areas are often hilly with relief of several hundred feet. High terrain in the county includes the Hudson

Highlands along the southern boundary of Dutchess, the Taconic Mountains in eastern Dutchess, and Stissing Mountain in Pine Plains. The crest of South Beacon Mountain in the Hudson Highlands is 1,602 feet above sea level while Brace Mountain in the Taconic Mountains has a crest of 2,311 feet.

Glacial Landforms

Glacial topographic features are superimposed on the larger-scale topography of the region. In some places, glacial till was sculpted into ridges parallel to the margin of the Laurentide ice sheet, known as **glacial moraines** (Figure 3.15). These ridges reflect both the bulldozing of material by the advancing glacier and the continuous delivery of new material to the glacier's edge by the movement of ice as the edge remained fixed in position for centuries. In Dutchess County, these moraines are traceable for 5 to 15 miles from west to east and rise up to 180 feet above the surrounding landscape (Connally & Sirkin, 1986).

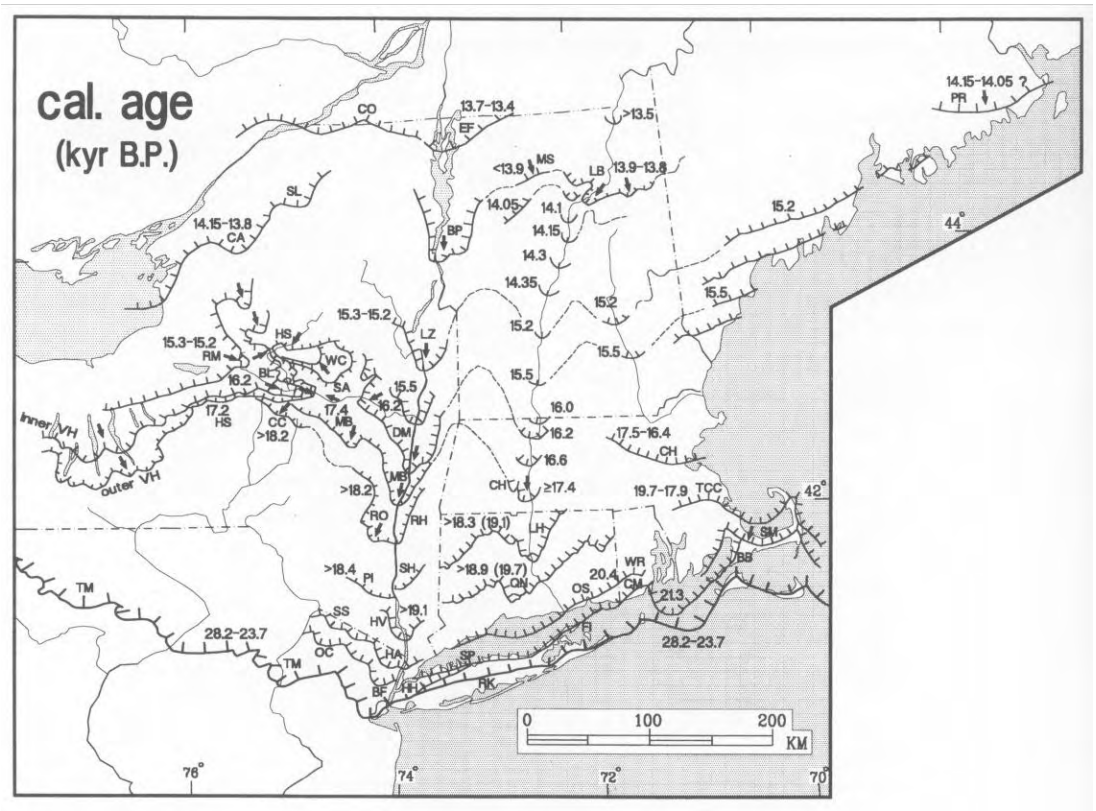


Figure 3.15: The location and ages of moraines left behind by the most recent ice sheet to impact the Northeast. Cal. Age kyr B.P. refers to calendar age in thousands of years before present. Dutchess County contains the Shenandoah (SH) and Red Hook (RH) moraines. (From Ridge, 2003)

Glacially streamlined rock knobs called drumlins are also mantled by glacial till. Examples of such hills include Spy Hill between Route 55 and Route 376 in the Town of Poughkeepsie and the College Hill park area in the City of Poughkeepsie.

