



Appalachian National Scenic Trail

Geologic and Soil Resources Inventory Summary



Franconia Ridge in the White Mountains of New Hampshire is a prominent ridge, forming the backbone of the range and connecting all of its major summits. It is the second-highest range of mountain peaks in the White Mountains. Photograph by Paulbalegend in 2008 available at https://commons.wikimedia.org/wiki/File:AT_-_Franconia_Ridge.JPG (accessed 6 January 2023). Unmodified and used under license, CC-BY-SA-3.0,2.5,2.0,1.0 (https://commons.wikimedia.org/wiki/Commons:GNU_Free_Documentation_License).

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Abstract

This document summarizes the status of National Park Service (NPS) Geologic and Soil Resources Inventory (GSRI) deliverables for Appalachian National Scenic Trail (APPA). It also provides information on current geology and soil resources management concerns with a focus on identified inventory needs related to geologic heritage, geohazards, and soil features and processes. This document is intended to assist APPA staff with prioritizing technical assistance or new inventory and assessment funding requests in the near term (roughly 1–5 years).

GRI hosted a baseline scoping meeting for APPA in 2016. Baseline geologic map footprints and state-specific index maps were delivered to APPA in 2017. These data were updated in 2024 and include protocols to maintain them as new mapping is completed. SRI started a soil survey geographic (SSURGO) for a legacy soil database and map to the scenic trail in 2012. However, this was not completed; thus, updated data and an “enhanced report” have not yet been developed nor delivered.

Geologic heritage resources, or geologic features, landforms, and landscapes characteristic of our nation which are preserved for the full range of values that society places on them, are myriad at APPA. Notable examples include the trail itself, wind and water gaps, the high ridges, iconic vistas, and geologic stratotype localities. Geologic heritage inventory needs are field-based surveys of stratotypes, notable geologic features GIS data, cultural GIS data, and archeological assessment.

The soils of the scenic trail are characteristically thin and rocky in the higher elevations and diverse in the lower valleys. Major differences also occur where the landscape was previously glaciated, contrasted to the unglaciated areas. Inventory needs include cohesive soil mapping, soil monitoring, assessments of areas affected by acid deposition, and site-specific erosion and compaction data.

Resource management issues for APPA include physical management of the trail, views beyond the trail and overuse, disturbed lands and abandoned mineral lands (AML), external development, slope movements, seismic activity, karst, and paleontological resource protection. Geologic and soil hazards include floods, climate change, landslides, shrink and swell soils, AMLs, cave and karst (sinkholes), wildfire, asbestos and dangerous soils, radon, and avalanches. Inventory needs include surficial geologic and soils mapping, derivative maps (e.g., slopes and soil properties), LiDAR data, and boundary survey data.

Additional guidance for park staff regarding proposal processes and timeframes for the new Inventories and Assessment (I&A) program is available on the [GSRI](#) and [I&A](#) SharePoint sites.

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Background of the GSRI

In the late 1990s, the Geologic Resources Inventory (GRI) and Soil Resources Inventory (SRI) programs were established as two of the 12 original baseline inventories in the NPS Inventory and Monitoring (I&M) program. These baseline inventories compiled existing information, acquired new information, and helped establish a minimum level of data for more than 270 parks, which served as a common starting point for natural resource monitoring. For both the GRI and SRI, the primary deliverable was a digital (GIS) map. Scoping summaries, geologic map posters, and GRI reports were also produced for most of the 270 parks. In addition, many soil surveys were produced. GRI and SRI products are available on the GRI publications website at <http://go.nps.gov/gripubs>, and on the NPS DataStore, accessed through the Integrated Resource Management Applications (IRMA) portal at <https://irma.nps.gov/>. Enter “GRI” or “SRI” as the search text and select a park from the unit list. Additional information regarding the GRI, including contact information, is available at <http://go.nps.gov/gri>.

As of 2024, the I&M program is transitioning from a baseline inventory strategy to a strategy that addresses park needs as proposed by park managers. The GRI and SRI are now unified as one inventory program—the [Geologic and Soil Resources Inventory \(GSRI\)](#)—and will be integrated into the new Inventories & Assessment (I&A) Program. Through the new I&A program, parks will submit geology- and soil-related project requests in PMIS during the Servicewide Comprehensive Call (SCC). This transition will begin in FY25, with new guidance enacted for GSRI. See the [GSRI SharePoint site](#) for more information regarding this transition.

In this transition period before the new guidance is completed, 13 “priority” parks, including Appalachian National Scenic Trail (APPA or the scenic trail throughout this document), were identified as having a scoping summary (see Port 2016) but missing a baseline GRI report. This GSRI summary serves as a substitute for a baseline GRI report and is intended to support the APPA participation in the new inventory program. This summary documents the status of GRI and SRI deliverables and provides information about current geology and soil resource management concerns with a focus on identified inventory needs. Information in this summary was compiled from existing reports, meeting(s) with APPA staff, and the “best professional judgment” of GSRI and WASO Geologic Resources Division (GRD) geoscientists. Baseline GRI reports are available for some NPS units along the scenic trail: Antietam National Battlefield, Chesapeake and Ohio Canal National Historical Park, and Harpers Ferry National Historical Park (Thornberry-Ehrlich 2005), Great Smoky Mountains National Park (Thornberry-Ehrlich 2008), Marsh-Billings-Rockefeller National Historical Park (Thornberry-Ehrlich 2011), Delaware Water Gap National Recreation Area (Thornberry-Ehrlich 2013), Shenandoah National Park (Thornberry-Ehrlich 2014), and Blue Ridge Parkway (Thornberry-Ehrlich 2020).

Introduction

APPA Background and Establishment

For over 3,520 km (2,180 mi) and across 11 degrees of latitude, the public footpath that makes up the Appalachian National Scenic Trail (herein referred to as APPA or the “scenic trail”) traverses the heights of the Appalachian Mountains through some of the most iconic scenery in the country. The greenway connecting local communities and wildlands is the longest continuously marked footpath in the world, with its iconic white blazes guiding millions of visitors every year. The scenic trail touches 14 states in the eastern United States: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, West Virginia, Virginia, Tennessee, North Carolina, and Georgia (Figure 1). Stretching from Mount Katahdin, Maine, southwest to Springer Mountain, Georgia, the scenic trail was conceived in 1921 by Benton MacKaye, constructed by private citizens under the coordination of the Appalachian Trail Conservancy (ATC), and completed in 1937. In 1968, the Appalachian Trail was designated as the first national scenic trail under the National Trails System Act. In addition, APPA is a national scenic trail granted authority under the Organic Act of 1916 and the General Authorities Act of 1970 (Vinch 1999; Janssen 2022). National scenic trails are extended trails located to provide for maximum outdoor recreation potential and for the conservation and enjoyment of nationally significant scenic, historic, natural, or cultural qualities of the areas through which the trail may pass.



Figure 1. Map of the APPA trace from Maine to Georgia. APPA trends southwestward from Mt. Katahdin in Maine through New England, across the Hudson River Valley, and into Pennsylvania. It crosses the Potomac River at Harpers Ferry and passes hundreds of miles through Virginia before tracing the Great Smoky Mountain crests in North Carolina and Tennessee. APPA ends its length at Springer Mountain in northern Georgia. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

Today, the scenic trail is a management marvel with responsibilities shared by the NPS, US Forest Service, the ATC, many state agencies, and thousands of generous volunteers. The scenic trail has more federal boundary (more than 1,900 km [1,200 mi]) than any other park in the system except for Wrangell-St. Elias National Park in Alaska. The NPS has overall responsibility, but the scenic trail crosses private, federal, and state lands. On average, the scenic trail spans a width of only about 300 m (1,000 ft) and encompasses an area of approximately 95,494 ha (235,973 ac). It passes through 14 states, 88 counties, 164 townships and municipalities, six NPS units, eight national forests, two fish and wildlife refuges, 24 wilderness areas, eight national natural landmarks, three national historic landmarks, and more than 70 state parks (Appalachian Trail Conservancy 2009; National Park Service 2015a). Virginia has the most trail length at about 885 km (550 mi), whereas West Virginia only has 2 km (4 mi). Broadly, the scenic trail is divided into four distinct geographic regions to provide a management framework for working with collaborators: New England, Mid-Atlantic, Virginia, and the Southern Region (National Park Service 2015a). The New England region starts at the northern terminus and ends at the border between Connecticut and New York. The Mid-Atlantic section then continues until the border between Maryland and Virginia, whereupon the Virginia section continues to the border with North Carolina. The remainder of the trail is considered the Southern Region (National Park Service 2015a; Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025).

Physiography Along the Way

The scenic trail runs along the backbone of the Appalachian Mountains, crosses ridge crests, descends into major valleys, passes through wind gaps, and traverses hundreds of streams and rivers along its great length (Shriver et al. 2005). The rocks encountered along the trail include some of the oldest rocks (more than one billion years old) in the eastern United States and some of the most recent deposits (Table 1). The scenic trail can be divided into three general physiographic (physical geography and natural landforms of a region) sections: the northern Appalachians of the New England states; the Valley and Ridge on the west side of the spine of the Appalachians, which the trail passes through from southern New York to southern Virginia; and the Blue Ridge Mountains on the east side of the spine, which the trail passes through from southern Virginia to Georgia (Tweet et al. 2010). These provinces are flanked on the west by the Appalachian Plateaus physiographic province and on the east by the Piedmont. As it passes through each state from north to south, the physiography varies:

- Maine (Figure 2). In Maine, starting at the northern trail terminus at Mt. Katahdin, the scenic trail runs through the White Mountains physiographic province. The landforms of the White Mountains are among the most rugged terrain in New England. Most of the rocks composing the White Mountains formed as molten magma plutons (igneous intrusions or masses of hot rocks forced into surrounding rocks) slowly cooled and were uplifted and weathered. Pleistocene-age (2.58 million to 10,000 years ago) glaciers were the primary sculptors of the mountains, forming U-shaped notches and valleys.
- New Hampshire (Figure 3). In New Hampshire, the scenic trail continues along the crests of the White Mountains physiographic province, commonly above tree line. Here the province includes the Franconia Range, Sandwich Range, Carter-Moriah Range and Kinsman Range. Mt. Washington rises to 1,917 m (6,288 ft), making it the highest peak in the state and the most topographically prominent point east of the Mississippi River. The rocks along the trail are younger than the rocks along the trail in other states—Jurassic-age granite, less than 200 million years old. Before reaching the border with

Vermont, the scenic trail passes into the New England Upland physiographic province—an area with a maturely dissected plateau and narrow valleys. Pleistocene-age glaciers were active here as well, rounding formerly rugged peaks and leaving glacial deposits on the landscape.

- Vermont (see Figure 3). The New England upland province extends into Vermont, and then the scenic trail passes into the Green Mountains physiographic province. The Green Mountains are a high, rugged area of abandoned and overgrown farmlands and large forested tracts. The rocks of the Green Mountains are mostly metamorphosed (changed by heat and pressure) sediments, lava flows, and some oceanic crust that was pushed by tectonic compression atop older basement rocks that compose the north-to-south trending spine of the Green Mountains.
- Massachusetts (Figure 4). In Massachusetts, the scenic trail traverses the western New England upland and Green Mountains physiographic provinces. Known locally as the Berkshires or the Berkshire Hills, western Massachusetts has steep rolling hills and valleys. The landforms are largely controlled by Ordovician-age (485.4 million–443.8 million years ago) sheets of rocks (now, metamorphic gneiss) that were thrust over younger, carbonate-rich rocks during the Taconic Orogeny (a mountain-building episode during the Ordovician). The gneiss underlies the peaks, and the valleys are underlain by marble, another metamorphic rock. A food-grade marble quarry is a point of interest along the trail in Massachusetts.
- Connecticut (see Figure 4). The steep rolling hills and valleys of the Green Mountains and western New England upland provinces continue along the trail until it enters the deep Housatonic River valley, which it follows until the border with New York.
- New York (Figure 5). Throughout its entire length in New York, the scenic trail is within the New England Upland physiographic province. In New York, rocks of this province are crystalline metamorphic rocks that are now eroded to form rugged terrain where the province is crossed by the Hudson River (Fenneman and Johnson 1946). The valleys and ridges generally trend southwest to northeast. Glacial deposits and landforms are located in the province valleys. The trail leaves the state by crossing the Hudson River Valley at its lowest point.
- New Jersey (Figure 6). In New Jersey, the scenic trail, running southeast to northwest, crosses the valleys and ridges of the Highlands and Valley and Ridge physiographic provinces before turning back toward the southwest, more or less parallel to the Valley and Ridge province. The New Jersey Highlands province is contiguous with the New England Upland province. In New Jersey, the erosion-resistant folded, faulted, and deformed rocks of the Highlands underlie ridges and hills. The Valley and Ridge in New Jersey features long, parallel ridges separated by valleys 100–200 m (330–660 ft) below the ridges. The trail leaves New Jersey at Delaware Water Gap National Recreation Area along the long ridge of Kittatinny Mountain.
- Pennsylvania (Figure 7). Just after the scenic trail enters the state of Pennsylvania, it passes from glaciated to unglaciated terrain. The scenic trail continues, and has its midpoint, in the Valley and Ridge physiographic province in Pennsylvania. The valleys formed in areas of more easily eroded shale and carbonate rock formations, and the ridges are commonly composed of more resistant sandstone units. The province contains strongly folded and faulted sedimentary rocks in central Pennsylvania. The eastern part of the Valley and Ridge province is the Great Valley section, a rolling lowland formed on folded carbonate rocks and shale. At two locations southwest of Harrisburg, the

scenic trail skirts the edge of the Piedmont physiographic province. The eastward-sloping Piedmont formed through a combination of folds, faults, uplifts, and erosion. The resulting eastern landscape of gently rolling hills starting at 60 m (197 ft) in elevation becomes gradually steeper westward toward the western edge of the province and reaches 300 m (984 ft) above sea level.

- Maryland (Figure 8). Upon crossing into Maryland, the scenic trail traverses the crest of the Blue Ridge physiographic province through the state along the ridge crest of South Mountain. Precambrian (more than 538.8 million years ago) and Paleozoic (538.8 million–251.1 million years ago) igneous, sedimentary, and metamorphic rocks were uplifted during several orogenic (mountain-building) events to form the steep, rugged terrain. Resistant Cambrian (538.8 million–485.4 million years ago) quartzite forms most of the high ridges, whereas Precambrian metamorphic rocks underlie the valleys. Eroding streams have narrowed the northern section of the Blue Ridge Mountains into a thin band of steep ridges that rise to heights of approximately 1,200 m (3,937 ft). Hagerstown Valley lies to the west, and Middletown Valley is to the east of the South Mountain ridge.
- West Virginia (Figure 9). The scenic trail's short foray into West Virginia begins at Harpers Ferry at the Shenandoah River's confluence with the Potomac River and parallels the Shenandoah River Valley within the Blue Ridge physiographic province. Harper's Ferry marks the notch carved by the rivers through the mountains, and the scenic trail crosses both rivers.
- Virginia (Figure 10). The scenic trail winds across Virginia's highest terrain. The first stretch from north to south is close to the border between the Blue Ridge physiographic province and the Great Valley province. The Great Valley is part of an extensive series of valleys that stretch from Quebec to Alabama. From there, the scenic trail traverses the long axis of Shenandoah National Park, where streams have caused the narrowing of the mountains into a thin band of steep ridges. Erosion-resistant Mesoproterozoic (1.6 billion–1 billion years ago) gneisses and granites, Neoproterozoic (1 billion–538.8 million years ago) greenstones and metasedimentary rocks, and Lower Cambrian quartzites form the heights of the Blue Ridge province in Virginia. Near Roanoke, the scenic trail swings westward, crossing the Great Valley and into the Valley and Ridge of the Jefferson and George Washington National Forests. Near Burke's Garden, the scenic trail turns south and recrosses the Great Valley back into the Blue Ridge province.
- Tennessee (Figure 11). Leaving Virginia, the scenic trail crosses into Tennessee, where the Blue Ridge province is referred to locally as the Unaka Mountains. The scenic trail runs along the crest of the mountains. The Unaka Mountains have been severely weathered and dissected by stream erosion and are characterized by steep slopes and deep, narrow valleys. Like the rest of the Blue Ridge province, the Unaka Mountains features predominately metamorphic bedrock with widespread igneous intrusions.
- North Carolina (Figure 12). The scenic trail trends along the border with Tennessee for much of its path through the state of North Carolina. It climbs to its highest point of 2,025 m (6,643 ft) at Clingmans Dome. At the western end of Great Smoky Mountains National Park, the scenic trail swings southeastward across the regional southwest-northeast trend of the Blue Ridge physiographic province in the Nantahala National Forest.
- Georgia (Figure 13). In Georgia, the scenic trail is entirely within the Southern Blue Ridge Mountains physiographic province (within the Chattahoochee National Forest). The elevations

become ever lower. Rugged ridges and rounded, weathered peaks of late Proterozoic metamorphic gneiss characterize the Blue Ridge province in Georgia, which itself peters out near the southern terminus of the scenic trail at Springer Mountain.

Table 1. Geologic time scale.

The geologic time scale puts the divisions of geologic time in stratigraphic order, with the oldest divisions at the bottom and the youngest at the top. Boundary ages are millions of years ago (MYA) and follow the International Commission on Stratigraphy (2022). Where no geologic time subdivision exists, “n/a” indicates not applicable.

Era(s)	Period(s)	Epoch(s)	MYA	States along the trail which feature rocks and sediments from this time
Cenozoic	Quaternary (Q)	Holocene (H)	0.0117–today	All
Cenozoic	Quaternary (Q)	Pleistocene (PE)	2.6–0.0117	Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania
Cenozoic	Neogene (N)	Pliocene (PL)	5.3–2.6	None known
Cenozoic	Neogene (N)	Miocene (MI)	23.0–5.3	None known
Cenozoic	Paleogene (PG)	Oligocene (OL)	33.9–23.0	None known
Cenozoic	Paleogene (PG)	Eocene (E)	56.0–33.9	None known
Cenozoic	Paleogene (PG)	Paleocene (EP)	66.0–56.0	None known
Mesozoic	Cretaceous (K)	Upper, Lower	145.0–66.0	None known
Mesozoic	Jurassic (J)	Upper, Middle, Lower	201.4–145.0	New Hampshire
Mesozoic	Triassic (TR)	Upper, Middle, Lower	251.9–201.4	Pennsylvania, Virginia
Paleozoic	Permian (P)	Lopingian, Guadalupian, Cisuralian	298.9–251.9	None known
Paleozoic	Pennsylvanian (PN)	Upper, Middle, Lower	323.2–298.9	Pennsylvania
Paleozoic	Mississippian (M)	Upper, Middle, Lower	358.9–323.2	Pennsylvania, Virginia
Paleozoic	Devonian (D)	Upper, Middle, Lower	419.2–358.9	Maine, New Hampshire, Vermont, New York, New Jersey, Pennsylvania, Virginia
Paleozoic	Silurian (S)	Pridoli, Ludlow, Wenlock, Llandovery	443.8–419.2	Maine, New Hampshire, Vermont, New Jersey, Pennsylvania, Virginia
Paleozoic	Ordovician (O)	Upper, Middle, Lower	485.4–443.8	Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Virginia, North Carolina
Paleozoic	Cambrian (C)	Furongian, Miaolingian, Series 2, Terreneuvian	538.8–485.4	Vermont, Massachusetts, Connecticut, New York, Pennsylvania, Maryland, West Virginia, Virginia, Tennessee, North Carolina
Neoproterozoic (Z)	Ediacaran, Cryogenian, Tonian	n/a	1,000–538.8	Pennsylvania, Maryland, Virginia, Tennessee, North Carolina, Georgia
Mesoproterozoic (Y)	Stenian, Ectasian, Calymmian	n/a	1,600–1,000	Vermont, Massachusetts, Connecticut, New York, New Jersey, Virginia, Tennessee, North Carolina

Era(s)	Period(s)	Epoch(s)	MYA	States along the trail which feature rocks and sediments from this time
Paleoproterozoic (X)	Statherian, Orosirian, Rhyacian, Siderian	n/a	2,500–1,600	None known
Neo-, Meso-, Paleo-, Eoarchean	n/a	n/a	4,031–2,500	None known
Hadean	n/a	n/a	4,567–4,031	None known

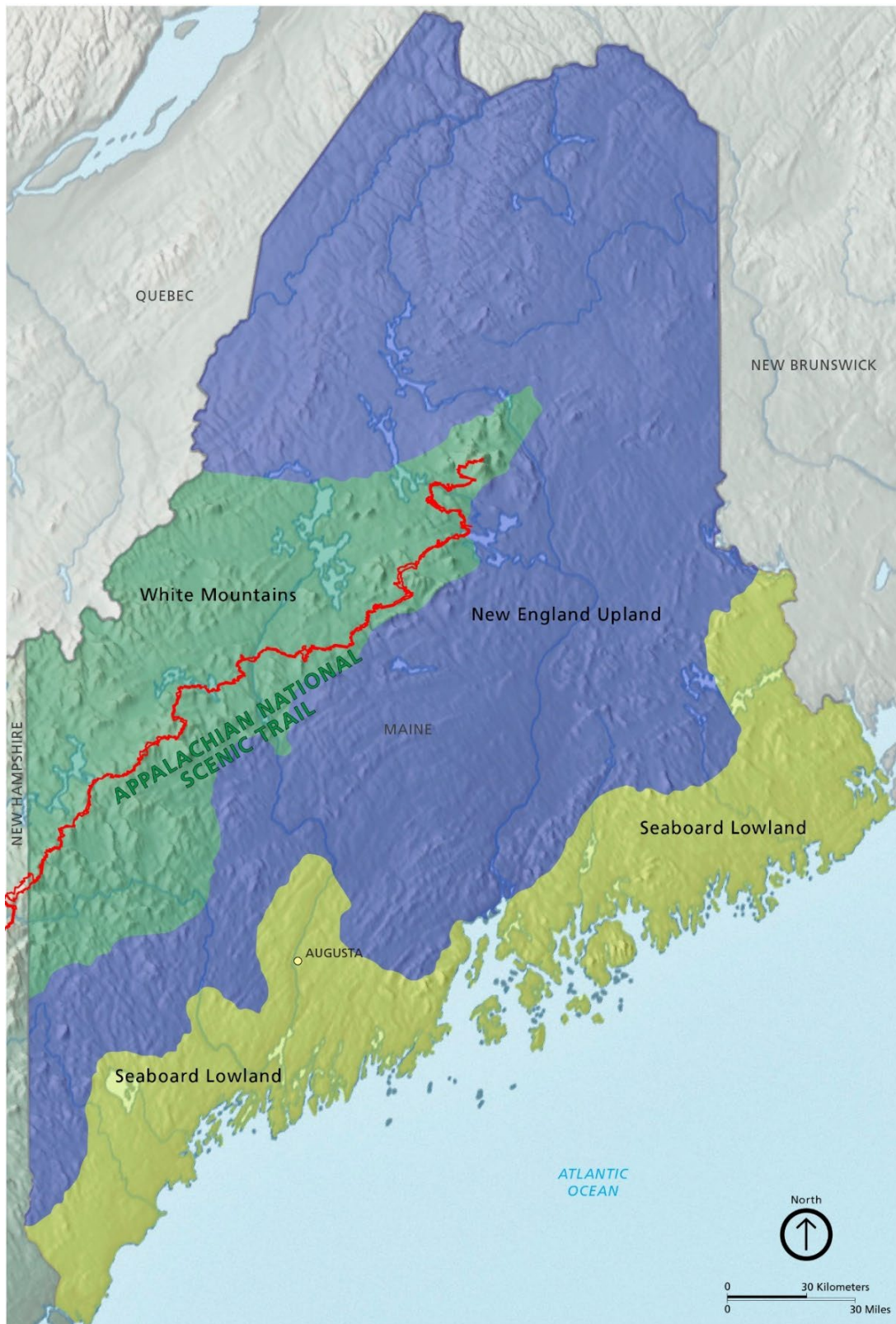


Figure 2. Map of physiographic provinces of Maine. The scenic trail's northern terminus is the peak of Mount Katahdin; from there it zigzags back and forth across the White Mountains physiographic province. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Fenneman and Johnson (1946). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