Flat valley floors testify to the former presence of glacial lakes and outwash plains in the county (Map 3.3). These easily eroded sands and gravels provided a ready pathway along which post-glacial streams currently flow. Streams like the Wappinger Creek, Fishkill Creek, and Tenmile River flow through many of these deposits and have subsequently left their own in the form of channel floodplain sediments (white areas in Map 3.3).

Topographic Data Resources

Several sources of topographic data exist for Dutchess County. The United States Geological Survey (USGS) produces maps containing topographic information for all of the United States (http://topomaps.usgs.gov). The USGS maps of Dutchess County have an interval between contour lines of 10 feet and therefore cannot resolve features only a few feet high. Dutchess County has obtained more detailed topographic data using LIDAR, which was used to produce contour lines at 5 foot intervals. Using this data, contour maps, shaded relief maps, and maps of steep slopes can be created at a higher level of detail than previously. Examples of maps from these databases are shown in Figure 3.16.

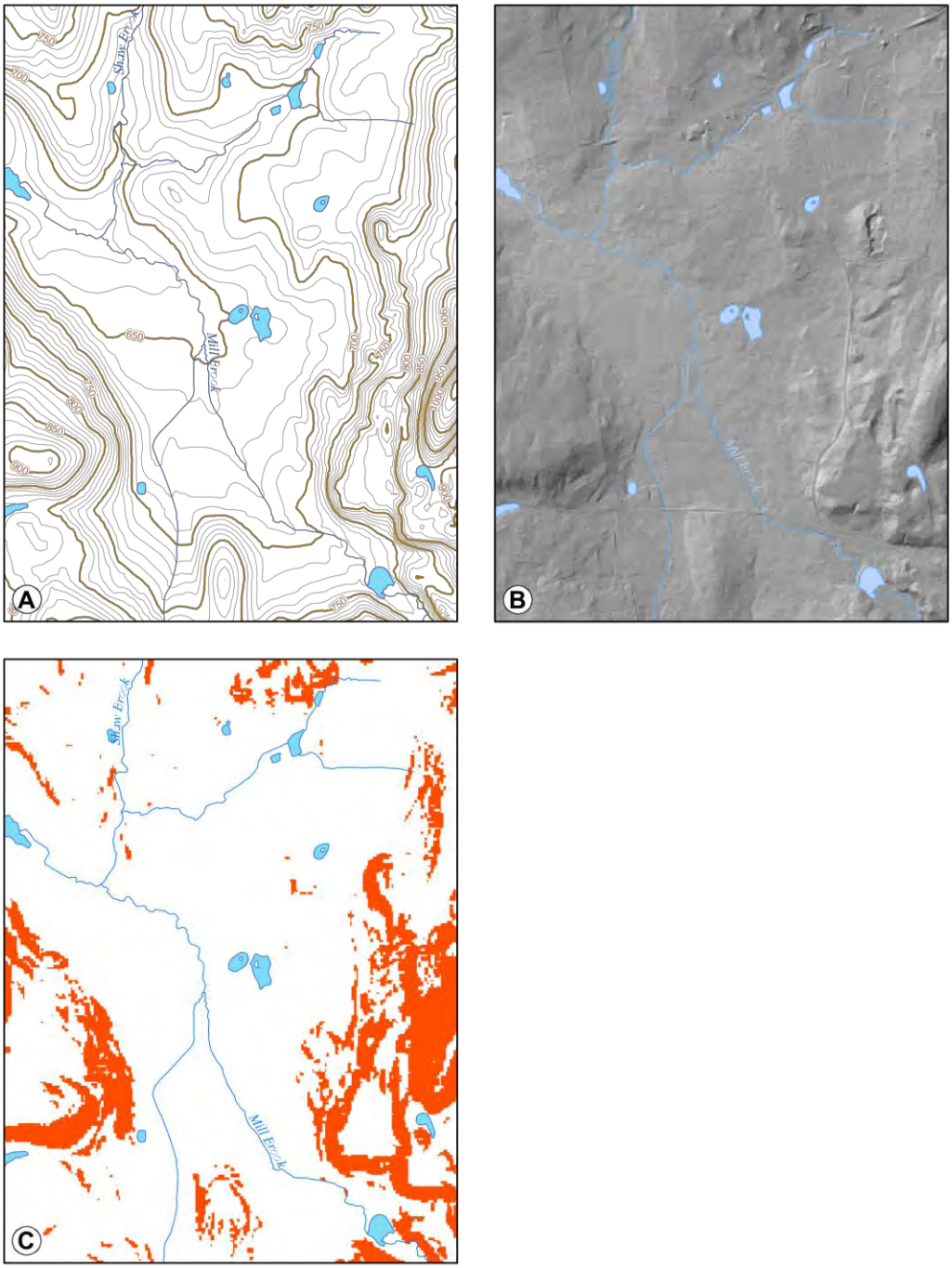


Figure 3.16: Different ways to express topographic information: a) topographic contours; b) shaded relief map; 3) steep slope map.

TRENDS AND CHANGES SEEN OVER TIME

Geologic processes typically proceed at a very slow rate within the interiors of tectonic plates. Consequently, the bedrock geology of Dutchess County has changed little since the current pattern of plate movements became established about 200 million years ago. The advance and subsequent retreat of the last ice sheet during the past 100,000 years shaped the topography created by millions of years of erosion. Uplands were eroded by the glacier and lowlands were filled with glacial debris.

The mines and quarries within Dutchess County have provided an adequate supply of high-quality aggregate for the needs of local residents and businesses since the start of European settlement. In contrast, resource-poor counties, west of the Hudson River, have had to rely largely on imported aggregate to supply their needs. Other geologic materials, such as cut stone, metals, and clay, are no longer supplied by local sources and must now be provided by mines outside of the region, and in some cases, outside of the country.

During historic times, minor changes in topography have occurred due to natural processes. Some streams have changed position a small amount through the natural processes of streambank erosion and sediment deposition. Some wind erosion has probably occurred in agricultural areas that are frequently plowed, but certainly not enough to be detected by the existing topographic data. Many small changes in topography have also occurred because of development, including changes in the drainage patterns of streams, removal of high points during mining operations, flattening areas to create parking lots, etc. The effects of these man-made changes in topography, and how each of them interacts with each other, are often not considered thoroughly when development is being planned. The result can be increased flooding in local streams, ponding of water on important roads and the filling of basements with water where this had never been a problem in the past.

Land-use conflicts have arisen during the last decades of the 20th century between mining and residential development. Glacial outwash deposits in the valleys are the sole sources of sand and gravel, as well as targets for suburban development. In addition, the visibility of mines has become equated with visual impacts. As a result, deposits that may have provided

high-quality aggregate to supply new developments and infrastructure maintenance are either developed for residential housing, or new mines are opposed by residents.

IMPLICATIONS FOR DECISION-MAKING

Three aspects of Dutchess County geology and topography have important implications for decision making: availability of mineral resources, steep slopes, and viewsheds.

Mineral Resources

Mineral resources are finite in extent and are rapidly being lost to development. As a result, aggregate has to be trucked increasing distances to satisfy continuing demand within the county. Mining Overlay Districts have been established in some Dutchess County towns to restrict mining rather than encourage it.

Municipalities elsewhere in the nation have recognized the importance of an adequate supply of aggregate to society and have taken steps to preserve mineral resources from conflicting land uses. In Oroville, California, for example, mineral resource areas have been identified to indicate the significance of mineral deposits and to reduce the threat of encroachment by incompatible land uses.

Steep Slopes

Generally speaking lowlands were developed first in Dutchess County. Early development occurred along the Hudson River, along major streams and along major roads and railroads, which were built in lowland areas first. Development of level areas is often relatively easy and inexpensive. Today, much of the development occurs on moderate to steep slopes. Development in areas of steep slope (Map 3.4) is more expensive, more difficult, and is prone to serious environmental impacts. Care must be taken to ensure that development on slopes does not adversely affect pre-existing development in the lowlands. For this reason a few municipalities have passed steep slope ordinances in recent years. Development on steep slopes can lead to significantly increased soil erosion and greatly increased stormwater

runoff which may lead to increased flooding in local streams and a variety of other problems. Local steep slope ordinances seek to reduce these problems.