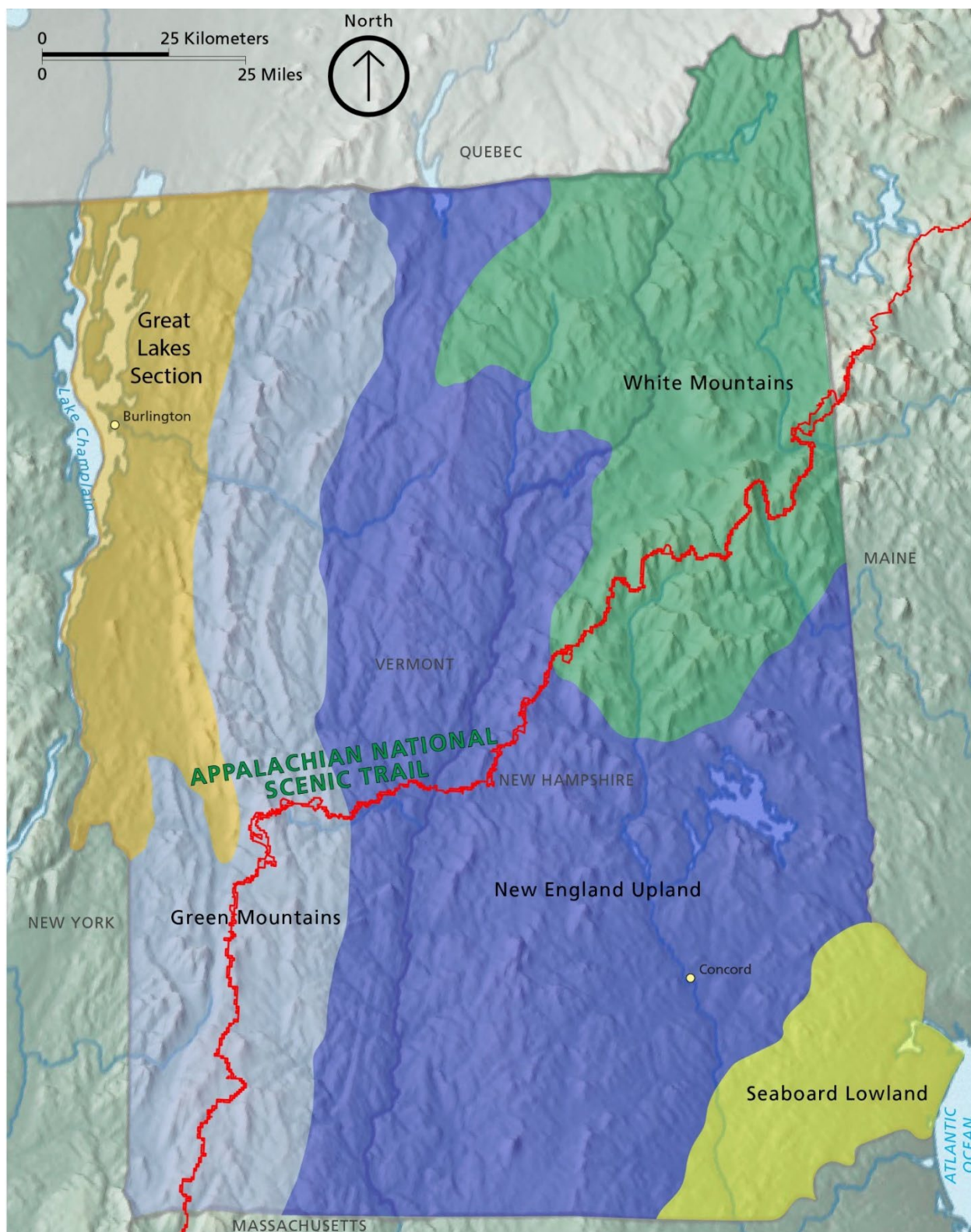


Figure 3. Map of physiographic provinces of New Hampshire and Vermont. The scenic trail's trace crosses the rugged heights of the White Mountains before descending down into the Connecticut River valley and climbing in the Green Mountains again. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Fenneman (1938). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).



Figure 4. Map of physiographic provinces of Massachusetts, Connecticut, and Rhode Island. The scenic trail trends along the zone between the Green Mountains and Western New England Upland provinces in Massachusetts (the Berkshires) and Connecticut. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Fenneman (1938) and NSTATE (2016). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

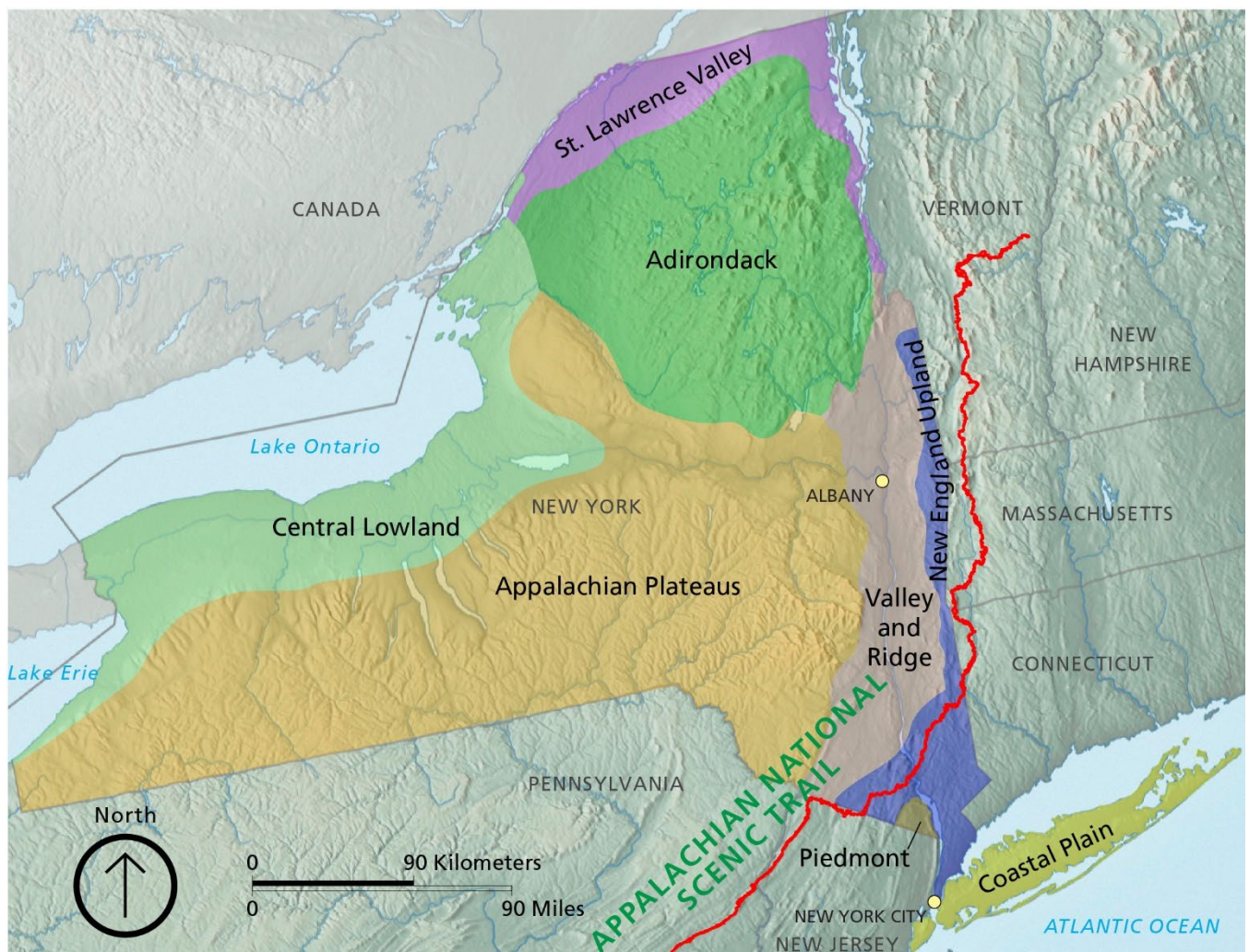


Figure 5. Map of physiographic provinces of New York. The scenic trail descends to one of its lowest points in New York, crossing the Hudson River valley in the New England Upland province, then climbing again toward New Jersey. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Fenneman and Johnson (1946). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).



Figure 6. Map of physiographic provinces of New Jersey. The scenic trail in New Jersey crosses linear ridges of the Highlands and Valley and Ridge provinces before turning southwestward to parallel a prominent ridge and crossing the Delaware Water Gap into Pennsylvania. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from New Jersey Geological Survey (2002). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

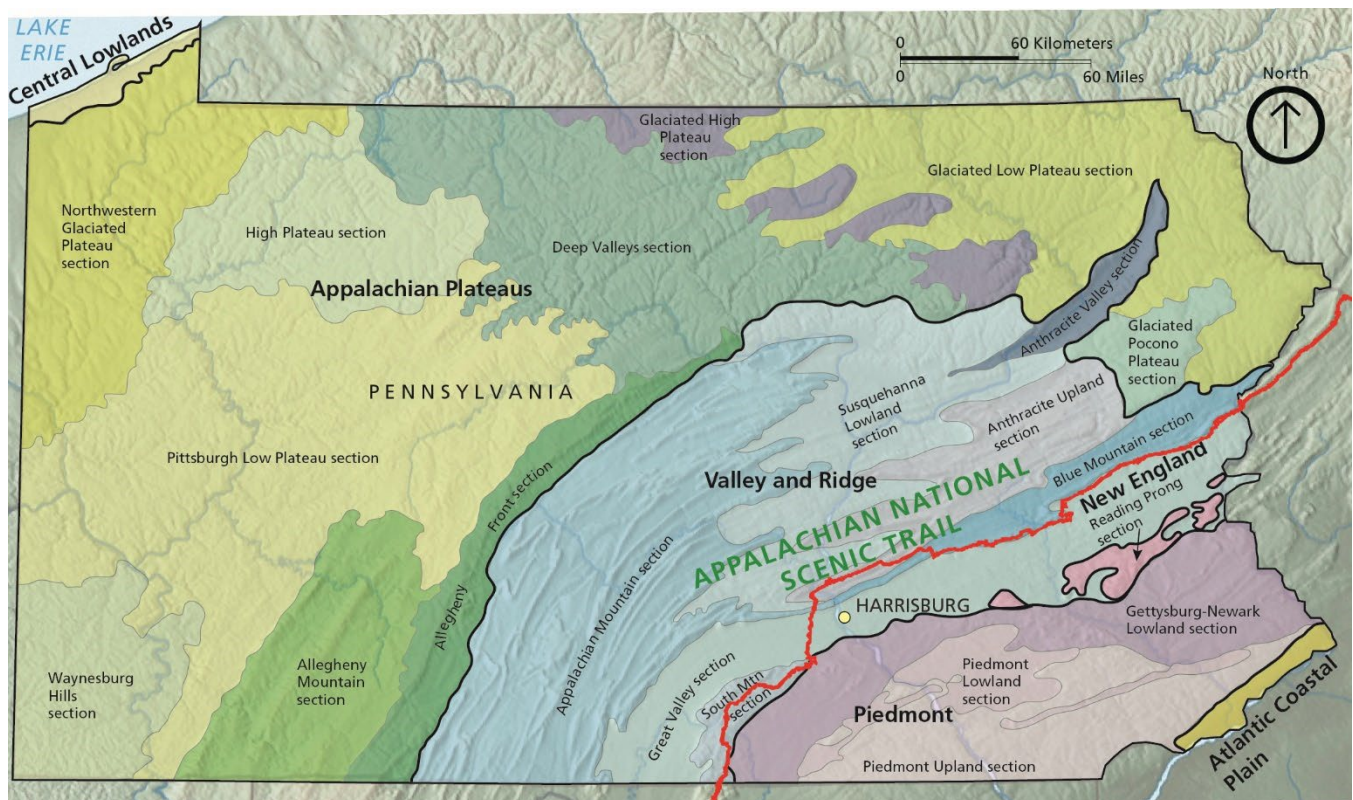


Figure 7. Map of physiographic provinces of Pennsylvania. The scenic trail in Pennsylvania skirts the boundary between the Blue Mountain section and Great Valley section of the Valley and Ridge province. Along this length, it parallels the regional northeast-southwest trend of the ridges and valleys. The scenic trail then crosses the Great Valley before climbing into the South Mountain section in southern Pennsylvania. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Sevon (2000). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

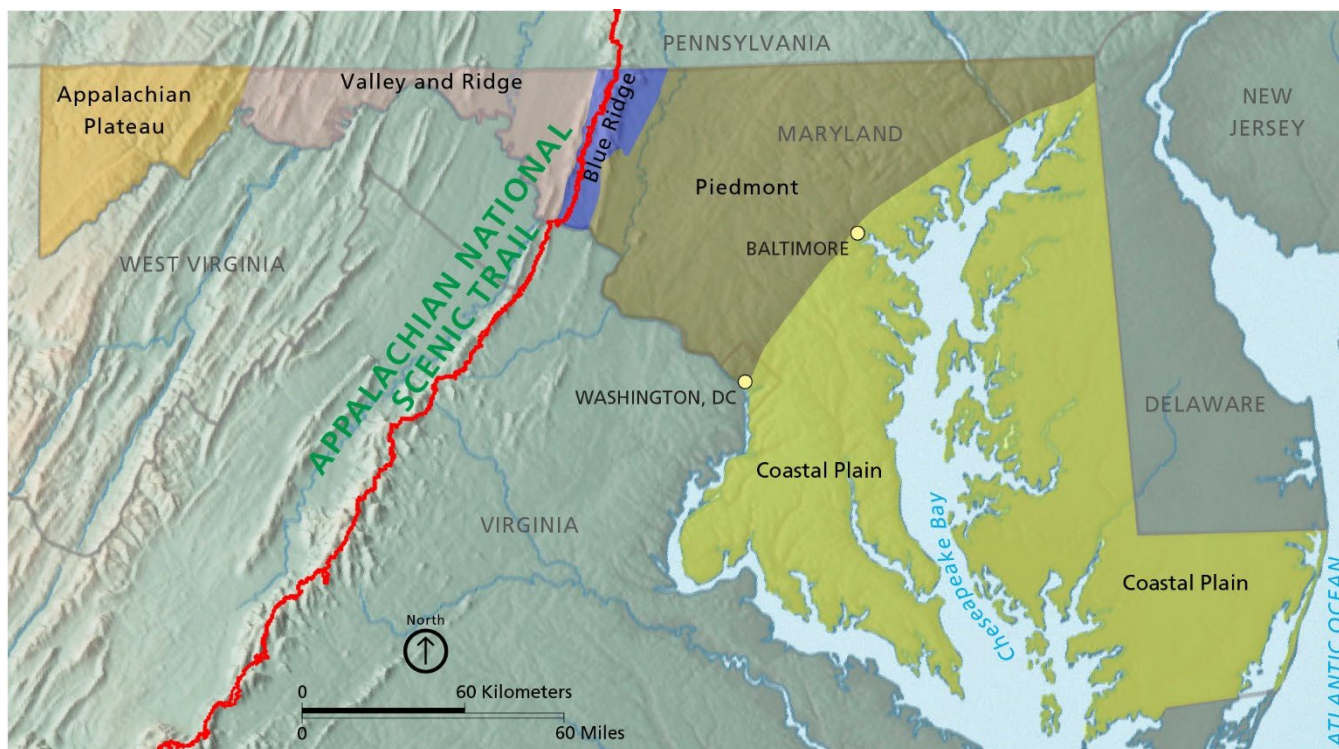


Figure 8. Map of physiographic provinces of Maryland. The scenic trail in Maryland runs along the crest of the Blue Ridge province before descending steeply to the Potomac River crossing at Harpers Ferry. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Maryland Geological Survey (2001). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

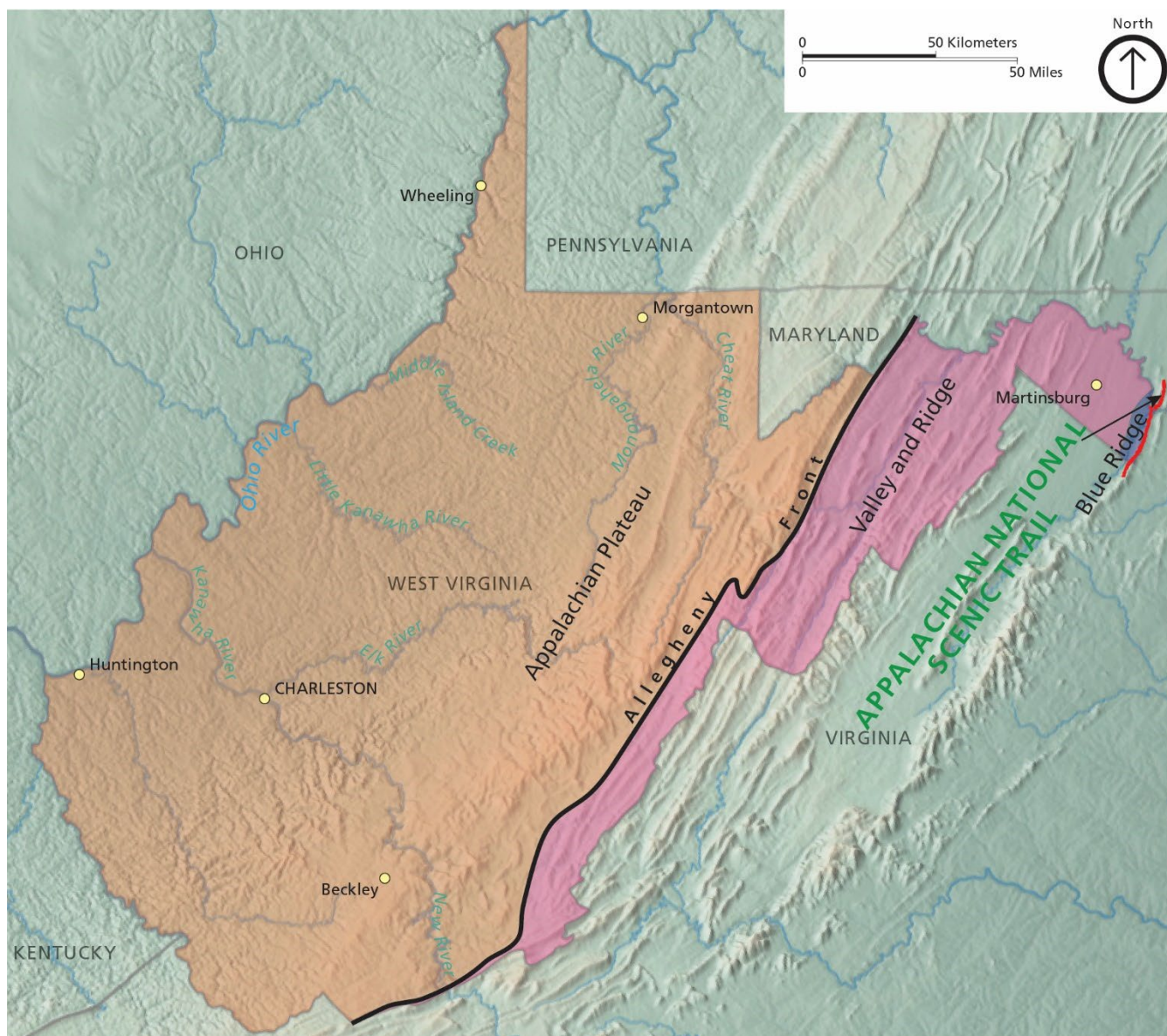


Figure 9. Map of physiographic provinces of West Virginia. The scenic trail in West Virginia runs along the crest of the Blue Ridge province along the border with Virginia after crossing the Potomac River at Harpers Ferry. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from West Virginia Geological and Economic Survey (2020). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

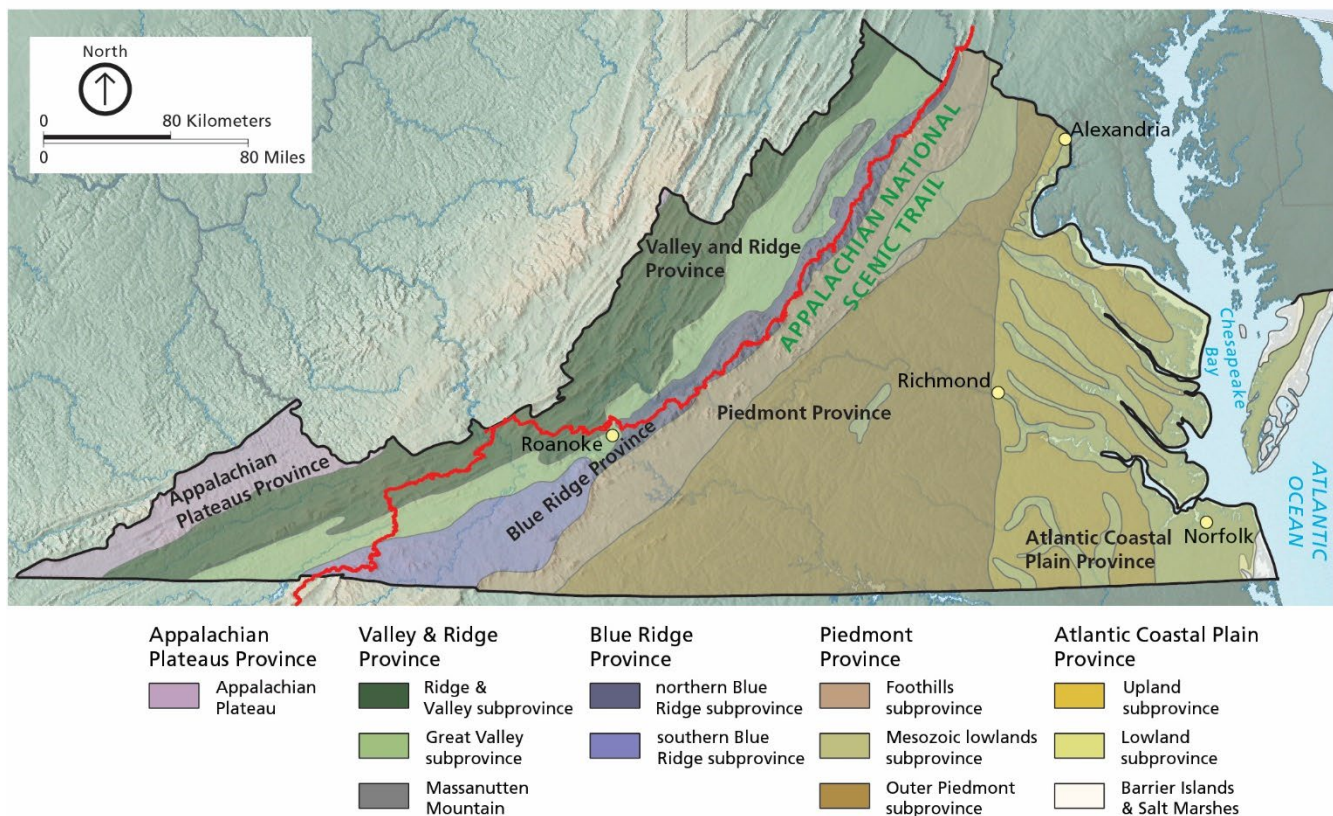


Figure 10. Map of physiographic provinces of Virginia. The scenic trail traverses the Blue Ridge and Valley and Ridge provinces along the length of Virginia. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Bailey (1999). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).