Viewsheds

Dutchess County has long been known for its spectacular views. A **viewshed** is the area that can be seen from a particular spot, the viewpoint, and its size and shape are determined by the local topography. Important viewsheds can be damaged by development. For example, a building on top of a hill may have a wonderful view, but damage the view of everyone living in the nearby lowlands. The viewshed from a scenic overlook may be considered an important resource worthy of preservation by a community. Viewsheds along the Hudson River were deemed so important by many people that they formed an organization, Scenic Hudson, to protect them. Viewsheds along scenic highways, trails and parks may also be considered important to the public. Of course the view from an individual house is also important to the owner of that house. Scenic views in Dutchess County contribute to residents' sense of place and improve our quality of life. Fortunately, there are simple ways to build on high areas without damaging the community's scenic views, and at least one municipality in Dutchess County has passed a Ridge Protection Ordinance to protect a scenic ridgeline from being damaged by development.

RESOURCES FOR ADDITIONAL INFORMATION

- **U.S. Geological Survey (USGS):** As the Nation's largest water, earth, and biological science and civilian mapping agency, the U.S. Geological Survey (USGS) collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems. See: http://www.usgs.gov/

REFERENCES

Cadwell, D.H., E.H. Muller and P.J. Fleisher. "Geomorphic history of New York state." In *Geoarcheology of landscapes in the glaciated Northeast*, edited by D.L. Cremeens and J.P. Hart. Albany, NY: New York State Museum Bulletin 497 (2003): 7-14.

Connally, G.G., and L. Sirkin. "Woodfordian ice margins, recessional events, and pollen stratigraphy of the mid-Hudson Valley." In *The Wisconsinan Stage of the First Geological District, Eastern New York* edited by D.H. Cadwell. Albany, NY: New York State Museum Bulletin 455(1986): 50-72.

Donnelly, J.P., N. Driscoll, E. Uchupi, L. Keigwin, W. Schwab, E.R. Thieler and S. Swift. Catastrophic meltwater discharge down the Hudson River Valley: a potential trigger for the Intra-Allerod cold period, *Geology* 33 (2005): 89-92.

Isachsen, Y.W., E. Landing, J.M. Lauber, L.V Rickard and W.B. Rogers. "Geology of New York, a Simplified Account." *New York State Museum/Geological Survey Educational Leaflet No. 28*. Albany, NY: New York State Museum, 1991

Knopf, E. B. Stratigraphy and Structure of the Stissing Mountain area, Dutchess County, N.Y. *Stanford University Publications in the Geological Sciences* 7, 1: 1962.

Murray, D.J. "Pleistocene history of the Millbrook, New York region." In New York State Geological Association Guidebook to Field Excursions edited by J. H. Johnsen, p. B-5-1 to B-5-10. 1976.

Oroville, California Municipal Code. "Chapter 23A, Surface Mining and Reclamation." Oroville, CA: 2008. http://oroweb.cityoforoville.org/citycode/_DATA/CHAPTER23A/23A_16_Mineral_resource_protec.html

Rayburn, J.A., P.L.K. Knuepfer and D.A. Franzi, D.A. A series of large, Late Wisconsinan meltwater floods through the Champlain and Hudson Valleys, New York State, USA. *Quaternary Science Reviews* 24 (2005): 2410-2419.

Ridge, J.C. "The last deglaciation of the northeastern United States: a combined varve, paleomagnetic, and calibrated ^{14}C chronology." In *Geoarcheology of landscapes in the glaciated Northeast* edited by Cremeens, D.L., and J.P. Hart. Albany, NY: New York State Museum Bulletin 497 (2003): 15-45.