Figure 11. Map of physiographic provinces of Tennessee. The scenic trail passes along the ridges of the Unaka Mountains, through Great Smoky Mountains National Park before entering North Carolina. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) adapted from Harris (2012) and TNGenWeb (2016). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

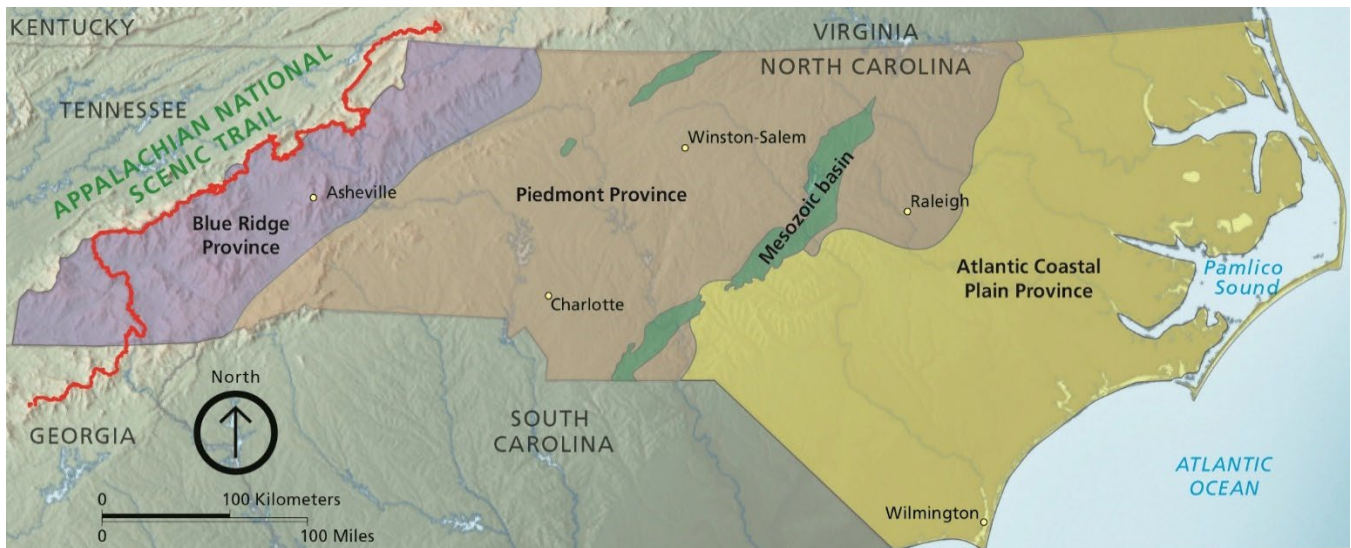


Figure 12. Map of physiographic provinces of North Carolina. The scenic trail reaches its highest point along this traverse, passing along the border between Tennessee and North Carolina. In the state, the scenic trail is entirely within the heights of the Blue Ridge province. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) using information from the North Carolina Geological Survey website (<http://www.geology.enr.state.nc.us/>). Basemap by Tom Patterson (NPS), available at <http://www.shadedrelief.com/physical/index.html> (accessed 20 June 2023).

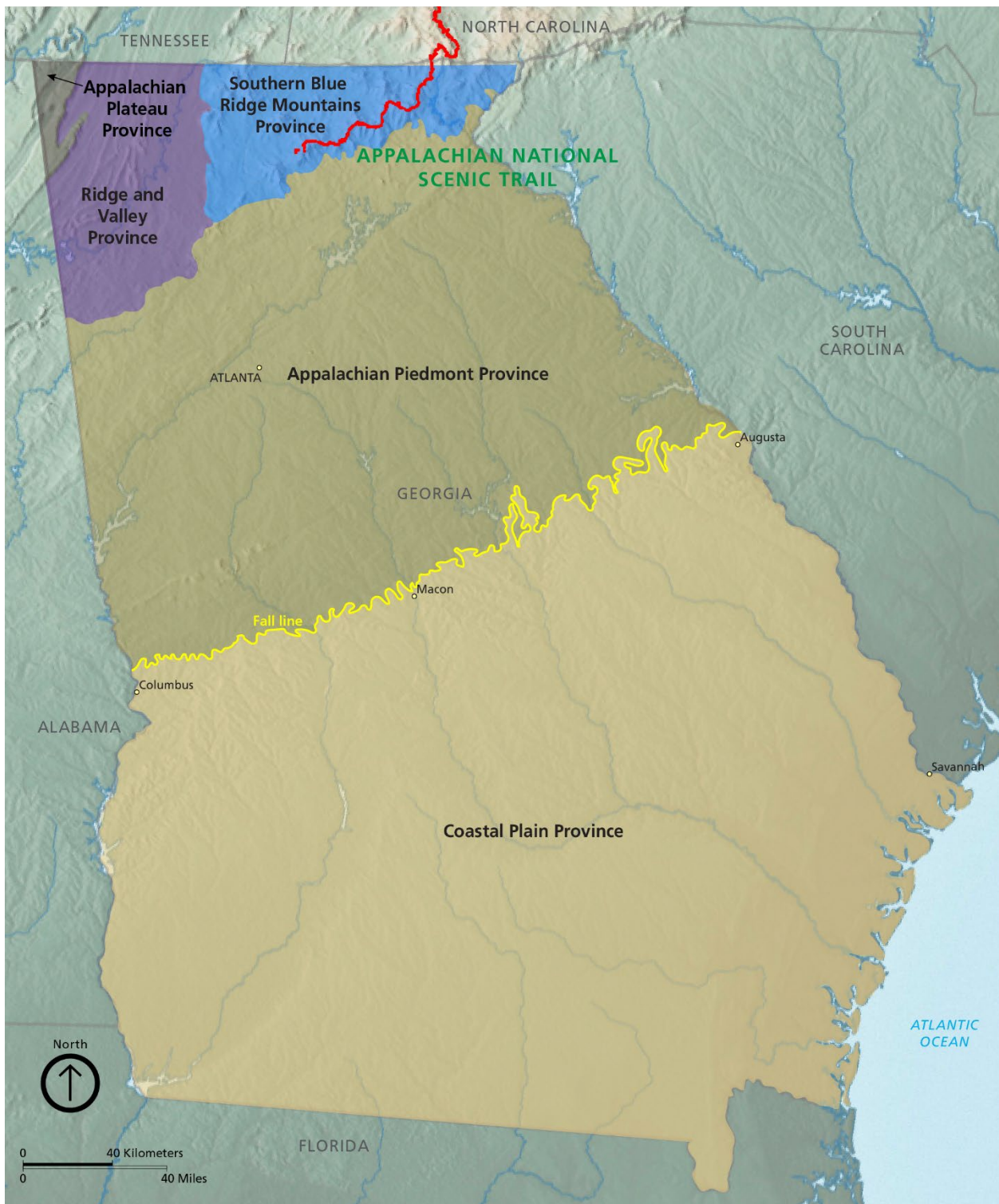


Figure 13. Map of physiographic provinces of Georgia. The scenic trail reaches its southern terminus at Springer Mountain in the Southern Blue Ridge Mountains province. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) with input from Tom Crawford and Jacob Bateman McDonald, using map data from the Georgia Geological Survey, available at <https://epd.georgia.gov/outreach/publications/georgia-geologic-survey-maps> (accessed 25 July 2022). Basemap by Tom Patterson (NPS) available at <http://www.shadedrelief.com/physical/index.html> (accessed 31 March 2020).

Geologic Heritage

Geologic heritage, or “geoheritage,” encompasses the significant geologic features, landforms, and landscapes characteristic of our nation that are preserved for the full range of values that society places on them. In 2015, the NPS GRD staff, in cooperation with the American Geosciences Institute, published a booklet introducing the American experience with geoheritage, geodiversity, and geoconservation: "America's Geologic Heritage: An Invitation to Leadership" (National Park Service and American Geosciences Institute 2015). This publication introduces key principles and concepts of America's geoheritage, which are the focus of ongoing collaboration and cooperation on geologic conservation in the United States.

At APPA, geologic features, landforms, landscapes, and stories are valued for their geologic heritage qualities. Connections between geologic resources and other scenic trail resources and stories are the essence of geoheritage. Wherever possible, geoheritage makes connections with the scenic trail's identified fundamental resources and values: the trail itself; the empowered volunteers; enduring collaborative spirit; experience; education; scenery along the treadway; views beyond the corridor; natural resource quality and ecological connectivity; and a journey through American heritage.

The foundation document (National Park Service 2015a) for the scenic trail lists significance statements to justify its merit as part of the National Park System. Many of these statements consider the uniqueness of the scenic trail, its multifaceted management, and its roots in volunteerism. The following statements are related to geology, natural resources, geologic heritage, and their connections to other resources:

- Traversing 14 states through wildlands and communities, the more than 2,100-mile-long world-renowned hiking trail and its extensive landscape protect the most readily accessible long-distance footpath in the United States. The scenic trail offers opportunities for self-reliant foot travel through wild, scenic, natural, and culturally and historically significant lands. It provides a range of experiences for people of all ages and abilities to seek enjoyment, inspiration, learning, challenge, adventure, volunteer stewardship, and self-fulfillment, either in solitude or with others.
- The trail's varied topography, ecosystem diversity, and numerous viewpoints offer a visual showcase, including wild, natural, wooded, pastoral, and historic environments. The trail offers opportunities for scenic enjoyment, ranging from the subtle beauty of a trillium to tranquil ponds and streams to the grand view of mighty Katahdin.
- The north-south corridor of the trail, traversing the highest and lowest elevations and myriad microclimates of the Appalachian Mountains, helps protect one of the richest assemblages of temperate zone species in the world and anchors the headwaters of critical watersheds that sustain more than 10% of the population of the United States.
- The trail corridor is one of the nation's most significant cultural landscapes, revealing the history of human use and settlement along the Appalachian Mountain range and the resulting distinct regional traditions. Visitors to the trail have the unique opportunity to interact with the communities and resources representing these diverse eras in US history and prehistory.

Geoheritage sites are conserved so that their lessons and beauty will remain as a legacy for future generations. Such areas generally have great potential for scientific studies, use as outdoor classrooms, and enhancing public understanding and enjoyment. Geoheritage sites are fundamental to understanding dynamic Earth systems, the succession and diversity of life, climatic changes over time, the evolution of landforms, and the origin of mineral deposits. Currently, there is no comprehensive national registry that includes all geoheritage sites in the United States. There are 14 national natural landmarks located within 8 km (5 mi) of the scenic trail, as well as 26 features on the National Register of Historic Places, eight historic districts, many archeological sites, and three national historic landmarks (National Park Service 2015a). The cultural landscapes of the scenic trail represent Appalachian Mountain range history and traditions, all underpinned by geology and developed by geologic processes (National Park Service 2015a).

Geologic Connections to APPA Resources

Human History and Cultural Resources

The journey through American heritage is one of APPA's fundamental resources (National Park Service 2015a). The scenic trail's lands are rich in human history, from the earliest Indigenous people to European pioneers, settlers, farmers, early trailblazers, and modern advocates (National Park Service 2015a). The combination of the scenic trail trace, its travelers, and the cultural and natural resources through which it meanders offers an exceptional opportunity to understand American heritage and values through time (National Park Service 2015a). The scenic trail also connects nationally significant areas such as Katahdin Woods and Waters National Monument, Marsh-Billings-Rockefeller National Historical Park, Delaware Water Gap National Recreation Area, Harpers Ferry National Historical Park, Chesapeake and Ohio Canal National Historical Park, Shenandoah National Park, Blue Ridge Parkway, and Great Smoky Mountains National Park. The geologic story of the scenic trail features prominently in scientific literature and first-person accounts; see Chew (1988), Bryson (1998), and Eckert (2021).

Animals were likely the first users of the trace of the scenic trail. Animals seek out the easiest ways across steep ridges and rivers and around obstacles. Humans followed suit. Wind, water, frost, and time worked in concert to carve handy notches and gaps through the imposing ridges of the Appalachian Mountains. Commonly, these forces are focused where a geologic structure (e.g., fault, joint, or fold) has created an area of weakness. Notable notches or gaps along the trail include Grafton Notch in Maine; Crawford, Franconia, Kinsman, and Mahoosuc notches in New Hampshire; Delaware Water Gap between Pennsylvania and New Jersey; Lehigh, Wind, Totts, Fox, Smith, Little, and Swatara gaps in Pennsylvania; Harpers Ferry between Maryland, West Virginia, and Virginia; Snickers, Rockfish, Blackhorse, and Ashby gaps in Virginia; Spivey and Davenport gaps between Tennessee and North Carolina; Stecoah Gap in North Carolina; Bly Gap between North Carolina and Georgia; and Dicks Cree and Neels Gaps in Georgia (Wilshusen 1983; Chew 1988). A clear example of gap formation and its relationship with transportation geoheritage is at Swatara Gap in Pennsylvania. Ongoing weathering by Swatara Creek and the angular rocks along its course created a gap. Animals created the initial path through the gap. This path was then a footpath for Indigenous groups in the area, and then a canal was excavated through it. The gap also featured an aqueduct, railroad, local road, interstate highway, and now a scenic trail (Wilshusen 1983).

In other places, human history and land use influenced the placement of the trail. The trail crosses more than 500 roads with 482 trailhead parking areas (National Park Service 2022). In places, the trail uses old logging

roads and railroad beds that were built by lumber companies (e.g., New Hampshire; Rick Chormann, state geologist, New Hampshire Geological Survey, scoping meeting communication, 6 May 2016; Port 2016). In Pennsylvania, at Rausch Gap, the trail uses the remains of a railroad bridge abutment built by hand from conglomerate of the Pottsville Group—a group of ridge-forming rocks that were deposited in the Pennsylvanian (323.2–298.9 million years ago; Wilshusen 1983). In other areas, mining history and operations influenced the location of the trail, have strong geoheritage ties, and occasionally lead to resource management challenges. For example, in Maine, pegmatites (very coarse-grained intrusive igneous rocks) include watermelon tourmaline (green tourmaline crystals with a red center), which is valued by collectors and is among the reasons for increased surveillance (Fred Dieffenbach, environmental monitoring coordinator, NPS Northeast Temperate Network, scoping meeting communication and written communication, 6 May 2016 and 12 September 2016, respectively; Port 2016). Iron works in Connecticut contributed to the American Civil War effort, as evidenced by several sites along the scenic trail (Port 2016). The iron ore deposits come from the Walloomsac Schist near the contact with the underlying Stockbridge Marble. These iron deposits are “bog ore” type, where iron precipitated from iron-rich waters of the ancient Iapetus Ocean (a precursor to the Atlantic Ocean present between 600 and 400 million years ago; Port 2016). Near Michaux State Forest, situated on the northern terminus of the Blue Ridge province, rhyolite was quarried for tool material by Indigenous groups, and evidence of their quarrying is still visible from the trail (Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025). The scenic trail passes several coal mining ghost towns, such as Rausch Gap and Yellow Springs in Pennsylvania; mining sites are also causing acid mine drainage (see “Resource Management Issues”; Wilshusen 1983; Port 2016).

Humans are naturally drawn to high points and viewpoints. The crests of the Appalachian Trail are geoheritage sites themselves, and the reason those crests exist is because of their geologic properties and histories. For example, in Georgia, the scenic trail follows the rises and falls of some of the state’s highest peaks, including 10 of its 32 mountains over 1,200 m (4,000 ft) in elevation (Georgia Appalachian Trail Club 2017). These mountains were uplifted hundreds of millions of years ago but persist today after continuous weathering and erosion because of their resistant gneiss composition. In the Great Smoky Mountains, the trail reaches its highest point at the summit of Clingmans Dome at 2,025 m (6,643 ft), named for North Carolina senator Thomas Lanier Clingman. This peak was previously known as Kuwahi or Kuwohi (ᵂᵂᵂ or ᵂᵂᵂ) in Cherokee, meaning “mulberry place,” and has a 1959 viewing tower listed on the National Register of Historic Places (Jones 2022). The mountain is composed of resistant metamorphosed conglomerate rocks of the Ocoee Supergroup that formed more than 500 million years ago (2005).

Another example, among the three “heights” at Harpers Ferry (Maryland, Loudoun, and Bolivar Heights), is the vantage point from Jefferson’s Rock, where, in 1783, Thomas Jefferson described the view of the confluence of the Potomac and Shenandoah Rivers. The geoheritage here is multifaceted with the rock itself, a slab of metamorphosed shale from the Harpers Formation, perched on a cliff of the same formation on the southern hillside of Harpers Ferry, where the rivers carve historically significant notches through South Mountain. Jefferson wrote that “this scene is worth a voyage across the Atlantic” (Jefferson 1787, p. 28). The rock slab posed a visitor safety hazard and required reinforcement pillars between 1855 and 1860 (Chew 1988; Sibug 2014; Port 2016). The heights later played roles in the American Civil War history of the area. In Pennsylvania, The Pinnacle offers a commanding view from its quartzite promontory (Wilshusen 1983).

In Vermont, high points along the trail—Stratton Mountain, Spruce Peak, Bromley Mountain, Styles Peak, and Peru Peak—are monadnocks (isolated hills of bedrock that persisted after millennia of weathering and erosion) as part of an old peneplain (low-relief plain formed by long-term erosion) formed during interludes between mountain-building events more than 300 million years ago (Don Wise, geologist, University of Massachusetts, scoping meeting communication, 6 May 2016; Port 2016). The term monadnock is named after Mt. Monadnock in Cheshire County, New Hampshire (Raymo and Raymo 1989).

When the scenic trail was established, historic structures were already dotted along its length. These structures have geoheritage relevance (e.g., they consist of locally sourced rocks), and include mine works, furnaces (e.g., Pine Grove Furnace, active for 120 years in Pennsylvania), rock walls, kilns, buildings, fire towers, and monuments (e.g., Washington Monument State Park). Additionally, infrastructure specific to the scenic trail itself (e.g., shelters, bridges, steps, etc.) was sourced in part from local geologic resources (National Parks Conservation Association 2010). Forty-one of the 280 shelters listed in APPA's online database

(<https://nps.maps.arcgis.com/apps/webappviewer/index.html?id=a14491fe257343e58f2244b7d4f3572d>) contain stone as a building material. Geologic outcrops, cliffs, and other features lend their names to many of the more than 1,400 vistas, including Pulpit Rock, Hawk Rock, Chimney Rocks, Carter Dome, and Pine Knob vistas.

Today, APPA connects millions of visitors to the geology and geoheritage of the scenic trail. Portions of the trail come into direct contact with more populated areas. In New Jersey, New York, and Connecticut, the throughgoing trail offers some respite from the urban and suburban landscape. The Bear Mountain Bridge takes the trail across the Hudson River in New York. In these areas, the trail may function as a geoheritage conduit, allowing access to more remote, natural areas as a respite from the cities of the eastern US. According to the ATC, approximately 3 million people visit the trail each year, more than 3,000 of whom attempt to hike the entire trail in a season, and about a quarter of those attempts result in successfully completing the trail (Appalachian Trail Conservancy 2015).