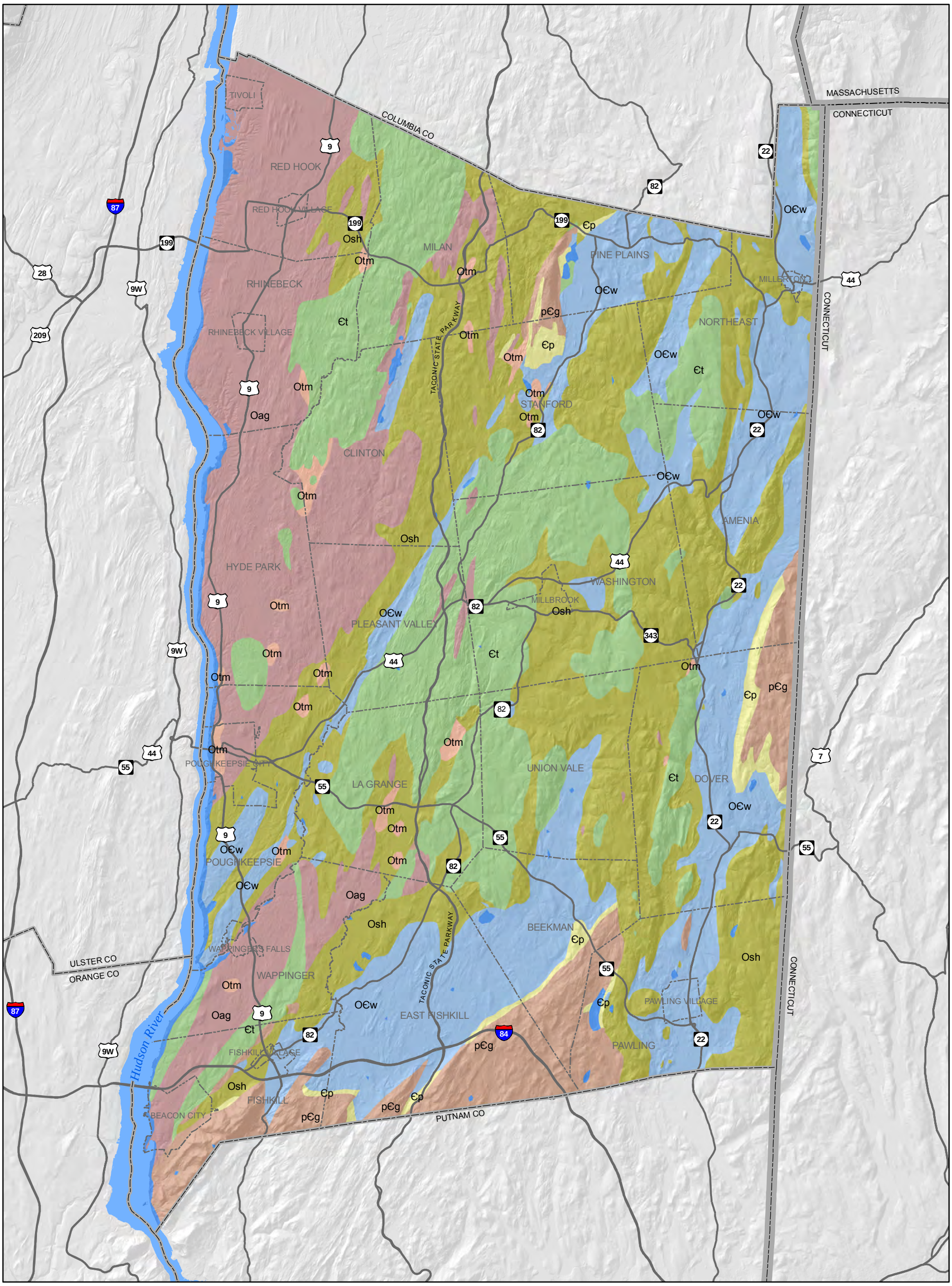
Ruddiman, W.F. Earth's Climate: Past and Future. New York: W.H. Freeman and Company, 2008.

Stanford, S.D. Onshore record of Hudson River drainage to the continental shelf from the late Miocene through the late Wisconsinan deglaciation, USA: synthesis and revision. *Boreas* 39(2009) 1-17.