The Glacial Collection

At its midpoint in Pennsylvania, the trail undergoes a change in character. This occurs at the boundary between the unglaciated landscape in the south and the formerly glaciated landscape in the north. South of the boundary marked at the quartzite outcrop called Wolf Rocks, the ridges and valleys of the Appalachian Mountains have been exposed to continuous weathering and erosion since the mountains were uplifted more than 300 million years ago (Wilshusen 1983). Throughout the Pleistocene Epoch (2.58 million to 10,000 years ago), vast glacial ice sheets descended from the north, covering and profoundly changing the landscape north of the boundary; the last glacial episode is called the Wisconsinan. APPA includes a vast collection of glacial landscape features, some of which helped define classical interpretations of glacial processes and history. Visitors can ponder the idea of an ice sheet thousands of feet thick covering their current location. Scientists can study the features left behind to understand the history of the area just as early people were starting to settle there.

Landscape features that are evidence of past glacial movement include U-shaped valleys, cirques, drumlins, roches moutonnées, polished surfaces, striations, glacial grooves, terminal moraines, and associated ice extents (Figures 14 and 15). Unlike rivers, which tend to carve V-shaped valleys, glaciers excavate broad U-

shaped valleys. Grafton Notch in Maine, as well as Pinkham, Crawford, and Franconia Notches in New Hampshire, are examples of U-shaped glacial valleys (Brosnahan 2004; Maine Department of Agriculture, Conservation and Forestry 2015). Cirques are amphitheater-like valleys formed by glacial erosion. Great Gulf and Tuckerman Ravine on the southeast face of Mt. Washington are examples of glacial cirques, as well as Great Basin on Mt. Katahdin in Maine (Brosnahan 2004; Knight 2009).

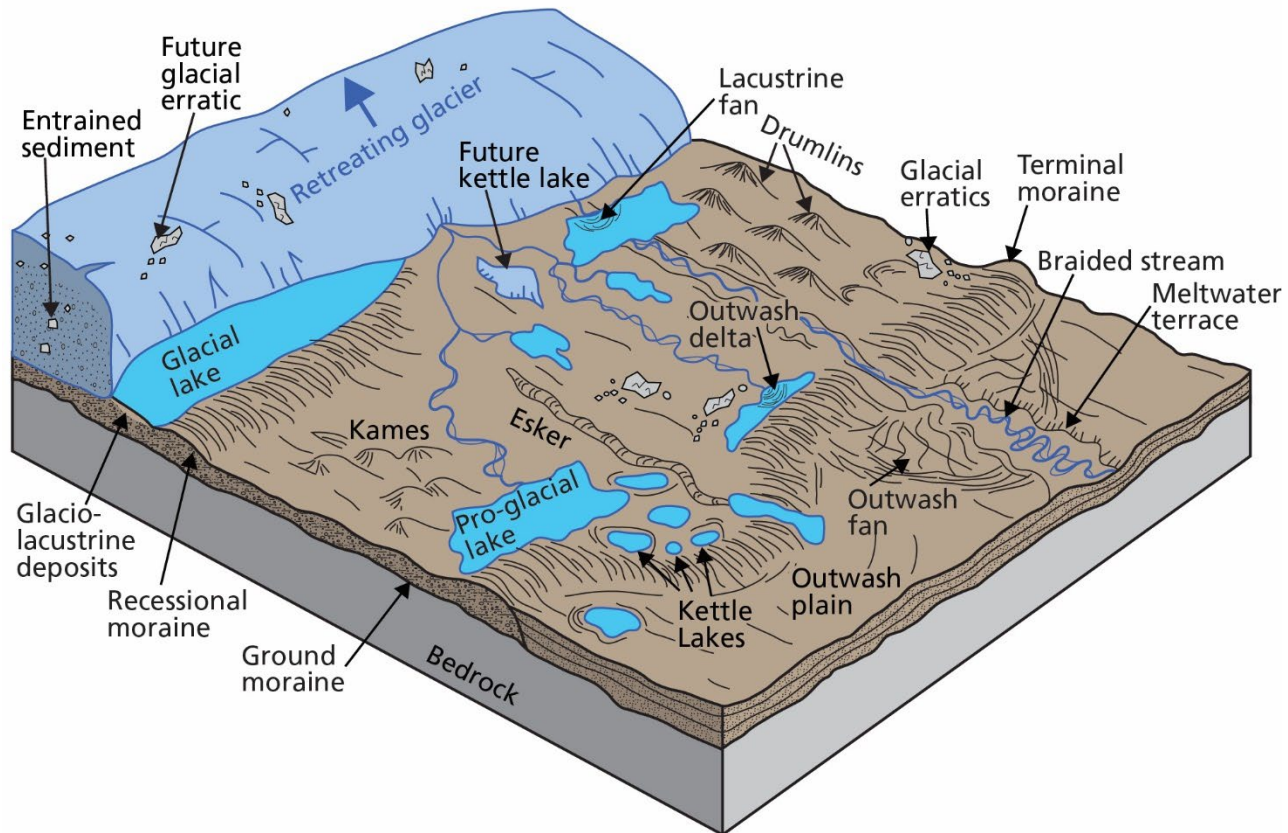


Figure 14. Diagram of general glacial features. Most of the listed glacial features occur within the APPA area. The scenic trail area contains both depositional (e.g., moraines and glacial erratics) and erosional (e.g., drumlins) features from central Pennsylvania northwards. South of this boundary, periglacial (near enough to the glacier to experience colder climates) conditions increased rates of weathering and erosion along the scenic trail. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University).

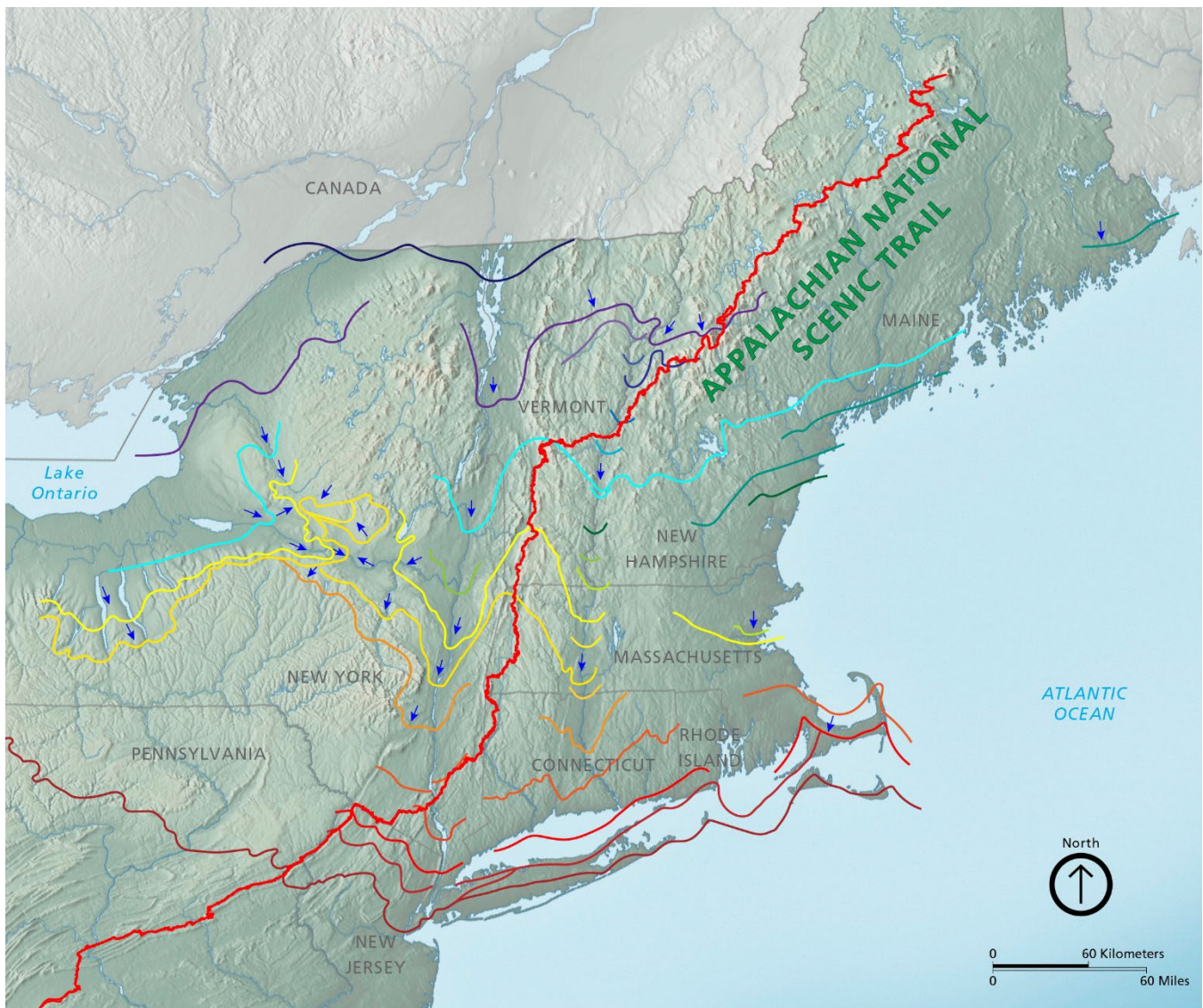


Figure 15. Map of intermittent ice margins during the Wisconsin retreat of continental ice sheets. As the glacial ice sheets retreated in fits and starts, moraines marked ice margins where the glacier stalled. Retreat progressed from southwest to northeast. The oldest terminal moraines are indicated in red, whereas the youngest margins are purple. The trace of the scenic trail is the bold red line. Blue arrows indicate advancing ice flow directions where known. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) using information from the Geological Survey of Canada (1986). Basemap by Tom Patterson (NPS), available online: <http://www.shadedrelief.com/physical/index.html> (accessed 19 August 2024).

Drumlins are elongated linear hills that formed when a glacier flowed over a mass of sediment (see Figure 14). Drumlins are visible from the scenic trail in New York, New Jersey, Massachusetts, and Maine (Chew 1988). In New England, drumlins are primarily oriented in a fanned pattern indicative of the spreading southward and outward of the different glacial lobes as they advanced. Roches moutonnées (French for sheep-shaped rock) form in bedrock exposures as the glacier flows over a resistant knob or ridge. The roches moutonnées rise as a smooth slope from the north and end abruptly in a south-facing cliff, formed as glaciers locally flowed from the north, froze to the rock, and then plucked away chunks of the rock on the

south face while they flowed over and away. Roches moutonnées are present along the trail in New Jersey, New York, Massachusetts, Vermont, and New Hampshire (Chew 1988).

Smaller-scale glacial scour features that are prevalent in the formerly glaciated extents of the scenic trail are polished surfaces, striations, and glacial grooves. These types of features also record the direction of ice movement as rocks entrained at the base of a glacier were scraped over the underlying bedrock. Glacial polishing is the result of sand and stones embedded in glacial ice passing over erosion-resistant bedrock (e.g., granite or gneiss) and grinding or polishing down the top of the rock into a smoother surface. Glacial striations may occur within glacial grooves, and both features are prominent on bedrock outcrops along the northern portion of the scenic trail.

In addition to scouring and scraping landforms, glaciers transport and deposit vast amounts of mixed sediments. Eskers, or sinuous ridges of stratified sediment deposited by streams flowing through meltwater tunnels or subglacial streams, formed within the glacier itself. The scenic trail crosses eskers near Flagstaff Lake in Maine (Chew 1988). Features deposited by moving ice include glacial till, moraines, and terminal moraines associated with former ice extents. Glacial till (a mixed assortment of sediments deposited directly from glacial ice) covers much of the bedrock in valleys traversed by the scenic trail. The unsorted clasts within glacial till tend to be angular because they were only carried by glacial ice and not rounded by flowing water. Till may be deposited in landforms called moraines.

Types of moraines found along the scenic trail are differentiated based on where they formed in relation to a glacier:

- Ground moraines are till that is distributed across the ground as a glacier retreats upvalley in warmer times. Ground moraines are widespread in valleys crossed by the scenic trail.
- Terminal moraines are material that was deposited in a ridge at the very maximum extent of the ice. It is formed where the glacier deposits material at its edge and then retreats away from the ridge. A well-known example of a terminal moraine comprises the bulk of Long Island, Nantucket, and Martha's Vineyard. The scenic trail crosses a terminal moraine in eastern Pennsylvania.
- Recessional moraines are similar to terminal moraines in their arcuate, ridge appearance. Recessional moraines are till material that is left behind when a retreating glacier remains stationary for long enough to melt and drop a large pile of sediments in one place. Many dated recessional moraines record the paths the glaciers melted along as they receded northwards at the end of the Wisconsinan (see Figure 15). The scenic trail crosses several of these recessional moraines in New Jersey, New York, Massachusetts, Vermont, New Hampshire, and Maine (Stone et al. 1998; Hodgdon 2016).

Glacial deposits throughout New England include those created by glacial meltwater in rivers or lakes. Glacial streams carried water away from melting glaciers. They transported vast amounts of sediment (glaciofluvial outwash), depositing them on features called outwash plains, which can commonly extend several hundred kilometers beyond the glacial extent (Encyclopaedia Britannica 2011). If the outlets to the streams were blocked (e.g., by ice, moraines, or bedrock), glacial lakes could form (Figure 16). Glacial lakes accumulated varved glaciolacustrine deposits. Varved deposits record a seasonal variation in grain size and amount of sedimentation. In winter, while the surface of the glacial lake was frozen, fine, dark mud settled slowly from the water to form thin, dark, fine-grained sedimentary layers. In summer, melting water carried

sand and coarser sediments from the glacier, depositing them as thicker, lighter-colored, coarser-grained sedimentary layers (Chew 1988; Ridge 2023). The scenic trail crosses several former glacial lake beds, including Glacial Lake Ashuelot in Vermont and Glacial Lake Albany in New York.



Figure 16. Map of the northeastern US showing extent of glacial lakes. At the end of the Wisconsin glacialation about 11,000 years ago, several of the large valleys in New England were impounded and flooded by post-glacial lakes. These lakes left features such as strand lines, deltas, and glaciolacustrine deposits on the landscape passed through by the scenic trail. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) with information from Fairchild (1917), Hooke and Ridge (2016), Balco et al. (2021), and Ridge (2023).

A retreating glacier commonly leaves large blocks of ice stranded in front of the edge of the glacier. These blocks may be surrounded, covered, or nearly buried by the vast amount of outwash flowing from the glacier. When the ice block eventually melts, the sediment collapses, leaving behind a depression (a kettle), which may or may not contain water. Arguably the most famous kettle in New England is Walden Pond. However,

kettles also feature prominently in the area around the Hudson River Valley in New York (e.g., Harriman State Park) and near Mt. Katahdin in Maine.

Commonly associated with kettles are kames. Kames are glaciofluvial or glaciolacustrine deposits of sand and gravel. They typically form from sediments deposited in hollows or depressions atop a retreating glacier. Characteristic of kames is bumpy, irregular topography. Kame deltas and terraces formed where sediment-bearing meltwater streams emerged from the edge of the ice sheet or at the mouth of a river and deposited sandy beds in the glacial lake and gravelly fluvial beds in the delta plain that extended out on top of the sand or as deltas and/or terraces at the glacier's edge (Byron Stone, US Geological Survey, geologist, written communication, 12 February 2017). The scenic trail passes through kames near Wawayanda Mountain in New Jersey (Chew 1988).

Fluvial Features and Processes

Fluvial features are landforms formed by flowing water. Fluvial processes (flowing water) both construct (deposit alluvium and terraces) and erode landforms (e.g., river valleys, gaps, notches, and potholes). Fluvial features along the scenic trail range from the tiniest rivulets to streams to the largest rivers in the eastern US. Streams and rivers have long-reaching influences on human experience. For example, many streams are named for local landforms or geographic features and vice versa (e.g., Katahdin Stream, Bald Mountain Brook, Leadmine Brook, Connecticut River, Greenwater Brook, Macedonia Brook, Canopus Creek, Copper Mine Brook, Surebridge Brook, Delaware River, Little Antietam Creek, Morgan Mill Stream, Tinker Creek, Nolichucky River, Little Tennessee River, and Justus Creek). Streams, even small streams, act as sediment conveyor belts, reworking and transporting sediment from their headwaters toward their outlets. Streams are the source of most of the sediment that makes up the Atlantic Coastal Plain.

Tracing the crest of Appalachian ridges, the scenic trail forms part of the headwaters of many watersheds; the trail crosses more than 1,700 streams and 100 rivers along its route (Argue et al. 2012). The crossings include a spectrum of structures designed and installed to help hikers get over the water feature: bog bridges (planks on supporting timbers), puncheon (split logs on other logs), stepping stones, log corduroy passages, crushed gravel "turnpikes," two-log bridges, canoe ferries, suspension bridges, stone bridges, and shared transportation bridges over the largest rivers (Cosmo 2015). These watersheds define the hydrological pattern of much of the eastern United States; they anchor the watersheds that provide drinking water to more than 19% of the US population (National Parks Conservation Association 2010). Approximately 1,030 km (640 mi) of perennial and intermittent rivers, streams, and canals are within or adjacent to the scenic trail management area.

Ecosystem Connections and Problems

Views, both near and far, and ecological connectivity are listed among the scenic trail's fundamental resources (National Park Service 2015a). The scenic trail passes through eight separate ecoregions, links extensive forest landscapes, and includes various aquatic and terrestrial habitats (National Parks Conservation Association 2010; National Park Service 2015a). The scenic trail spans a diverse array of habitats, such as subalpine forests, alpine tundra, open (heath and grassy) balds, rocky outcrops, talus slopes, meadows, and wetlands, providing a home for abundant flora and fauna, including rare, threatened, and endangered species in an increasingly populated part of the country (National Parks Conservation Association 2010; NPS 2015a).

Vegetation changes and biodiversity along the trail can be linked to changes in rock type. Bedrock types influence the soils formed atop them and, in turn, the ecosystem. For example, magnesium- and calcium-rich soils derived from weathered bedrock support grassy, prairie-like glade communities at high elevations. Mafic and ultramafic bedrock give rise to magnesium- and iron-rich soils that, in some areas, support mafic woodland seeps (Carter et al. 2017). The Chilhowee Group rocks (see “Type Section Localities as Geoheritage”) decompose to a silty, gritty, non-fertile soil, which supports a few bushes (e.g., mountain laurels) in cracks and mosses and ferns in seep areas (Carter et al. 2001). Metagraywacke and metasiltstone in North Carolina break down to form thin, stony, relatively infertile acidic soils (Carter et al. 2001). These types of soils support particular flora such as Blue Ridge goldenrod (*Solidago spithamea*), liverwort (*Frullania appalachiana*), and spreading avens (*Geum radiatum*). Spring assemblages, which include plants like ramps and jack-in-the-pulpits, only occur in carbonate valleys (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting presentation, 6 May 2016).

Geologic Stratotype Localities as Geoheritage

Commonly, when geologic mappers describe and name a new geologic unit (such as a formation), a specific and well-exposed section or outcrop area of the unit is designated as the stratotype—the standard exposure (Henderson et al. 2022). Geologic stratotypes are important geoheritage resources with historic and scientific significance and should be preserved and remain available for other researchers to evaluate in the future (Henderson et al. 2022). The significance of stratotypes is that they represent important comparative sites where past investigations can be expanded upon or re-examined. Stratotypes can also serve as teaching sites for the next generation of geoscientists (Brocx et al. 2019; Henderson et al. 2022). The geoheritage value of stratotypes is analogous to libraries and museums because they are natural repositories of Earth history (Henderson et al. 2022). Geologic stratotypes are part of our national geoheritage and function as a cornerstone of the scientific value used to define the societal significance of geoheritage sites (Henderson et al. 2022). At APPA, rock formations are named after topographic or geologic features and geographic landmarks that are recognizable to scenic trail staff and visitors.

There are three kinds of stratotypes that are relevant to the national scenic trail: type section, type locality, and type area. A type section is an important reference exposure for a named stratified (layered) geologic unit. It presents a relatively complete and representative example of this unit. Once a type section is assigned, it is never changed. Type localities are specific geographic locations encompassing the type section of a formally recognized and defined geologic unit. A type area applies to rocks that are not stratified or layered (e.g., a granite body) and includes larger territories that can encompass type localities and type sections (North American Commission on Stratigraphic Nomenclature 2021; Henderson et al. 2022). The scenic trail contains or is in very close proximity (defined as within 1 km [0.6 mi]) to 27 identified stratotypes: 11 type sections, 11 type localities, and five type areas (Henderson et al. 2022). These are located in New Hampshire, Vermont, Massachusetts, New York, Pennsylvania, New Jersey, Maryland, West Virginia, Virginia, North Carolina, and Tennessee (Figure 17; Keith 1894, 1895; Emerson 1899; Merrill et al. 1902; Greene 1970; Dyson 1967; Epstein and Epstein 1972; Ratcliffe 1991; Southworth et al. 2009; Henderson et al. 2022).



Figure 17. Map showing locations of stratotype locations. The scenic trail includes and passes near geologic stratotypes that are significant to the scientific community as geoh heritage. Graphic by Trista L. Thornberry-Ehrlich (Colorado State University) using GIS data provided by Tim Henderson (Colorado State University) and ESRI aerial imagery.

Stratotypes from north to south:

- Kinsman Granodiorite (type locality at Kinsman Notch, New Hampshire) is a Devonian-age (419.2–358.9 million years ago) intrusive igneous rock that has been metamorphosed. (Moench et al. 1995).
- Wilcox Formation (type locality near Wilcox Hill, Rutland County, Vermont) includes Mesoproterozoic metamorphic rocks. (Ratcliffe 1994).
- Cardinal Brooke Intrusive Suite (type locality Cardinal Brook, Bennington County, Vermont) is Mesoproterozoic biotite granite and rapakivi granite (an unusual composition with grains of the

mineral orthoclase [potassium-rich] feldspar rimmed by the mineral oligoclase [calcium- and sodium-rich] feldspar; Ratcliffe 1991).