Map 3.1: Bedrock Geology

Dutchess County, New York

Prepared by:
CCEDC GIS Lab, 2010



Geologic Formations

Oag	Austin Glen Formation	pЄg	Precambrian granite and gneiss
OЄw	Autochthonous limestone	Otm	Taconic Melange
Osh	Autochthonous shale	Єt	Taconic sequence
Єp	Poughquag Quartzite	h2o	Unknown

Miles
2 1 0 2
4 2 0 4
Kilometers
N

1:225,000

Map 3.2: Surficial Geology

Dutchess County, New York

Prepared by:
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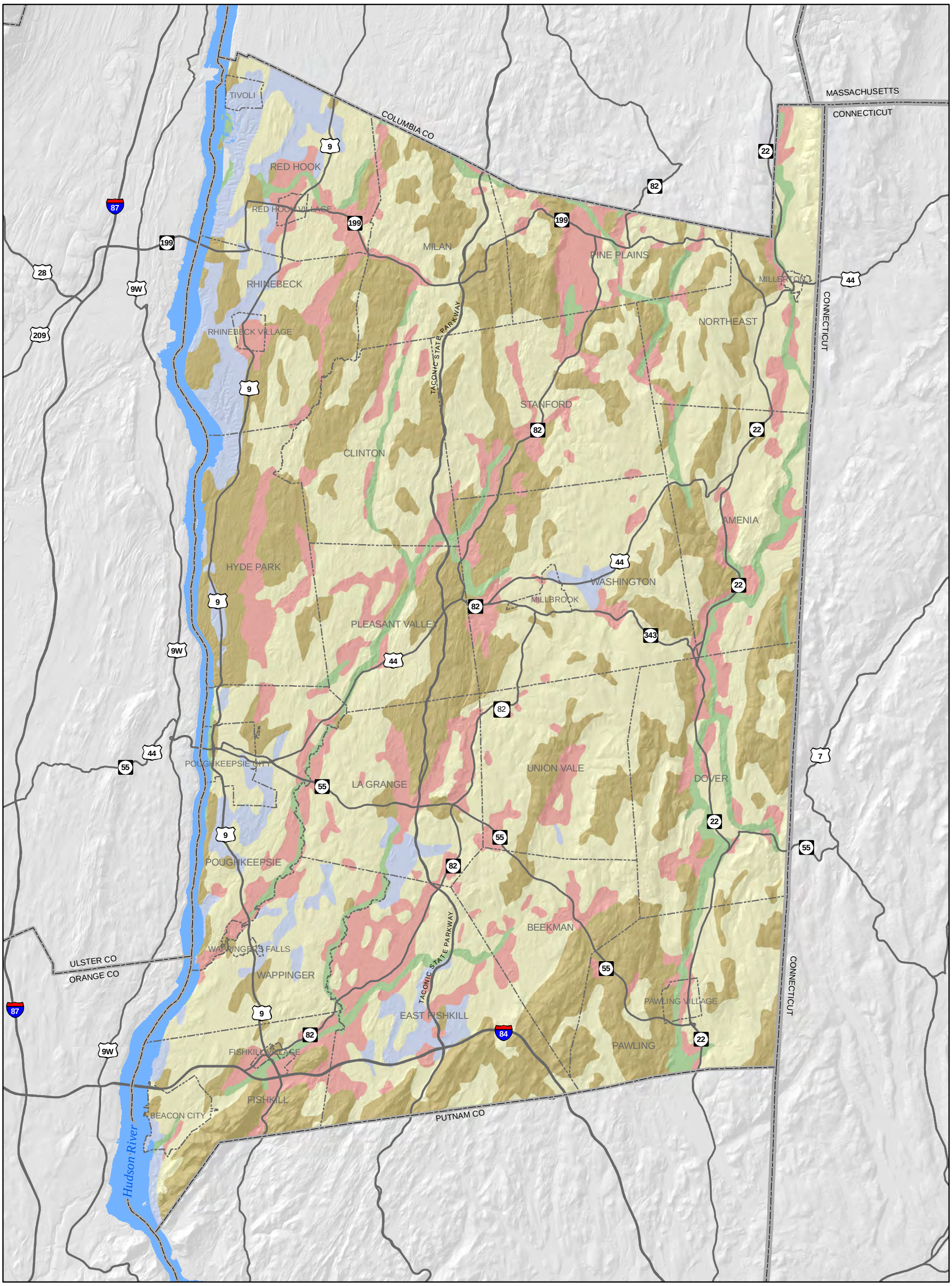

Surficial Geology

- Bedrock
- Glacial Outwash
- Lake Sediments
- Stream Sediments
- Till

Miles
2 1 0 2
4 2 0 4
Kilometers
1:225,000
N

Map 3.3 Shaded Relief

Dutchess County, New York

Prepared by:
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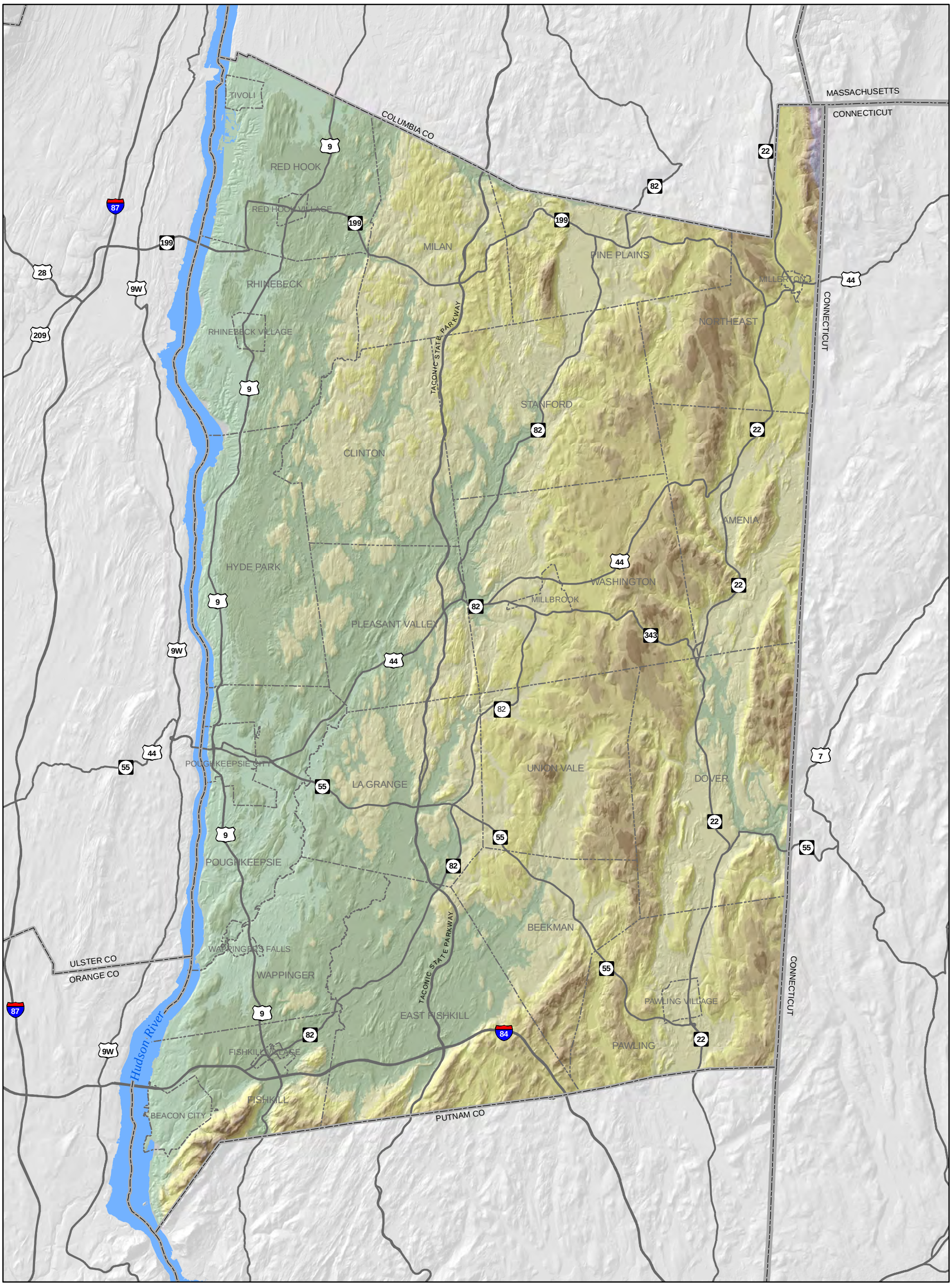

Elevation Range (ft)

- 0-200
- 201-400
- 401-600
- 601-800
- 801-1000
- 1001-1200
- 1201-1400
- 1401-1600
- 1601-1800
- 1801-2000
- 2001-2200
- 2201-2400