- Dalton Formation (type locality near Dalton, Berkshire County, Massachusetts) includes a Neoproterozoic–Cambrian variety of metamorphic rocks, including quartzite, metamorphosed conglomerate, schist, and granofels (a rock in which quartz and feldspar crystals are dispersed [i.e., not foliated] with similar grain size). In outcrop, these rocks range in color from greenish gray to white to dark gray (Emerson 1917; Ratcliffe 1984).
- Poughquag Quartzite (type locality at Poughquag, Dutchess County, New York) is early Cambrian quartzite, which appears white to brown with some minor yellow-green conglomerate layers (Dana 1872; Merrill et al. 1902; Ratcliffe and Burton 1990).
- Minsi Member, Shawangunk Formation (type section at Delaware Water Gap, Warren County, New Jersey) includes Silurian (443.8–419.2 million years ago) quartzite, conglomerate, and siltstone. In exposures, the rock is gray to olive gray (Epstein and Epstein 1972).
- Tammany Member, Shawangunk Formation (type section at Delaware Water Gap, Warren County, New Jersey) is Silurian gray, cross-bedded (layers formed by wind or moving water) quartzite with minor amounts of dark gray shaly siltstone. Some layers have quartz or shale pebbles (Epstein and Epstein 1972).
- Lizard Creek Member, Shawangunk Formation (type section at Lehigh Gap, Northampton County, Pennsylvania) contains Silurian gray sandstone, siltstone, and silty shale, with some red-bed layers. Red beds are sedimentary layers that contain oxidized iron minerals (Epstein and Epstein 1972).
- Weiders Member, Shawangunk Formation (type section at Lehigh Gap, Northampton County, Pennsylvania) contains early Silurian, gray to greenish-gray conglomerate and quartzite. (Epstein and Epstein 1972).
- Clarks Ferry Member, Catskill Formation (type section at Peters Mountain and Susquehanna River, Dauphin County, Pennsylvania) is Devonian, gray to grayish-red quartzite and sandstone containing pebbles of red shale (Dyson 1963, 1967).
- Duncannon Member, Catskill Formation (type section at Peters Mountain and Susquehanna River, Dauphin County, Pennsylvania) consists of Devonian, red siltstone, shale, and sandstone below gray sandstone interbedded with grayish-red siltstone and shale (Dyson 1963, 1967).
- Sherman Creek Member, Catskill Formation (type area Sherman Creek, Perry County, Pennsylvania) includes Devonian grayish-red to brownish-red shales, siltstones, and sandstones (Dyson 1967).
- Buzzard Knob Member, Weverton Formation (type section Raven Rock Hollow, Washington County, Maryland) is an early Cambrian, light gray to greenish-gray quartzite with some greenish to bluish phyllites. Geologists consider this unit to be the single most significant ridge-forming unit in the northern Blue Ridge province (Brezinski 1992).
- Weverton Formation (type section at South Mountain, Washington County, Maryland, and type locality at the Weverton Cliffs and Potomac River in Washington County, Maryland) is quartzite, phyllite, and metamorphosed conglomerate, siltstone, and graywacke (Brezinski 1992).

- Maryland Heights Member, Weverton Formation (type section at Maryland Heights, Washington County, Maryland) contains graywacke, sandy metamorphosed siltstone, and phyllite. In exposures, the rock appears gray to olive gray (Brezinski 1992).
- Harpers Formation (type locality at Harpers Ferry, Jefferson County, West Virginia) is Cambrian metamorphosed siltstone and sandstone. Outcrop exposures are greenish black to gray to brownish black. This unit contains fossilized burrows (Brezinski 1992; Southworth 1994).
- Swift Run Formation (type locality at Swift Run Gap and Skyline Drive in Greene County, Virginia) consists of Neoproterozoic phyllite and metamorphosed arkose (a feldspar-rich sandstone), siltstone, and pebble- to cobble-conglomerate (King 1950; Southworth et al. 2009).
- Pedlar River Charnockite Suite (type section near Hog Camp Gap and Cole Mountain, Rockbridge County, Virginia) is a Mesoproterozoic metamorphosed intrusive igneous rock, charnockite. Charnockite is a granite that contains minerals indicative of formation deep in Earth's crust (e.g., orthopyroxene, a greenish calcium- and aluminum-poor mineral; Sinha and Bartholomew 1984).
- Mount Rogers Formation (type area between Whitetop Mountain and Pine Mountain in Virginia to Nella, North Carolina) contains Neoproterozoic rocks that formed in a rift setting where Earth's crust split apart. This formation includes graywacke, phyllite, conglomerate, arkose, greenstone, and rhyolite (Rankin 1993).
- Buzzard Rock Member, Mount Rogers Formation (type locality at Buzzard Rock in Smyth and Washington Counties, Virginia) includes Neoproterozoic volcanic lava flows. At its type locality, the member appears grayish-purple or maroon with small (typically 2–4 mm [0.08–0.16 in]) grains of feldspar (Rankin 1993).
- Konnarock Formation (type area along Whitetop Laurel Creek in Washington County, Virginia) contains Neoproterozoic diamictite (a metamorphosed glacial deposit; see “Glaciation and Glacial Features”), rhythmite (a sedimentary rock in which layers of sediment were deposited with an obvious periodicity and regularity), and arkose. In outcrop, the layers range in color from maroon to pink (Rankin 1993; Rankin and Caldwell 2010).
- Rich Butt Sandstone (type section on Big Creek above Mount Sterling, Cocke County, Tennessee, and type area at Rich Butt Mountain, Cocke County, Tennessee) is a Neoproterozoic mixture of metamorphosed lighter-colored sandstone and conglomerate, both of which contain significant feldspar grains, and darker siltstone and mudstone (King et al. 1958; King 1964).
- Anakeesta Formation (type locality at Anakeesta Ridge to Newfound Gap, Sevier County, Tennessee) contains Neoproterozoic dark gray slate, metamorphosed siltstone, and phyllite that contain local thin beds of metamorphosed sandstone, graywacke, and sandy dolomite (King et al. 1958; King 1964).
- Thunderhead Sandstone (type area at Thunder Head, Blount County, Tennessee and Swain County, North Carolina) is a Neoproterozoic mixture of metamorphosed light gray sandstone and conglomerate and darker siltstone (King 1964; Southworth et al. 2012).

- Cades Sandstone (type locality near Cades Cove, Blount County, Tennessee) includes Neoproterozoic metamorphosed sandstone and graywacke interbedded with dark-colored siltstone, slate, and conglomerate (King et al. 1958; King 1964).

Baseline GSRI Products

GRI Existing Geologic Map Data as Map Footprints

The GRI team compiled the geologic map footprints data for the scenic trail in 2017 (updated in 2024; available on the NPS DataStore, accessed through the Integrated Resource Management Applications (IRMA) portal: <https://irma.nps.gov/DataStore/Reference/Profile/2194543>). The GRI geologic data for APPA consist of geologic map footprints of available maps that intersect the 7.5' quadrangles of interest (QOI) for the park. Each footprint depicts the respective map's extent and contains information conveying map name, scale, publication year, and type. These data are the principal deliverables of the GRI. The GRI team did not conduct original geologic mapping but compiled existing geologic information (i.e., paper maps and/or digital data) into the GRI geologic map footprints data. Scoping participants and the GRI team identified the best available source maps based on coverage (area mapped), map scale, date of mapping, and compatibility of the mapping to the current geologic interpretation of an area.

Because of the scale and sheer size of the scenic trail, passing through 14 states, a cohesive and comprehensive, large-scale geologic map in geologic information system (GIS) format was not feasible. Therefore, the GRI geologic map footprints data facilitates resource managers to find the best geologic map for specific segments of the scenic trail in specific states. In 2017, this product included a hybrid PDF map showing a compiled representation of all bedrock geologic maps, as well as a list of map citations, referenced by GRI map footprints data. The GRI adopted the term “hybrid map” to describe the geologic compilation that combines maps from various scales, authors, and vintages. However, in 2024, in an ongoing effort to optimize GRI products, this static, unmaintainable product was exchanged for an updated geodatabase of geologic map footprints, complete with detailed protocols and instructions for adding new mapping as it becomes available. The GRI geologic map footprints are but a snapshot of the status of geologic mapping along the scenic trail. Mapping is ongoing and constantly changing at agencies such as the state surveys, academic institutions, and the US Geological Survey. The 2024 GRI GIS map product includes the following:

1. A readme file (appa_geology_gis_readme.doc) explaining the GRI data product and a map search protocol document (APPA_Map_Search_Protocol.docx) detailing how to search for new maps (e.g., US Geological Survey National Geologic Map Database [NGMDB] and individual state geological surveys) and maintain the map footprint geodatabase.
2. A map footprint index (geodatabase: appa_map_footprints.gdb) showing the location, extents, and GRI map footprint number of the best available bedrock and surficial geologic maps.
3. An ArcGIS Pro3.x file (appa_map_footprints.mapx) that launches the project to show the geologic map footprint data in thematic layers, categorizing and symbolizing them by publication year, map type, and scale.
4. A custom python script and toolbox (FindMapsInArea.atbx and mapsInArea.py) designed to find geologic maps in a designated area in ArcGIS Pro and export the information to a CSV file for use in spreadsheet programs (e.g., MS Excel).
5. GRI GIS map products for NPS units along the scenic trail:

- Chesapeake and Ohio Canal National Historical Park (<https://irma.nps.gov/DataStore/Reference/Profile/1048803>),
- Harpers Ferry National Historical Park (<https://irma.nps.gov/DataStore/Reference/Profile/2171317>),
- Great Smoky Mountains National Park (<https://irma.nps.gov/DataStore/Reference/Profile/2229056>),
- Marsh-Billings-Rockefeller National Historical Park (<https://irma.nps.gov/DataStore/Reference/Profile/2171386>),
- Delaware Water Gap National Recreation Area (<https://irma.nps.gov/DataStore/Reference/Profile/2171329>),
- Shenandoah National Park (<https://irma.nps.gov/DataStore/Reference/Profile/2171426>),
- Blue Ridge Parkway (<https://irma.nps.gov/DataStore/Reference/Profile/2194447>).

SRI Products, Needs, and Guidance

The underlying geology significantly influences APPA soils, which are characteristically thin and rocky in the higher elevations and are diverse in the lower valleys. Major differences also occur where the landscape was previously glaciated compared to the unglaciated areas. Soils and surficial deposits data are vital to managing and protecting the trail footpath, being prepared for slope stability issues, predicting and understanding trail response to human impacts, managing ecosystem response to changing atmospheric deposition, and climate change (National Park Service 2015a). The NPS SRI initiated a soils project in 2012.

SRI Products: <https://irma.nps.gov/DataStore/Reference/Profile/2190841>

The most up-to-date soils data are available via the USDA Natural Resources Conservation Service (NRCS) Web Soil Survey, and management-focused maps for potential project areas can be developed on-demand at that site. The Web Soil Survey homepage gives instructions for how to view and download soil data.

Web Soil Survey is broken down into county-level soil survey areas. APPA passes through 87 soil survey areas. The soil survey is complete for all but two of those areas. NRCS plans to complete all soil survey areas in the US by 2026 (Thompson et al. 2020). Table 2 lists the soil survey areas and their completion status, arranged alphabetically. The Web Soil Survey area code can be used to find that area directly on Web Soil Survey. Contact the NRCS state soil scientist for technical assistance with Web Soil Survey or soils data.

Table 2. Soil survey area status

Web Soil Survey Area Code	Web Soil Survey Area Name	Status
CT601	State of Connecticut, Western Part	Complete
GA137	Habersham County, Georgia	Complete
GA622	Cherokee, Gilmer, and Pickens Counties, Georgia	Complete
GA632	Dawson, Lumpkin, and White Counties, Georgia	Complete
GA637	Fannin and Union Counties, Georgia	Incomplete
GA651	Rabun and Towns Counties, Georgia	Complete

Web Soil Survey Area Code	Web Soil Survey Area Name	Status
MA003	Berkshire County, Massachusetts	Complete
MD021	Frederick County, Maryland	Complete
MD043	Washington County, Maryland	Complete
ME610	Franklin County Area and Part of Somerset County, Maine	Complete
ME613	Oxford County Area, Maine	Complete
ME615	Piscataquis County, Maine, Southern Part	Complete
ME619	Somerset County Area and Parts of Franklin and Oxford Counties, Maine	Complete
ME620	Northern Piscataquis and Northern Somerset County Area, Maine	Complete
NC011	Avery County, North Carolina	Complete
NC043	Clay County, North Carolina	Complete
NC075	Graham County, North Carolina	Complete
NC113	Macon County, North Carolina	Complete
NC115	Madison County, North Carolina	Complete
NC121	Mitchell County, North Carolina	Complete
NC199	Yancey County, North Carolina	Complete
NC605	Swain County Area, North Carolina	Complete
NC606	Haywood County Area, North Carolina	Complete
NH009	Grafton County, New Hampshire	Complete
NH603	Carroll County Area, New Hampshire	Complete
NH605	White Mountain National Forest, New Hampshire and Maine	Incomplete
NH607	Coos County Area, New Hampshire	Complete
NJ031	Passaic County, New Jersey	Complete
NJ037	Sussex County, New Jersey	Complete
NJ041	Warren County, New Jersey	Complete
NY027	Dutchess County, New York	Complete
NY071	Orange County, New York	Complete
NY079	Putnam County, New York	Complete
NY087	Rockland County, New York	Complete
NY119	Westchester County, New York	Complete
PA001	Adams County, Pennsylvania	Complete
PA011	Berks County, Pennsylvania	Complete
PA025	Carbon County, Pennsylvania	Complete
PA041	Cumberland County, Pennsylvania	Complete
PA043	Dauphin County, Pennsylvania	Complete
PA055	Franklin County, Pennsylvania	Complete
PA075	Lebanon County, Pennsylvania	Complete
PA077	Lehigh County, Pennsylvania	Complete
PA089	Monroe County, Pennsylvania	Complete
PA095	Northampton County, Pennsylvania	Complete
PA099	Perry County, Pennsylvania	Complete
PA107	Schuylkill County, Pennsylvania	Complete
TN019	Carter County, Tennessee	Complete
TN059	Greene County, Tennessee	Complete
TN091	Johnson County, Tennessee	Complete
TN163	Sullivan County, Tennessee	Complete
TN171	Unicoi County, Tennessee	Complete
TN606	Cocke County Area, Tennessee	Complete

Web Soil Survey Area Code	Web Soil Survey Area Name	Status
TN640	Great Smoky Mountains National Park, Tennessee and North Carolina	Complete
VA003	Albemarle County, Virginia	Complete
VA009	Amherst County, Virginia	Complete
VA015	Augusta County, Virginia	Complete
VA019	Bedford County, Virginia	Complete
VA021	Bland County, Virginia	Complete
VA023	Botetourt County, Virginia	Complete
VA043	Clarke County, Virginia	Complete
VA045	Craig County, Virginia	Complete
VA061	Fauquier County, Virginia	Complete
VA071	Giles County, Virginia	Complete
VA077	Grayson County, Virginia	Complete
VA079	Greene County, Virginia	Complete
VA107	Loudoun County, Virginia	Complete
VA113	Madison County, Virginia	Complete
VA121	Montgomery County, Virginia	Complete
VA125	Nelson County, Virginia	Complete
VA139	Page County, Virginia	Complete
VA157	Rappahannock County, Virginia	Complete
VA161	Roanoke County and the Cities of Roanoke and Salem, Virginia	Complete
VA163	Rockbridge County, Virginia	Complete
VA165	Rockingham County, Virginia	Complete
VA173	Smyth County, Virginia	Complete
VA185	Tazewell County, Virginia	Complete
VA187	Warren County, Virginia	Complete
VA191	Washington County Area and the City of Bristol, Virginia	Complete
VA606	Jefferson National Forest, Virginia	Complete
VA850	Blue Ridge Parkway - Bedford County, Virginia Peaks of Otter Area	Complete
VT003	Bennington County, Vermont	Complete
VT021	Rutland County, Vermont	Complete
VT025	Windham County, Vermont	Complete
VT027	Windsor County, Vermont	Complete
WV037	Jefferson County, West Virginia	Complete
WV037	Jefferson County, West Virginia	Complete

Resource Management Issues and Inventory Needs

This section summarizes the geologic resource management hazards, issues, and inventory needs that have been identified by discussions with APPA staff. Geologic hazards refer to notable hazards stemming from geologic features or processes that may require active management. Geologic issues refer to problems that result in the damage or theft of geologic resources. Inventory needs are highlighted to summarize what is currently known and what is needed to ensure appropriate management of the scenic trail. Refer to the [Guidance for Resource Management SharePoint](#) for more information regarding geologic resource management.

Physical Management of the Trail

The trail itself is listed as first among APPA's fundamental resources (National Park Service 2015a). Management of the trail is a collaborative effort, with at least 99% of the footpath protected through acquisitions, easements, public lands, and other means (Appalachian Trail Conservancy 2009; National Park Service 2015a). The trail is a protection corridor in agreement with adjacent and/or underlying landowners (conference call participants, conference call, 3 April 2023). The NPS retains the primary authority and responsibility for the acquisition, development, and administration of the scenic trail under the National Trails System Act, whether the land is federally owned or not (Appalachian Trail Conservancy 2009; conference call participants, conference call, 3 April 2023). For any fee lands (excluding North Carolina, Tennessee, and Georgia; conference call participants, conference call, 3 April 2023), the NPS assumes increased responsibility and authority. APPA staff may not always have the final word in decision-making but require scientific information to inform their trail management decision inputs (conference call participants, conference call, 3 April 2023). For this, annual walk-through inspections by local clubs and volunteers are vital. The ATC produced a web-based local management planning guide to provide trail-maintaining clubs with a comprehensive reference document to help in the local planning process (Appalachian Trail Conservancy 2009). The NPS and ATC work with more than 60 maintaining clubs and community partners to perform trail maintenance, build and repair shelters and structures, and monitor and protect the trail corridor, among other functions (Appalachian Trail Conservancy 2015).

Not all sections of the trail are used in the same ways or as frequently as others. The trail areas closest to towns and cities receive heavy use compared to more rural sections. Overall visitation is increasing from year to year, and the number of "thru-hikers" (people who complete the entire trail) is increasing (National Park Service 2015a). Threats to the trail from humans include encroachment from neighboring lands, increased erosion from foot traffic degrading stabilizing vegetation, vandalism, climate change, traversing utility and transportation corridors (e.g., pipelines, electrical lines, roads), and the introduction and spread of invasive species from neighboring landowners, commerce, trade, and visitors (National Park Service 2015a; Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025). Rerouting of the trail is planned in several areas to improve visitor experience and trail sustainability. Erosive surface water is managed in part through trail drainage features as a means of diverting runoff from the footpath (Burroughs et al. 2017). In addition to this, infrastructure such as bridges, shelters, and trail treads is in constant need of rehabilitation, replacement, and/or removal (National Park Service 2015a).

In 2010, the ATC and the Appalachian Trail Park Office initiated the Appalachian Trail MEGA (from Maine [ME] to Georgia [GA])-Transect program, designed to unite existing research efforts while identifying new

opportunities to monitor, understand, and communicate the long-term ecological health of the Appalachian region. Federal, state, and local agencies; private organizations; nonprofits; research universities; schools and youth groups; and individuals, including hikers, supply data on various components, including but not limited to air and water quality; invasive non-native plant locations and dispersion rates; rare, threatened, and endangered species; visitor impacts (e.g., effects on soil, water, and vegetation); seasonal life cycles (i.e., the timing of plant flowering and other seasonal biological events); and the effects of global climate change on natural resources (National Parks Conservation Association 2010). Potential additional topics could include new slope movements, paleontological resources, mineral resources, and other notes of geologic and/or soils interest. As of 2025, very little capacity currently exists to support, lead, and grow this program within the NPS and partners (Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025).

Climate change will be an issue of increasing importance over the next century for APPA. Climate change has significant and complex impacts on geology and soils. Increased storm intensity will cause increased runoff, erosion, and weathering of the scenic trail. Changes in precipitation patterns may cause slope instability (landslides and rockfalls) and change fluvial patterns (extreme floods and/or droughts). Soils will increasingly erode, degrade (desiccate), change chemistry (organic content and pH), and may become less fertile overall (Intergovernmental Panel on Climate Change 2023).

The trail and its associated corridor may function as a vital pathway for adaptive movements of species in response to predicted climate change. For this reason, if climate change threatens the integrity of the trail (e.g., increased erosion or risk of slope movements with more frequent extreme events), its natural function is also under threat. The Appalachian Mountains and, by extension, the scenic trail will likely be a critical area for connectivity under a changing climate (McKinley et al. 2019). Strategies to support connectivity include better management of national forest lands and permanent protection of roadless lands with high species richness or high integrity. Other strategies will require outright purchase of non-protected private lands in small non-industrial parcels along the trail corridor in places such as the Mid-Atlantic region and purchase of large-scale private industrial forestlands in northern New England or at least purchase of working forest easements (McKinley et al. 2019).

APPA possesses high species diversity at the southern end (peak species richness near the Georgia-South Carolina border), where much of the adjacent land is protected federally, and high ecological integrity in the north on private timberlands (lowest species richness in northern Maine). Inadequately protected areas with high biological diversity and ecological integrity occur along the length of the trail (McKinley et al. 2019). The ecosystems along the scenic trail are under threat from many factors: forest pests, invasive species, climate change, lack of connectivity, visitor and adjacent landowner use, and acid deposition from polluted air. These threats relate to the scenic trail's geology in complex ways. A geologic map for the scenic trail was identified as a data need for the management of natural resource quality and ecological connectivity (National Park Service 2015a). Climate change is causing an increase in the frequency and overall intensity of storms and extreme weather events (e.g., droughts), which impacts vegetation and flood regimes. Any changes to vegetation (from overuse, poor trail alignment, flood scouring, or drought die-off) reduce the ability of plant roots to stabilize sloped areas, leading to erosion. Alpine areas are particularly at risk of negative impacts from climate change. Acid pollution and geology are related in the ability of a soil or bedrock to buffer the acid. Some rock types are excellent buffers, whereas others are ineffective. Scientists

are noticing biodiversity declines, open areas (e.g., open balds) and soil loss, negative water quality trends, upslope shifts in northern hardwood forests, and northward shifts in bird winter ranges (National Park Service 2015a).