Miles
2 1 0 2
4 2 0 4
Kilometers

N

1:225,000

Map 3.4: Steep Slopes

Dutchess County, New York

Prepared by:
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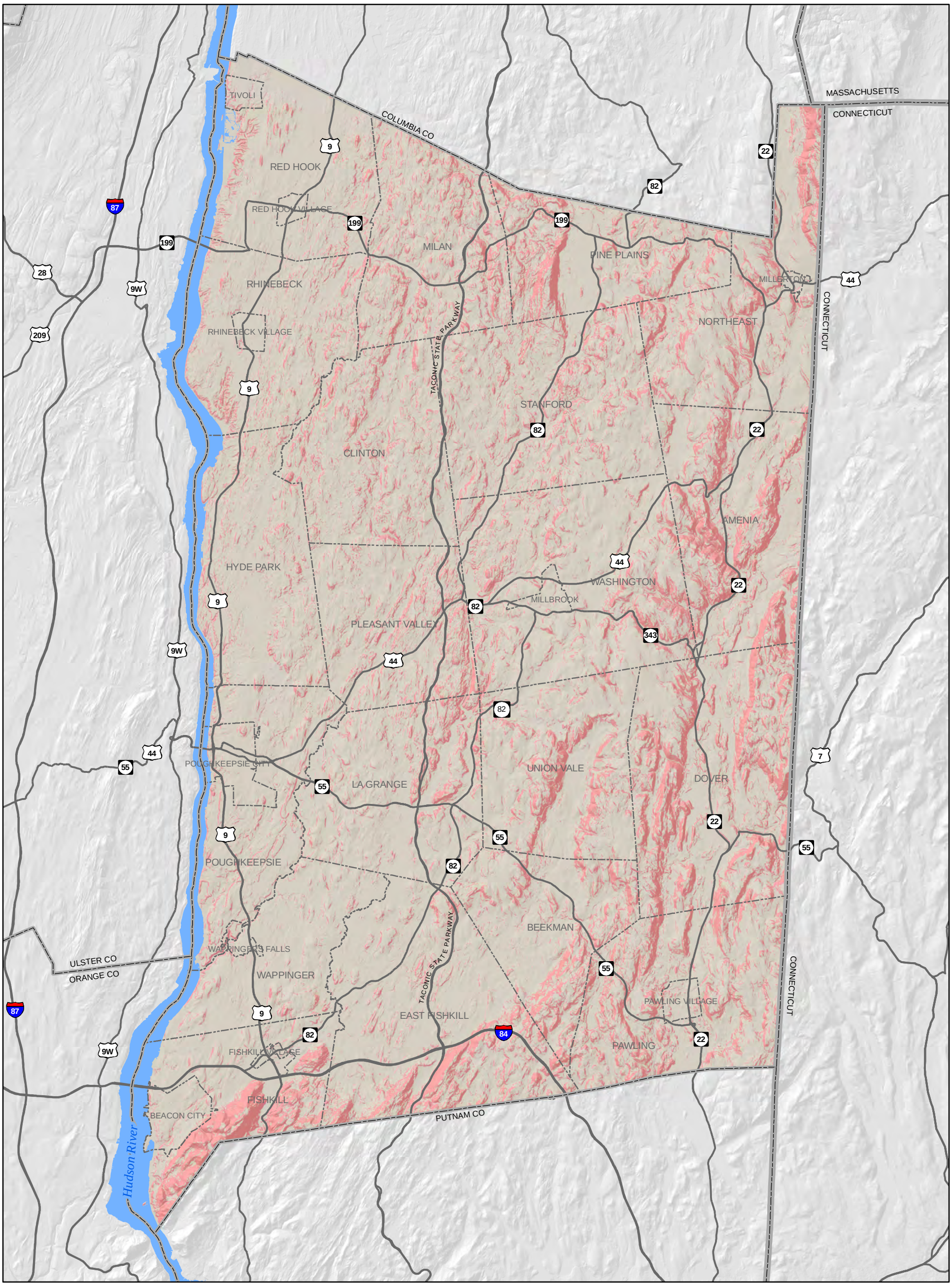

Slopes

- Slopes <= 20%
- Steep Slopes (> 20%)

Miles
2 1 0 2
4 2 0 4
Kilometers

N

1:225,000