A natural resource condition assessment is in progress for APPA. As of 2025, an Appalachian Trail natural resource condition assessment dashboard website (<https://appalachian-trail-natural-resource-condition-assessment-clus.hub.arcgis.com/>) serves as an accompaniment to the forthcoming report. This website provides geospatial datasets, including reference boundaries, 2016 land cover, protected areas, geology (at various scales), Eastern Wildway resilient and connected networks, and scenic areas. The website also features natural resource status and trends data covering breeding birds, average light pollution ratio and soundscape, trail system impairment, wetlands, moderate resolution imaging spectroradiometer (MODIS)-based phenology (study of the timing and cyclical patterns of events in nature) trends, forest fragmentation, forest health, land use changes, air quality status, forest condition, and alpine and high-elevation vegetation. The website also highlights demographics of people living close to the scenic trail (population, housing, and social characteristics), threats, and stressors (insect and disease risk, climate trends, and invasive plants).

Views Beyond the Corridor and Overuse

The scenic trail is a narrow trace along the heights of the Appalachian Mountains. Vistas are fundamental resources for the scenic trail. There are more than 1,400 recognized vistas, including views from geologic features such as mountaintops, balds, and prominent rock outcrops (APPA database:

<https://nps.maps.arcgis.com/apps/webappviewer/index.html?id=a14491fe257343e58f2244b7d4f3572d>).

These geologic features play a significant role in the identified planning need of protection and response strategies at the scenic and landscape levels to protect land (vistas and focus areas) from overuse and encroaching development. This was listed as a high-priority need in the scenic trail's foundation document (National Park Service 2015a). In 2019, APPA and the ATC partnered on an [Enjoy The View](#) pilot study, and in 2021 began a comprehensive effort to document, inventory, and assess every viewpoint along the length of the trail following the NPS Visual Resource Assessment Process. As of the end of 2024, 43% of APPA had been assessed and 5.5 trail states had been inventoried. All assessment data are available through IRMA: <https://irma.nps.gov/ETV/> (Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025).

Encroachment of residential and commercial development in adjacent areas is the largest threat to APPA's cultural and natural resources (National Parks Conservation Association 2010). In 2015, the Appalachian Trail Landscape Conservation Initiative was launched to develop strategies to conserve and protect the iconic landscapes and scenic views that are so fundamental to the scenic trail. Primary focus areas include the 100-Mile Wilderness and Maine High Peaks in Maine, Upper Valley (Hanover to Lyme) in New Hampshire, Hudson Highlands in Connecticut and New York, NY/NJ State Line, Kittatinny Ridge and South Mountain in Pennsylvania, Northern Virginia, Catawba Valley-Triple Crown in Virginia, and Roan Highlands in North Carolina (Belleville 2021).

The Northeast Temperate Network monitors visibility in a database as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) for at least eight sites along the trail: Great Gulf Wilderness, Lye Brook Wilderness, Mohawk Mountain, Arendtsville, Shenandoah National Park, Jefferson National Forest, James River Face Wilderness, and Great Smoky Mountains National Park (Dieffenbach 2014). Views

from these sites are valued as a high-priority need in the vital signs monitoring plan for APPA (Dieffenbach 2011). Visibility monitoring is needed in other sections of the trail: southern Virginia, Maryland, central and northern Pennsylvania, New Jersey, New York, the Vermont-New Hampshire border, and Maine (Shriver et al. 2005).

The trail itself is the primary recreational feature of APPA; however, recreation may endanger the goal of resource protection (Marion et al. 2020). Issues stemming from use along the trail include soil compaction, trail widening, informal (social) trail proliferation, uneven surfaces, muddiness, exposure of tree roots, spread of invasive species, and vegetation loss (Marion et al. 2020; Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025). Increased off-road vehicle and mountain bike use along the narrow boundaries of the scenic trail represents a perennial management challenge (National Parks Conservation Association 2010). Overuse of certain sections of the trail is contributing to substantial erosion problems. Eroded sediment is transported downslope or downstream and is then deposited (Shriver et al. 2005). Some of the scenic trail's most used sites include McAfee's Knob, Nuclear Lake, and Bulls Bridge (National Park Service 2015a). The scenic trail needs development concept plans to provide site-specific direction to these high-use areas. Accurate data on trail conditions are vital to monitoring trends and directing trail maintenance (Shriver et al. 2005). Land cover, use, and disturbance events were noted as vital signs and are listed as needing to be monitored in the future with deferred protocol due to funding limitations. Land cover categories include urban, urban grass, herbaceous vegetation, grass-open land, shrubland, deciduous forest, coniferous forest, mixed forest, water, wetlands, barren land, and bare rockface (Shriver et al. 2005; Mitchell et al. 2006).

Anthropogenic impacts to APPA's resources come from use of the footpath itself (69%), overnight campsites (19%), social trails (6%), and day-use sites (5%), with visibly impacted lands covering over 280 ha (700 ac) of the scenic trail lands (Marion et al. 2020). Strategies to sustainably manage the footpath include 1) increasing the design width of the tread, shifting it to side-hill alignments in sloping terrain, improving water drainage, and hardening the tread by augmenting substrates with rock or angular gravel; 2) installing bog bridging or boardwalks for areas with wet soils; and 3) paving for areas where the trail passes through towns, accommodates exceptionally heavy traffic, or needs to be accessible to those with disabilities (Figure 18; Marion and Wimpey 2017; Marion et al. 2020; Meadema et al. 2020). Burroughs et al. (2017) presented an assessment tool to accurately determine the effectiveness of trail drainage features, while considering sediment and trail characteristics, maintenance, and characteristics of the trail drainage feature itself.

For campsites and day-use sites, construction and maintenance of sustainable campsites (e.g., side-hill campsites) and established tent pads would help concentrate impact, and closure and restoration of so-called mega-clusters of campsites along with educational outreach to inform hikers about the issue may reduce those impacts (Marion et al. 2020; Arredondo et al. 2021). Some social trails in high-use areas could be formalized and managed to reduce impacts ([APPA's online database](#) lists more than 1,100 side trails), whereas others should be closed and restored (Marion and Wimpey 2017; Marion et al. 2020). Accurate GIS-based analyses for trail/site sustainability assessments require LiDAR data, which are not yet available (Marion et al. 2020).

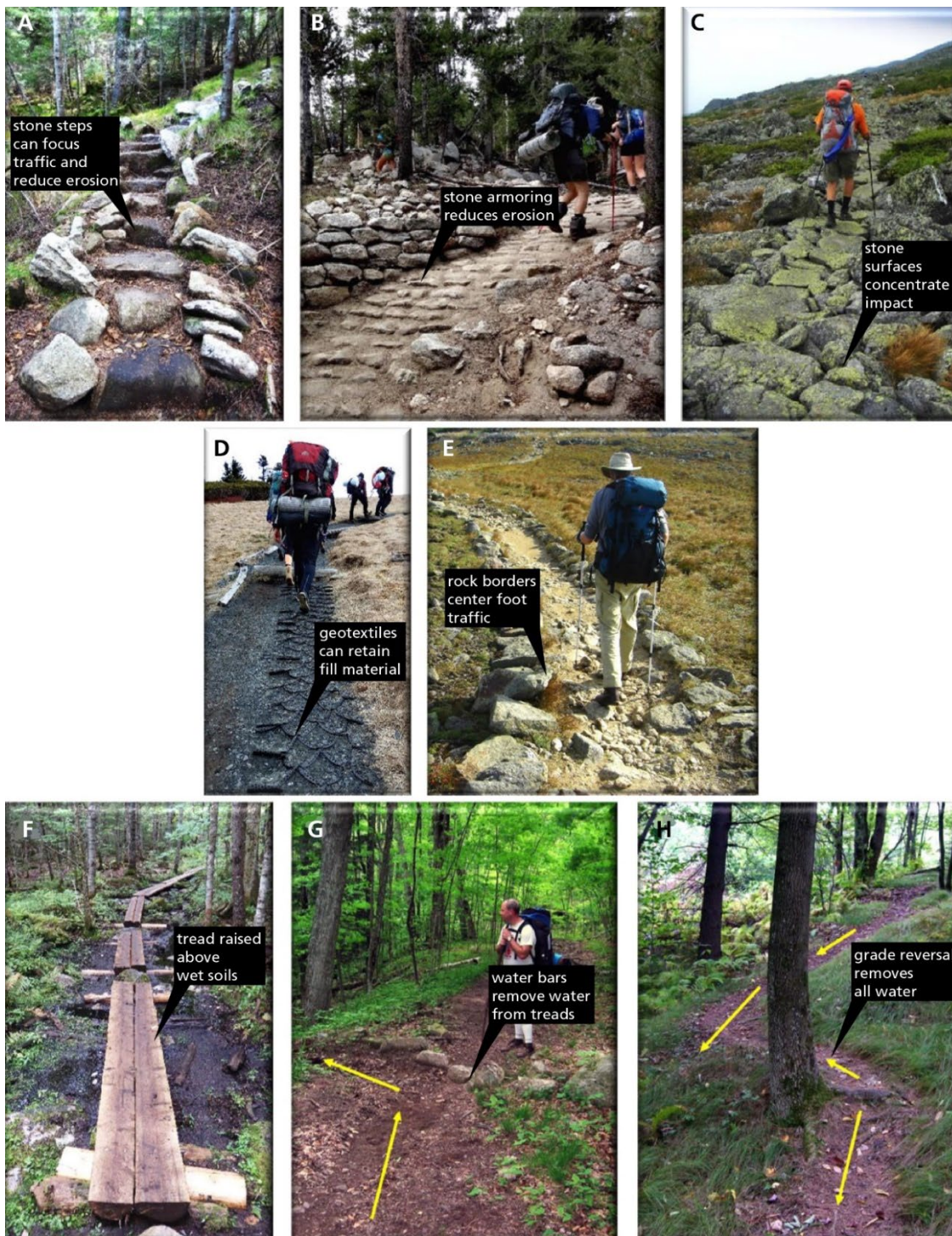


Figure 18. Photographs of sustainable trail protection techniques. A) Stone steps help visitors scale steep slopes without widening the trail or eroding. B) Stone armoring and C) Stone surfaces create durable trails with traction and reduce impact to adjacent areas. D) Geotextile products can reduce erosion; however, if the fill material is displaced, the geotextile can degrade because of exposure to UV radiation and foot traffic. E) Rock borders and screen walls keep visitors on the main path, reducing widening and social trail development. F) Boardwalks and bog bridges remove foot traffic from perennially or ephemerally wet soils. G) Rock or wood bars remove water from the trail but require annual maintenance. H) Strategic reversals of the trail grade on a slope remove all water with little maintenance. Graphic compiled from figures 29, 30, and 31 in Marion et al. (2020). Annotation by Trista L. Thornberry-Ehrlich (Colorado State University).

APPA managers have already targeted certain areas for protection. Due to high visitation, illegal camping (outside the 231 official campsites), open fires, parking shortages (APPA has 482 parking areas), vandalism, littering, and/or friction with private landholders, many locations have limited-use hours, public use limits, closures, and/or area designations for specific uses (Clark and Speers 2024; Marion Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025):

- Triple Crown region, VA 624 (Newport Road) to VA 652 (Mountain Pass Road)
- McAfee Knob, VA, special use closure
- McAfee Knob, VA, climbing closure
- Keys Gap (VA Route 9), area closed to camping
- White Rocks, PA
- Scott Farm, PA
- Lehigh Gap, PA
- Nuclear Lake, NY
- Bull's Bridge, CT/NY West
- Bull's Bridge, CT East
- River Road, CT (north of St. Johns Ledges parking area)
- Franconia Ridge, NH
- Katahdin, Baxter State Park, ME

Disturbed Lands and Abandoned Mineral Lands

Disturbed lands are those scenic trail lands where the natural conditions and processes have been directly impacted by human activities such as development, agricultural activities (such as farming, grazing, timber harvest, and abandoned irrigation ditches), and overuse or inappropriate use. Disturbed lands require restoration, which return a site, watershed, or landscape to some previous condition, commonly some desirable historic baseline. Usually, lands disturbed by natural phenomena such as landslides, earthquakes, floods, and fires are not considered for restoration unless influenced by human activities.

Abandoned Mineral Lands (AML) present various resource management issues for visitor and staff safety; air, water, and soil quality; as well as providing habitat for animals. Resource management of AML features requires accurate inventory and reporting. However, when appropriate for resource management and visitor safety, features can also present opportunities for interpretation as cultural resources. All AML features should be recorded in the NPS AML database (the NPS GRD can provide assistance). An accurate inventory can identify human safety hazards and facilitate the reclamation and restoration of features. According to the NPS AML database and Burghardt et al. (2014), APPA contains five inventoried AML features, three of which require mitigation. Geologists with the NPS GRD provided a site visit, survey, and advice when APPA was considering the addition of a tract of land in Virginia that included the Hightop Copper Mine (Burghardt 2005). The project evaluated the condition of the mine, determined habitat potential, and provided detailed maps (Figure 19). Such services should be considered for all AML features within or

A Mining access road bed

B Twin mine adits

C Passable adit with bat habitat

D Unvegetated mine pit

E Spoil pile next to the adits

F Map of the adits and surrounding area. The map includes the following information:

- APPALACHIAN NATIONAL SCENIC TRAIL TRACT 437-01 — NIGHTOP MINE**
- TWIN ADITS**
- SURVEY DATE: 09/22/05**
- JOHN BUGHARST, NPS - GWD**
- UTM ZONE 17**
- 712653E**
- 4248554N**
- MAGNETIC DECL. 9°W**
- Scale bar: 0, 10, 20 FEET**
- 40°N CLIFF LINE**
- RECOMMEND BAT GATE 9.5'W x 7' h**
- PZ @ PORTAL + 13'**
- 500' R 11'W x 7' h ANG.**
- PORTAL + 73'**
- STOPPED AREA 20-25' h**
- STOPPED AREA 15' h**
- RECOMMEND BAT GATE 7.5'W x 8' h**
- FOETESICUS FOSCUS (BIG BROWN BAT) ROOSTING 52' IN FROM PORTAL, 1.5' ABOVE FLOOR.**
- (ALL CORRIDORS ARE ESSENTIALLY FLAT - WATER Pools SLIGHTLY AT NORTH PORTAL.)**

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Some rocks, when exposed at the surface through natural or anthropogenic means, react with water to produce acid. Acid-producing rocks probably occur along the trail in at least North Carolina, Tennessee, and Virginia; further investigation is required to pinpoint locations (Bart Cattanaach, North Carolina Geological Survey, geologist, scoping meeting comment, 2 May 2016; Port 2016). Mining or other land-disturbing activities can exacerbate this acid production. Burns et al. (2019) note that acidification along the trail is muted in areas with soils developed in glacial sediments in the northern reaches of APPA, whereas soils developed from weathered, older bedrock in the southern portion of APPA had increased acidity (decreased pH). In Pennsylvania, anthracite coal mining, part of the state's history, contributes to acid mine drainage (outflow of acidic water from metal and coal mines) along the Appalachian Trail (Gary Fleegeer, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016; Port 2016). The Palmerton Zinc Superfund site, just adjacent to APPA at Lehigh Gap and Blue Mountain, is devoid of vegetation due to toxic smelting that released zinc, lead, cadmium, and sulfur dioxide plumes; remediation at the site is ongoing as part of NRSS-funded project work (Figure 20; see "Prior NRSS-Supported Work"; National Park Service 2010).

South of the scenic trail in Pennsylvania, the slate belt (a geographic region named for widespread slate quarrying) is the site of slate scrap dumps and abandoned quarries. Near Rausch Gap, the trail passes a long-abandoned strip mine situated on the Mammoth coal seam (Gary Fleegeer, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016; Port 2016). The trail skirts Fuller Lake—an abandoned 27-m (90-ft) deep iron ore pit mine—in Pine Grove Furnace State Park (Gary Fleegeer, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016; Port 2016). Michaux State Forest, situated on the northern terminus of the Blue Ridge province, has a long history of iron ore production. Hikers traversing this 64 km (40 mi) section of the South Mountain cross over many charcoal hearths (flat, cleared areas where wood was burned slowly to produce charcoal for industrial use) and pass many excavation pits (Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025).



Figure 20. Photograph of the unstable, unvegetated slope at the scenic trail approaching Lehigh Gap. Vegetation in the area was degraded due to toxic zinc smelting at the Palmerton Zinc Pile Superfund site. Remediation and slope stabilization are ongoing. Photograph by Gary Fleege (Pennsylvania Geological Survey) presented as figure 10 in Port (2017).

Northwest Connecticut was the foremost iron producer in the nation for over 200 years. Iron furnace (furnace in which iron is smelted or worked in any way) ruins are located at Great Falls and Bull's Bridge sites, and charcoal pits (low-lying places where wood was fired to make charcoal for the furnaces) are along the trail from the base of Bear Mountain to the Riga campsite (James Bogart and Margaret Thomas, Connecticut Geological Survey, intern and state geologist, respectively, scoping meeting presentation, 6 May 2016; Port 2016). Marble, granite, pegmatite, mica, siderite, and gravel mines and quarries dot the landscape across western Connecticut. Most, but not all, of these mines and quarries in Connecticut are inactive (Altamura 1987). The hazard potential of these former iron and quarry operations in Connecticut in relation to APPA is not yet identified (Port 2016).

In New Hampshire, the Appalachian Trail passes an old lead, copper, and zinc mine that was abandoned in 1915: the Ore Hill mine in Grafton County (Rick Chormann, New Hampshire Geological Survey, state geologist, scoping meeting presentation, 6 May 2016; Port 2016). The owners left several piles of exposed tailings and waste rock on site, through which draining water became contaminated and impacted water

quality and aquatic species downstream in Ore Hill Brook (Rick Chormann, New Hampshire Geological Survey, state geologist, scoping meeting presentation, 6 May 2016; Port 2016). After decades of attempted remediation, the US Forest Service, in cooperation with the NPS, excavated approximately 27,500 m³ (36,000 yd³) of tailings and waste rock, treated them with solid Enviroblend™ mix (a phosphate-based treatment), and then placed the material in an unlined and soil-capped on-site repository area. Monitoring of the site is indefinite (Interstate Technology Regulatory Council 2010).

Many abandoned mines exist in New York, and some are located near APPA. The iron ore Phillips mine in Putnam County may be an issue along the scenic trail because of acid mine drainage, the potential for radioactive uraninite, and visitor exposure to the still open shafts (Bill Kelly, New York Geological Survey, state geologist, scoping meeting presentation, 6 May 2016; Port 2016; Betts 2024). More data inventorying is needed to determine the severity of abandoned mine impacts along the scenic trail.

Most state surveys or other organizations host some kind of mines and minerals database:

- Maine: <https://www.maine.gov/dacf/mgs/explore/mining/index.shtml>
- New Hampshire: <https://thediggings.com/usa/new-hampshire>
- Vermont: <https://dec.vermont.gov/geological-survey/resources-energy/minres>
- Massachusetts: <https://mgs.geo.umass.edu/resources/mineral-resources>
- Connecticut: <https://portal.ct.gov/deep/geology/connecticut-bedrock-mining-sites-database-2022>
- New York: <https://gisservices.dec.ny.gov/gis/maw/>
- New Jersey: https://njogis-newjersey.opendata.arcgis.com/datasets/db9be6bd7db64b2f8be544c26779620d_3/about
- Pennsylvania: <https://www.minemaps.psu.edu/>
- Maryland: <https://msa.maryland.gov/msa/mdmanual/01glance/html/mines.html>
- West Virginia: <https://www.wvgs.wvnet.edu/www/geology/geology.htm#env-haz>
- Virginia: <https://energy.virginia.gov/geology/MineralResources.shtml>
- North Carolina: <https://data-ncdenr.opendata.arcgis.com/maps/ncdenr::north-carolina-mining-permits-1/about>
- Tennessee: <https://www.tn.gov/environment/mineral-geologic/amlp.html>
- Georgia: https://quarriesandbeyond.org/states/ga/ga-photos_1ad.html

External Energy Development and Telecommunication Towers

Energy development (e.g., coal, wind, solar, natural gas) adjacent to or within the viewshed of APPA may impact the quality of resources along the trail. The narrow, linear nature of the trail corridor, combined with its incredible length along the crest of the Appalachian Mountains, leaves it susceptible to an array of development threats (National Parks Conservation Association 2010). Companies are proposing renewable energy operations, specifically wind turbines, in Maine and Vermont (Port 2016), and building large grid solar operations that are becoming very common in the viewshed, particularly in the Mid-Atlantic (Marian

Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025). Wind turbine designs are getting progressively taller and more efficient, increasing their potential to visibly impact the trail and, with their construction and maintenance, degrade fragile high-elevation terrain and other resources (National Parks Conservation Association 2010; Port 2016). APPA and GRD staff work together to address these issues (Port 2016). Decisions affecting the placement and design of anything crossing the trail (e.g., roads, electric-transmission corridors, gas pipelines, wireless communications facilities, wind-energy projects, etc.) should reflect the special and fragile characteristics of the scenic trail (National Parks Conservation Association 2010).

Potential mining operations near the trail include crushed stone operations in North Carolina; prospecting for uranium in granite, as well as iron and manganese in Tennessee; metal deposits associated with a pluton (igneous intrusion that cooled slowly under Earth's surface) in Maine; and glacial till gravel pits in the glaciated northern third of the scenic trail (Port 2016). APPA crosses areas in New York, Pennsylvania, Maryland, West Virginia, Virginia, and Tennessee, overlying or near the Marcellus Shale—an organic-rich unit that contains natural gas. Improvements in directional drilling and hydraulic fracturing, commonly called “fracking,” have renewed industry interest in many areas of the US, including the northeast United States, where the organic-rich oil and gas formations (e.g., Marcellus Shale and the Cambrian Rogersville Shale) are located (Figure 21).



Figure 21. Map of National Park System units and approximate extent of Marcellus Shale (orange area). The dashed line indicates the extent of other shales with similar ages. NPS units atop or near the Marcellus Shale are labeled. Green text and lines denote the trace of APPA. Green dots and areas denote other NPS units. Map by Trista Thornberry-Ehrlich (Colorado State University) with information from Moss (2009) and Soeder and Kappel (2009). NPS base map available at <https://www.nps.gov/subjects/gisandmapping/nps-maps.htm>.

As detailed by Moss (2009), many resource management concerns are associated with oil and gas operations. New gas or oil well drilling may cause a decline in surface water quality due to erosion from access roads, drill sites, and pipeline corridors; contamination of surface water and groundwater by drilling muds, fuels, brines, wastes, and other pollutants; deep zone salt water intrusion into shallow freshwater zones due to inadequately constructed, maintained, or plugged wells; and increased soil erosion and soil instability due to clearing, grading, and cut-and-fill activities associated with roads, pipelines, and drilling site preparation. Oil and gas development impacts may also include damage to archeological, cultural, and geologic resources due to blasting for road or pad construction, seismic exploration, construction, drilling, and production operations. Resource managers are also concerned about oil- and gas-related waste dumping and underground injection wells around NPS units. In dealing with external oil and gas exploration and

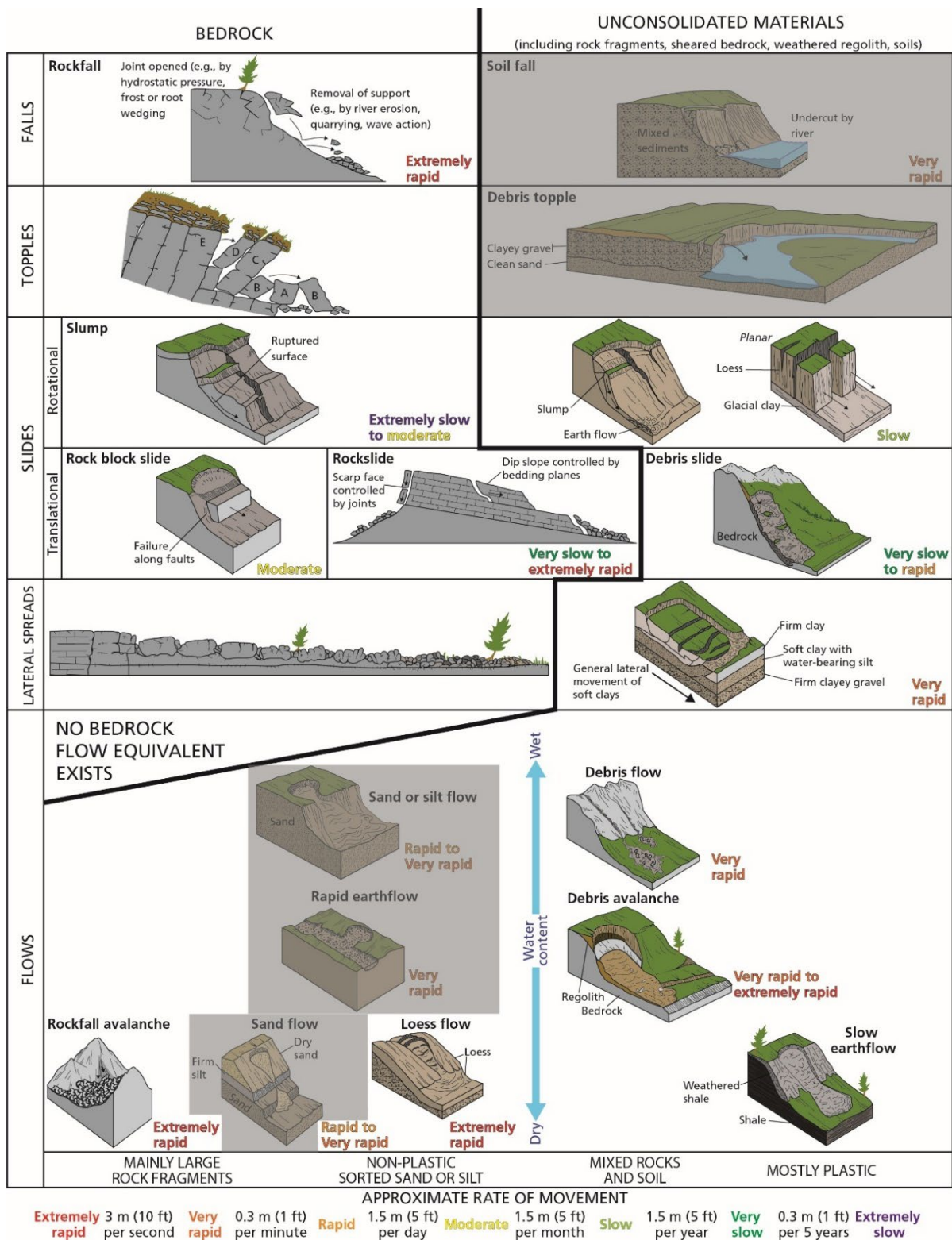
development at APPA, the best option is to work directly with the state oil and gas permitting agencies (Moss 2009):

- New York: Environmental protection oil and gas <https://dec.ny.gov/environmental-protection/oil-gas>
- Pennsylvania: Environmental protection <https://www.dep.pa.gov/Pages/default.aspx>
- Maryland: Oil and gas regulations <https://onestop.md.gov/licenses/oil-gas-exploration-production-5d1540bd54f24d03e99986bb>
- West Virginia: Office of Oil and Gas <https://dep.wv.gov/oil-and-gas/Pages/default.aspx>
- Virginia: Gas and Oil <https://energy.virginia.gov/gas-oil/gasoil.shtml>

Increased demand for wireless communications services (i.e., telecommunications infrastructure) has caused additional resource management problems for the scenic trail. Wireless technology industries have targeted peaks and high mountain ridge lines for telecommunication towers, thus potentially impacting the trail and scenic views (Vinch 1999). A voluntary agreement was reached between the ATC and the telecommunications companies that calls for early notification of wireless communications facilities proposed within 1.6 km (1 mi) of any national scenic trail, including APPA (National Parks Conservation Association 2010). In some cases, the “uniqueness” of APPA or the presence of important areas or features (e.g., defined geologic stratotypes) may provide justification for denying potentially harmful adjacent projects (conference call participants, conference call, 3 April 2023). In other cases, successful strategies for reducing impacts to the scenic trail have included co-designing sites in a way that protects the trail experience, strategic placement of towers, limits tower height, utilizes/upgrades existing structures, and designs strategies that encourage structures to minimize visual disruptions or even mimic natural features (i.e., trees; National Parks Conservation Association 2010).

Slope Movements

Slope movements are the downslope transfer of material (e.g., soil, regolith, and/or rock; Figure 22) and are possible on any slope. Slope movements can occur rapidly (e.g., debris flows or rockfalls) or over long periods of time (e.g., slope creep). The magnitude of slope failures depends on slope, aspect, soil type, and geology. Frost and plant-root wedging, fluvial undercutting, erosion, and swelling clays are the primary causes of slope instability in the scenic trail area.



Potential for slope movement exists on most APPA slopes, particularly where the rivers cut steeply through the rocks. Trail construction and maintenance have the potential to trigger slope movements. Slopes with bedding planes (surfaces separating layers of rock) that dip down and toward the trail should be avoided by visitors or any future trail development. Debris flows can be expected in some areas after a long period of heavy rain that saturates the ground on the steep slopes. Debris flows are common in the central part of APPA, particularly on the south slopes of Mount Le Conte, along Anakeesta Ridge, in the vicinity of Charlies Bunion, and east of Mount Mingus (Schultz and Seal 1997). In Pennsylvania, large rockfalls occurred throughout the 1990s and early 2000s at Lehigh Gap near the Palmerton Zinc Pile Superfund site (Jack Epstein, US Geological Survey, emeritus geologist, scoping meeting comment, 4 May 2016; Port 2016); here, the slope was destabilized by historic smelter emissions (see “Abandoned Mineral Lands and Disturbed Lands”) and has since been stabilized (National Park Service 2010). In Massachusetts, landslide scars on Mount Greylock are visible from the east (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting comment, 6 May 2016; Port 2016). In New Hampshire, rockslides were documented in King Ravine, and the Carter Dome quadrangle geologic map has one landslide deposit mapped right on the Appalachian Trail (Chew 1988). Also in New Hampshire, the Willey slide of 1827 killed nine people and severely restricted travel in and out of Crawford Notch (Rick Chormann, New Hampshire Geological Survey, state geologist, scoping meeting presentation, 6 May 2016; Port 2016).

Seismic Activity

Earthquakes occur when there is sudden movement along a fault, releasing accumulated energy in the form of land vibrations and shakes (Braile 2009). APPA is not located in a particularly active seismic zone (Figure 23); however, earthquakes do happen. The Southern Appalachian seismic zone, which runs northeastward from Alabama to West Virginia, activates periodically every 40–60 years (Kenneth Taylor, North Carolina Geological Survey, state geologist, scoping meeting comment, 2 May 2016; Port 2016). It is one of the most active seismic zones in eastern North America; more than 44 detectable (felt by humans) earthquakes have occurred since 1982 (Chapman et al. 2002). Intra-plate seismic zones such as the Southern Appalachian seismic zone are far from plate boundaries, which are the typical locations of earthquakes. The focal depths (where the fault slip occurred) of most earthquakes in the seismic zone range from 5 to 22 km (3 to 14 mi) beneath large faults.

Much of the eastern US was considered seismically “quiet”. However, as indicated by its occurrence in the US Geological Survey (USGS) Quaternary fault database (<https://www.usgs.gov/programs/earthquake-hazards/faults>), an area between Richmond and Charlottesville has experienced the most recent seismic activity—called the Central Virginia seismic zone. In 2003, a 4.8 magnitude earthquake occurred in the area. In August 2011, shaking from a magnitude 5.8 earthquake that occurred in central Virginia, about 50 km (31 mi) east of APPA, was felt along the eastern seaboard from Canada to Florida and as far west as Denver, Colorado (Horton et al. 2015). This event caused no documented damage in APPA, but a USGS team documented landslides along the Blue Ridge Parkway (Matt Heller, Virginia Division of Geology and Mineral Resources, geologist supervisor, scoping meeting comment, 4 May 2016; Port 2016). In addition, the Federal Emergency Management Agency (FEMA) placed the Lancaster seismic zone in south-central Pennsylvania in the moderate-risk category. Adjacent to this zone was an earthquake swarm that was most active from 2008 to 2009 near Dillsburg, Pennsylvania, just west of the Lancaster seismic zone (Marian Orlousky, Appalachian Trail Conservancy, written communication, 28 April 2025). The relationship between these two earthquake areas is not yet well understood. Earthquakes occur in New York and Vermont

occasionally, likely related to Mesozoic-age faults along the Hudson River (Randy Orndorff, US Geological Survey, Director, Eastern Geology and Paleoclimate Center, scoping meeting comment, 4 May 2016; Port 2016). The Weston Observatory at Boston College monitors seismic activity in New England, where small earthquakes happen but almost never cause damage or are felt by people.

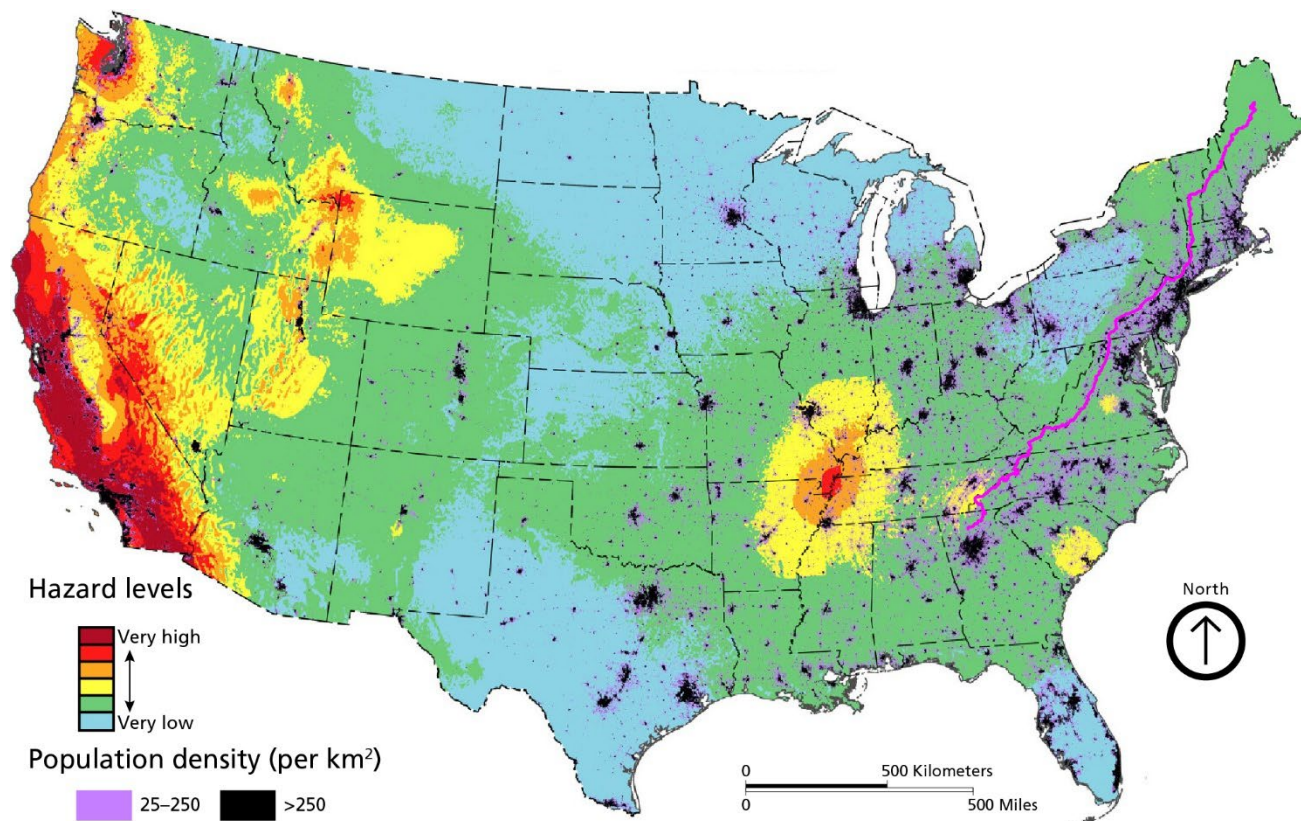


Figure 23. National seismic hazard map. The map shows the chance of any level of damaging earthquake shaking in 100 years from the 2023 50-State National Seismic Hazard Model. The map displays population density superimposed on a map of seismic hazard levels. Locally, the hazard may be greater than shown because site geology may amplify ground motions. APPA is the bright purple trace from Maine southwest to Georgia. Map by Petersen et al. (2024, figure 3), available at <https://doi.org/10.1177/87552930231215428>, modified by Trista L. Thornberry-Ehrlich (Colorado State University).

As proven by the 2011 Virginia earthquake, major damage from an earthquake can occur in an area previously considered to be relatively inactive. Far from a tectonic plate boundary, it was possibly caused by reactivation of ancient faults as a result of a build-up of stress within Earth's crust. The rigidity of the rocks in the area transmitted the earthquake energy far from the actual epicenter (US Geological Survey 2019). In addition to the ground shaking associated with earthquakes, landslides, damage to buildings and structures, and ground- and surface water disturbances can occur. Though the probability of a destructive seismic event at APPA is low, resource management should be aware of the potential. Currently, no earthquake plans are in place for APPA.

Braile (2009) describes the following methods and vital signs for understanding earthquakes and monitoring seismic activity: (1) monitoring earthquakes, (2) analysis and statistics of earthquake activity, (3) analysis of historical and prehistoric earthquake activity, (4) earthquake risk estimation, (5) geodetic monitoring and

ground deformation, and (6) geomorphic and geologic indications of active tectonics. The GRD Seismic Monitoring website (<https://go.nps.gov/geomonitoring>) and the USGS Earthquake Hazards website (<http://earthquake.usgs.gov/>) provide more information.

Legislatively Required Geologic Inventories

Caves and Karst

Karst is a landscape that forms through the dissolution of soluble rocks, commonly carbonate rocks such as limestone or dolomite (Toomey 2009). Caves are naturally occurring underground voids and include solutional caves (commonly associated with karst), lava tubes (tunnel-like caves in a lava flow after lava has stopped flowing), sea caves (clefs or cavities in a sea cliff), talus caves (voids among collapsed boulders), regolith caves (formed by soil piping), and glacier caves (ice-walled caves) (Toomey 2009).

All cave features are nonrenewable resources. The Federal Cave Resources Protection Act of 1988 stipulates that all “significant caves” in NPS areas will be identified, and regulation or restriction of use will be employed as needed to protect cave resources, and significant caves will be included in land management planning. The act also imposes penalties for causing harm to a cave or cave resources and exempts APPA managers from releasing specific location information for significant caves in response to a Freedom of Information Act request.

Caves provide habitat for wildlife such as burrowing animals, foxes, and bats. Some species are federally listed as threatened or endangered. For example, boulder fields in APPA, commonly found as slope deposits or talus (e.g., Devils Potato Patch in Pennsylvania), create small caves that are known to be inhabited by small-footed bats, an endangered species (Wilshusen 1983; Brian Witcher, NPS Appalachian Highlands Network, program manager, scoping meeting comment, 2 May 2016). Other talus caves inhabited by bats occur in the Mahoosuc Range on the border between Maine and New Hampshire (Port 2016). Combining slope data and geology may help predict the location of such habitats. The presence of threatened and endangered species’ habitats (e.g., northern long-eared bats in features such as mines, caves, or cavernous rock outcroppings) may provide justification for denying potentially harmful adjacent development projects (conference call participants, conference call, 3 April 2023).

A cave and karst inventory has not been completed for APPA (Port 2016). However, caves are known to exist based on geologic units mapped along the scenic trail. According to digital karst maps of the US, soluble carbonate rocks and minerals underlie portions of the scenic trail with potential for karst in most of the 14 states; however, in New England, these are largely buried by glacial deposits (Weary and Doctor 2014). Caves are documented in the Shady Valley Dolomite of North Carolina and Tennessee, though they are not abundant and not known directly on the trail. In Pennsylvania, karst features form where the trail crosses the Cumberland Plateau and in the Great Valley. Ice caves (sheltered low-lying crevices where ice can persist into summer) are located in Stockbridge, Massachusetts (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting comment, 6 May 2016). Even beyond NPS boundaries, knowing the existence of any karst (e.g., sinkholes and caves) is important in that it might affect the stability of a project adjacent to or crossing the scenic trail (conference call participants, conference call, 3 April 2023). In Jefferson County, West Virginia, 24 sinkholes were filled improperly on an APPA-adjacent property. Educating adjacent landowners about the risks of karst is an important first step in avoiding stability issues

(conference call participants, conference call, 3 April 2023). Land et al. (2013) provided an evaluation of cave and karst programs and issues in national parks, along with suggestions.

Geothermal Features and Springs

Geothermal refers to heat or energy produced in Earth's interior. Geothermal features may include geysers, fumaroles, hot springs, and bubbling mud pits. The Geothermal Steam Act of 1970, amended in 1988, prohibits geothermal leasing in parks and authorizes the Secretary of the Interior to mitigate or not issue geothermal leases outside parks that would have a significant adverse impact on significant thermal features in the 16 park units listed in the act. The scenic trail is not included on the list of 16 parks that are designated under the act as having significant thermal features; however, several geothermal features are associated with the scenic trail and remain to be inventoried. Heasler et al. (2009) present monitoring ideas for geothermal features and springs.

A manganese-rich spring occurs in the Shady Valley Dolomite in North Carolina. The spring is 41°C (105°F)—just warm enough to be considered a geothermal feature. A geothermal spring is defined as any spring with an average temperature that is 8.3 °C (14.9 °F) greater than the mean ground temperature at the same location (Elbabary et al. 2018). Rainwater infiltrates the subsurface along fractures where it is heated as a result of the natural geothermal gradient (rate of increase in temperature with increasing depth in Earth's interior) and therefore returns to the surface warm (Kenneth Taylor, North Carolina Geological Survey, state geologist, scoping meeting comment, 2 May 2016). In Massachusetts, a 22°C (72°F) “hot” spring occurs, which may be considered a historical resource related to geology (geoheritage) on the scenic trail (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting comment, 6 May 2016). These are meteoric (derived from the atmosphere) waters that infiltrate the subsurface and are heated by the natural geothermal gradient before returning relatively quickly to the surface.

Not all springs at APPA are geothermal. Boiling Springs is a spring in Pennsylvania; however, it is not a geothermal spring. The water is not even warm. It gets its name from the boiling appearance of water that is forced to the surface by flow against a barrier formed by a Jurassic-age (201.3 million–145.0 million years ago) diabase dike (a tabular type of igneous intrusion that cuts across the layering of the intruded rocks; Gary Fleeger, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016). Such springs are invaluable water sources along the scenic trail, and most shelters are located near a spring or other water source (Burge 2024). Human use and climate change-driven drought threaten these features. Double Spring and springs at Molly's Ridge and Russell Field in Tennessee experienced low to no flow in 2024 (Grainger 2024).

Paleontological Resources Inventory and Protection

Paleontological resources (fossils) are any evidence of life preserved in a geologic context (Santucci et al. 2009). All paleontological resources are nonrenewable and subject to science-informed inventory, monitoring, protection, and interpretation as outlined by the 2009 Paleontological Resources Preservation Act (PRPA). Fossils in NPS areas occur in rocks or unconsolidated deposits, museum collections, and cultural contexts such as building stones or archeological resources. As of October 2023, 286 parks have documented paleontological resources in at least one of these contexts, including APPA (Justin Tweet, paleontologist, NPS GRD, written communication, 12 October 2023). The presence of fossil resources may

provide justification for denying potentially impactful adjacent development projects per the PRPA (conference call participants, conference call, 3 April 2023).

Although there is not an official record or inventory of fossils along the scenic trail, there is a strong possibility of finding fossils (Table 3), especially from the early and middle Paleozoic Era (Vincent Santucci, paleontologist, NPS Geologic Resource Division, scoping meeting communication, 4 May 2016; Port 2016). Fossils known from the Chilhowee Group (Neoproterozoic to Lower Cambrian) are trace fossils (*Skolithos* worm burrows), as well as the occasional trilobite (Santucci et al. 2008; Merschat et al. 2008; Carter et al. 2015). *Skolithos* trace fossils are possible in at least Pennsylvania, Virginia, North Carolina, and Tennessee (Port 2016). The Valley and Ridge province, across which the trail passes in New Jersey, Pennsylvania, and Virginia, has myriad documented fossils. Plant fossils have been collected from DeHart Reservoir in Pennsylvania (Vincent Santucci, paleontologist, NPS Geologic Resource Division, scoping meeting communication, 4 May 2016). Fossil fish scales occur where the trail crosses the Delaware River in Pennsylvania (Jack Epstein, emeritus geologist, US Geological Survey, scoping meeting communication, 4 May 2016). Conodonts (eel-like jawless vertebrates) and/or graptolites (filter-feeding colonial animals) may occur in rocks along the trail in Vermont (Port 2016). There is potential for fossils in archeological contexts and unconsolidated (surficial) deposits. Fossiliferous chert deposits in the Allentown Dolomite were used for stone tools by Indigenous peoples, and more recently, fossiliferous Keyser Formation rocks have been used for building materials, such as along the Chesapeake and Ohio Canal (Tweet et al. 2010).

Table 3. Fossil potential by state.

Table3 lists the fossils known from rocks that intersect the scenic trail after literature review by Tweet et al. (2010). List was simplified to increase readability. This does not replace necessary investigations in the field to confirm or deny the presence of these fossils.

State from North to South	Potential Fossils	Rock Formation Names
Maine	Crinoids, corals, brachiopods, bivalves, gastropods, mollusks, vertebrates, pollen, spores, microfossils (diatoms), insect larvae, plant fragments, crustaceans, midges, fish, ostracodes, and trace fossils	Silurian-age The Forks Formation Devonian-age Littleton Formation Pleistocene-age surficial deposits
New Hampshire	Corals, brachiopods, gastropods, trilobites, echinoderms, colonial sponges, bryozoans, bivalves, conodonts, vertebrates, pollen, spores, microfossils (diatoms), insect larvae, plant fragments, crustaceans, midges, fish, ostracodes, and trace fossils	Silurian-age Clough Quartzite (or Formation) and Fitch Formation Devonian-age Littleton Formation Pleistocene-age surficial deposits
Vermont	Giant fungus, corals, trilobites, crinoids, microfossils, plant fragments, echinoderms, vertebrates, pollen, spores, insect larvae, crustaceans, midges, fish, bivalves, gastropods, ostracodes, and trace fossils	Devonian-age Gile Mountain Formation and Waits River Formation Pleistocene-age surficial deposits

State from North to South	Potential Fossils	Rock Formation Names
Massachusetts	Stromatolites (microbial mats), corals, graptolites, conodonts, vertebrates, pollen, spores, microfossils (diatoms), insect larvae, plant fragments, crustaceans, midges, fish, bivalves, gastropods, ostracodes, and trace fossils	Cambrian-age Stockbridge Formation Ordovician-age Walloomsac Formation Pleistocene-age surficial deposits
Connecticut	Trace fossils, stromatolites, corals, vertebrates, pollen, spores, microfossils (diatoms), insect larvae, plant fragments, crustaceans, midges, fish, bivalves, gastropods, and ostracodes	Cambrian-age Manhattan Schist and Stockbridge Formation Ordovician-age Walloomsac Formation Pleistocene-age surficial deposits
New York	Stromatolites, trace fossils, corals, graptolites, conodonts, brachiopods, trilobites, scale trees (<i>Lepidodendron</i>), plant fragments, sponges, bryozoans, crustaceans, crinoids, worm-like invertebrates, vertebrates, pollen, spores, microfossils (diatoms), insect larvae, midges, fish, bivalves, gastropods, and ostracodes	Cambrian-age Briarcliff Dolostone, Manhattan Formation, Pine Plains Formation, Poughquag Quartzite, Stissing Formation Cambrian–Ordovician-age Stockbridge Formation Ordovician-age Austin Glen Formation and Walloomsac Formation Devonian-age Hamilton Group Pleistocene-age surficial deposits
New Jersey	Stromatolites, foraminifera, brachiopods, trilobites, spores, fungi, seaweed, corals, bryozoans, bivalves, gastropods, horseshoe crabs, sea scorpions, crinoids, jawless fish, trace fossils (including <i>Skolithos</i>), sponges, sea stars, and graptolites.	Cambrian-age Leithsville Formation Cambrian–Ordovician-age Allentown Dolomite Ordovician-age High Point and Ramseyburg members of the Martinsburg Formation Silurian-age Bloomsburg Red Beds and Shawangunk Formation
Pennsylvania	Ostracodes, trilobites, trace fossils (including <i>Skolithos</i>), microbial reefs, conodonts, mollusks, brachiopods, algal mats, corals, plants, bryozoans, echinoderms, sponges, graptolites, cephalopods, fecal pellets, worm jaws, phytoplankton, fish, crustaceans, arthropods, sharks, early tetrapods, amphibians, foraminifera, mosses, and rare fish teeth	Cambrian-age Antietam Formation, Elbrook Formation, Harpers Formation, Shadygrove Formation, Tomstown Formation, Waynesboro Formation, and Zullinger Formation Ordovician-age Bald Eagle Formation, Chambersburg Formation, Juniata Formation, Martinsburg Formation, Pinesburg Station Formation, Rockdale Run Formation, Saint Paul Group, and Stonehenge Formation Silurian-age Bloomsburg Formation, Clinton Group, Mifflintown Formation, Shawangunk Formation, Tuscarora Formation, and Wills Creek Formation Silurian–Devonian-age Keyser and Tonoloway formations (grouped), and Onondaga, Ridgeley, Rondout, Decker, Bossardville, and Poxono Island Limestone formations (grouped) Devonian-age Catskill Formation, Hamilton Group, undivided Onondaga Formation and Old Port Formation, and Trimmers Rock Formation Devonian–Mississippian-age Spechty Kopf Formation Mississippian-age Mauch Chunk Formation and Pocono Formation Pennsylvanian-age Llewellyn Formation and Pottsville Formation
Maryland and West Virginia	Trace fossils (including <i>Skolithos</i>), bivalves, mollusks, plant fragments	Cambrian-age Harpers Formation Ordovician-age Juniata Formation and Oswego Formation

State from North to South	Potential Fossils	Rock Formation Names
Virginia	Brachiopods, ostracodes, trilobites, trace fossils (including <i>Skolithos</i>), stromatolites, foraminifera, sponges, brachiopods, mollusks, pellets, microbial reefs, conodonts, echinoderms, graptolites, cephalopods, bivalves, worms, arthropods, fish, tetrapods, plants, and corals	Cambrian-age Chilhowee Group (including the Erwin, Hampton, Shady, and Unicoi formations), Conococheague Formation, Elbrook Formation, Honaker Formation, Nolichucky Formation, Rome Formation, and Waynesboro Formation Cambrian-Ordovician-age Knox Group and undivided formations Ordovician-age Beekmantown Group, Eggleston Formation, Juniata Formation, Reedsville Formation, and Trenton Limestone; Silurian-age sedimentary rocks Devonian-age Brallier Formation, Chemung/Foreknobs Formation, Huntersville Chert, Millboro Shale, Needmore Formation, and Rocky Gap Sandstone Mississippian-age Maccrady Formation and Price Formation
Tennessee and North Carolina	Conodonts, algae, foraminifera, bryozoans, mollusks, ostracodes, trilobites, brachiopods, trace fossils (including <i>Skolithos</i>), patch reefs, stromatolites, other algal structures, sponges, early mollusks, and pellets	Precambrian-age Longarm Quartzite, Sandsuck Formation, Shields Formation, and Wilhite Formation Cambrian-age Erwin Formation, Hampton Formation, Rome Formation, Shady Dolomite, and Unicoi Formation
Georgia	None known	None known

Paleontological resources, in addition to their protected status, pose resource management issues when visitors attempt to collect them. For example, the Swatara Gap quarry in Pennsylvania was a popular (unofficial) collection site for Silurian-age trilobites. This location was permanently closed in 1990 when excavations made by potential collectors started to undermine an adjacent roadway (Gary Fleeger, geologist, Pennsylvania Geological Survey, scoping meeting communication, 4 May 2016; Port 2016). Resource managers should be aware of every fossil location within reasonable proximity to the trail.

NPS paleontology reports exist for all the Inventory and Monitoring Division networks through which the scenic trail passes: Northeast Temperate (Tweet et al. 2010), Eastern Rivers and Mountains (Koch and Santucci 2004), Mid-Atlantic (Kenworthy et al. 2006), National Capital Region (Kenworthy and Santucci 2004), Appalachian Highlands (Santucci et al. 2008), and Cumberland Piedmont (Hunt-Foster et al. 2009) Networks.

Summary of Geologic and Soil Hazards

The dynamic landscapes of many NPS units present a variety of natural hazards that threaten NPS facilities, staff, visitors, or resources. Many of these natural hazards are geologic in nature (e.g., volcanoes, earthquakes, and landslides). The Addressing Climate Change and Natural Hazards Handbook (National Park Service 2015b, 2023), grounded in NPS Policy Memorandum 15-01 (Jarvis 2015), provides a process and information to help teams and decision-makers identify, avoid, and mitigate risks associated with environmental change hazards and effects on proposed and planned facility investments. The handbook supports NPS planning guidance, policy directives, and executive orders and does not supersede existing mandated compliance processes and policies. Additional guidance for facility management, e.g., Climate-Smart Planning Principles and Recommended Practices, can support effective decision-making.

According to PM 15-01, managers should apply handbook guidance to identify options to manage natural hazards and climate change risks throughout all levels of facility planning and design. Project teams are

required to submit the completed Natural Hazards Checklist (Table 4) as part of Regional and Bureau Investment Review Board submissions. This information can also be used as part of the updated (2024) Automated Investment Review Board submittal process at the Investment Concept stage. Table 4 includes selected geologic and soil hazards listed in Part 1 of National Park Service (2023). The GSRI team has added additional hazards where appropriate for the scenic trail. If needed, Part 2 of the handbook could inform completion of the checklist, such as whether a hazard is applicable. Table 5 compiles the identified geologic and soil resource inventory needs for APPA. Contact the NPS GRD with any questions.

Table 4. Geologic and soil hazards checklist.

This summary table is a synthesis of existing GSRI-compiled map data and information, as well as published US Geological Survey and other government agency information. It is suitable for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or NEPA analysis. Ground-disturbing activities should neither be approved nor denied based on the information here. This table is modeled after the Natural Hazard Checklist (see National Park Service 2015a, 2023 and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the park.

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment (SHIRA hazard level)	Source(s) of Information (some links require DOI network access)
Sea Level Change	Inundation. Shoreline erosion. Destruction of infrastructure, e.g., through saturation. Water quality effects. Water supply diminished.	Potential hazard (susceptible)	NPS Coastal and Ocean Advisory & Support Team (COAST): Coastal and Ocean Advisory & Support Team NOAA Sea Level Rise Viewer https://coast.noaa.gov/slr/ NASA Interagency Sea Level Rise Scenario Tool https://sealevel.nasa.gov/task-force-scenario-tool DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com) .
Coastal Storm Surge	Wind driven rising water, e.g., hurricane, nor'easter.	Not applicable	NPS: Sea level rise and storm surge projection (Caffrey et al. 2018) NOAA SLOSH https://sealevel.nasa.gov/task-force-scenario-tool FEMA: National Flood Hazard Layer (NFHL) https://www.fema.gov/flood-maps/national-flood-hazard-layer DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Flash Flood	Sudden rising water, e.g., in a dry wash or canyon. Loss of life due to unexpected flooding. Destruction of infrastructure, e.g., through impact or saturation. Reduced or precluded visitation. Power failure due to areawide power outages.	Known hazard	DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com) Climate Toolbox: Climate Mapper (for Western US) https://marine.usgs.gov/coastalchangehazardsportal/ FEMA: NFHL https://www.fema.gov/flood-maps/national-flood-hazard-layer

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment (SHIRA hazard level)	Source(s) of Information (some links require DOI network access)
Riverine Flood	Inundation. Destruction of infrastructure, e.g., through impact or saturation. Stream channel migration and streambank erosion. Water quality effects. Water supply diminished. Reduced or precluded visitation.	Known hazard (extreme)	DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com) Lord et al. (2009) Climate Toolbox: Climate Mapper (for Western US) https://marine.usgs.gov/coastalchangehazardsportal/ FEMA: NFHL https://www.fema.gov/flood-maps/national-flood-hazard-layer
Lake and Reservoir Level Change	Water supply diminished. Flooding and erosion impacts to infrastructure. Diminished or lost recreational opportunities	Potential hazard	USGS: Lakes and reservoirs dataset https://waterdata.usgs.gov/nwis/current/?type=lake&group_key=state_cd US Bureau of Reclamation Water Operations https://www.usbr.gov/main/water/#GP
Precipitation: Increased Extreme Events	Surface erosion. Floods. Water damage to structures from driven rain Unstable saturated soils. Reduced or precluded visitation. Power failure due to areawide power outages.	Known hazard (Category 4 hurricane) 16% increase in precipitation by 2100 14% increase in average annual temperature by 2100 (data from NOAA's National Weather Service, National Hurricane Center)	NPS: National Park historical and projected climate change trends https://irma.nps.gov/DataStore/Reference/Profile/2266988 Human-caused climate change in United States national parks and solutions for the future (Gonzalez et al. 2018; Gonzalez 2020). NASA: DAYMet gridded climate data https://daymet.ornl.gov/ DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Precipitation: Altered Patterns and Changing Humidity	Local flooding. Mold growth. Wood decay. Drought. Fire. Water supply change.	Known hazard	NPS: National Park historical and projected climate change trends https://irma.nps.gov/DataStore/Reference/Profile/2266988 Human-caused climate change in United States national parks and solutions for the future (Gonzalez et al. 2018; Gonzalez 2020). NASA: DAYMet gridded climate data https://daymet.ornl.gov/

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment (SHIRA hazard level)	Source(s) of Information (some links require DOI network access)
Drought: Increased Frequency, Intensity, Magnitude, and Duration	Limited water supply for visitor, staff, and operational needs (e.g., potable and fire suppression water). Increased competition for available water and water supply impacts (e.g., water supply curtailment by state agencies). Crack/heave damage in drier soils. Increased vulnerability to wildfire.	Potential hazard (low)	Climate Toolbox: Climate Mapper (for Western US) https://marine.usgs.gov/coastalchangehazardsportal/ FEMA: Drought risk https://hazards.fema.gov/nri/drought Human-caused climate change in United States national parks and solutions for the future (Gonzalez et al. 2018; Gonzalez 2020). University of Nebraska-Lincoln: Drought Monitor https://droughtmonitor.unl.edu/ DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Permafrost Dynamics	Thawing. Surface collapse. Increased landslide susceptibility. Road/service disruption. Frost heave.	Not applicable	NASA: Permafrost dataset https://neo.gsfc.nasa.gov/view.php?datasetId=PermafrostNSIDC DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Landslide	Rockfall. Trail washing away. Visitation reduced or precluded. Mud or debris slides or flows onto or from under structures. Reduced or precluded visitation.	Known hazard (susceptible)	FHWA Unstable Slope Management Program (USMP): Geologic and Geotechnical Services FHWA (dot.gov) . FEMA: Landslide risk https://hazards.fema.gov/nri/landslide USGS: Emergency Assessment of Post-Fire Debris-Flow Hazards https://landslides.usgs.gov/hazards/postfire_debrisflow/ DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Earthquake	Falling objects. Collapsing structures. Inoperability of major building systems, e.g., power, sewer, water. Liquefaction - loss of strength to foundations silt deposition, standing water. Trigger to other hazards, e.g., landslides, debris flows.	Potential hazard (low)	USGS: Earthquake Probability Mapping https://www.usgs.gov/natural-hazards/earthquake-hazards/hazards FEMA: Earthquake risk https://hazards.fema.gov/nri/earthquake DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Tsunami	Coastal area inundation. Extreme coastal erosion.	Potential hazard (susceptible)	FEMA: Tsunami risk https://hazards.fema.gov/nri/tsunami DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment (SHIRA hazard level)	Source(s) of Information (some links require DOI network access)
Shrink/Swell Soils	Damage to structure. "Heaving" of ground beneath structure. Increased landslide susceptibility.	Potential hazard	NPS: Soil Resources Inventory USDA: Soils Survey https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/ (look for "linear extensibility" interpretation)
Volcanic Eruption	Lava flows. Fire. Tsunamis. Toxic gas releases. Ash and air quality degradation. Reduced or precluded visitation.	Not applicable	USGS: Volcano Hazards Program https://www.usgs.gov/volcano FEMA: Volcanic activity risk https://hazards.fema.gov/nri/volcanic-activity Red Cross: Map of Volcano Risk Areas https://maps.redcross.org/website/maps/arc_map_links.html DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Hydrothermal Activity (e.g., geysers)	Toxic gas release. Explosion. Boiling water. Steam. Surface collapse into void.	Potential hazard	NREL: Geothermal resource data, tools, and maps https://www.nrel.gov/gis/geothermal.html USGS: Geothermal resources https://www.usgs.gov/programs/energy-resources-program/science/science-topics/geothermal
Subsurface Hazards: Abandoned Mineral Lands Cave/Karst (sinkholes)	Surface collapse into void. Reduced or precluded visitation. Damage to overlying infrastructure. Contamination.	Known hazard (very high)	USGS: Karst in the United States: A Digital Map Compilation and Database (Weary and Doctor 2014) Evaluation of cave and karst programs and issues at US national parks (Land et al. 2013) DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Wildfire Probability	Removal of stabilizing vegetation. Increased erosion on slopes. Fire. Ash and air quality degradation. Reduced or precluded visitation.	Known hazard (high to very high)	Fire Management Plan: SWCA Environmental Consultants and Wildland Fire Associates (2014) FEMA National Risk Index: Wildfire https://hazards.fema.gov/nri/wildfire USGS: Fire Danger Forecast https://www.usgs.gov/fire-danger-forecast USFS Wildfire Risk: https://data-usfs.hub.arcgis.com/datasets/d93720867d1a4aa69f4a15dbf3ddeaea/explore National Interagency Wildland Fire Potential Outlook: https://www.nifc.gov/nicc-files/predictive/outlooks/ DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)

Hazard	Examples of Risk or Secondary Hazard	Best Professional Judgment (SHIRA hazard level)	Source(s) of Information (some links require DOI network access)
Asbestos and dangerous soils	Public health issues (e.g., mesothelioma). Toxic soils containing arsenic, <i>Bacillus Anthracis</i> (naturally occurring anthrax), cadmium, lead, selenium.	Known hazard (high)	US EPA: https://www.epa.gov/asbestos/learn-about-asbestos DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Radon	Airborne radiation. Lung damage. Indoor hazard.	Known hazard (high)	US EPA map of radon zones: https://www.epa.gov/radon/epa-map-radon-zones DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)
Avalanche	Slope failures. Burial in snow. Destroyed trees and other vegetation. Reduced or precluded visitation.	Known hazard (susceptible)	FEMA National Risk Index: Avalanche https://hazards.fema.gov/nri/avalanche Avalance.org https://avalanche.org/#/current DOI Strategic Hazard Identification and Risk Assessment (SHIRA) SHIRA - Home (sharepoint.com)

Future GSRI Direction and Inventory Needs

Moving forward, the GSRI program will fund projects that:

- collect new data or derive new information from existing data regarding the presence, absence, abundance, distribution, and significance of geologic heritage, soil features or processes, or geohazards;
- include features or processes on an individual feature or landscape scale;
- include groups of features or maps of multiple features in a defined area of management needs;
- are a snapshot in time and may set a baseline for monitoring or assessment; and will
- typically include a geospatial (GIS) component.

Table 5. Summary list of identified geologic and soil resource inventory needs for the scenic trail.

Subject	Inventory Need(s) and Action Items	Reference(s)
Climate change	Climate change vulnerability assessment for the scenic trail and structures along the scenic trail. Climate change scenario planning. Flora and fauna adaptation study case.	NPS (2015a)
Geology	Unique features and/or features of geoheritage need to be inventoried with points in GIS. Baseline GRI report. A geoheritage inventory. Mapping of acid-producing rocks.	APPA staff in 2023 conference call
Surficial geologic mapping	Surficial geologic map coverage for compliance exercises and disturbance management.	APPA staff in 2023 conference call
Paleontological resources	Perform site-specific field surveys to identify paleontological resources along the scenic trail. Establish the current conditions of APPA's paleontological resources as a baseline. Monitor known fossil sites or other geologic sites of interest.	Tweet et al. (2010); Santucci et al. (2009); National Parks Conservation Association (2010); APPA staff in 2023 conference call
Trail maintenance and management	Refine the trail drainage assessment tool with larger sample sizes, additional/more accurate field measurements, side slope measurements, canopy cover, trail grades, and landscape grades. Identify management zones. Wayfinding plan. Visitor-use management plan. Sustainable trail and campsite planning. Maintained landscape inventory and management plan. Sustainable trail design study and guide. Scenic trail assessment studies to evaluate trail conditions to document maintenance deficiencies and include a database management component. Monitor land cover, use, and disturbance events.	Burroughs et al. (2017); NPS (2015a)

Subject	Inventory Need(s) and Action Items	Reference(s)
Stratotype resources	Perform field inventories to establish baseline conditions. Establish a monitoring plan to identify threats or impacts.	Henderson et al. (2022)
Soil resources	Needs for compiled data covering the length of the scenic trail persist. Areas affected by acid deposition need to be identified. Site-specific soil erosion and compaction problems require more information and maintenance. Mapping of soils with respect to their acidification and acid-buffering capacities.	Appalachian National Scenic Trail (2008); Burns et al. (2019)
GIS needs	Geologic map of APPA. Develop up-to-date reports and summaries for trail managers. Need comprehensive inventories of the scenic trail's resources, as well as a means to update, manage, and analyze the information. LiDAR data for sustainability (and other) analyses. Boundary survey data. Slope analyses. Derivative maps of specific areas and/or subjects (e.g., slopes, geohazards, karst potential, etc.). Geothermal location data.	Appalachian National Scenic Trail (2008); Marion et al. (2020)
Geologic sources of building materials	Combine historical searches and cultural resource inventory efforts to identify where quarried stones that make up structures such as foundations, bridges, old furnace/mine works etc. were sourced.	National Parks Conservation Association (2010)
APPA management	Update comprehensive management plan. Boundary monitoring and maintenance tracking system. Encourage citizen scientists to note new slope movements, fossil locations, mineral locations, and other notes of geologic interest. Scenic and landscape-level protection and response strategy for vistas.	National Parks Conservation Association (2010); NPS (2015a)
Natural resource quality and ecological connectivity	Biodiversity decline studies. Monitor visibility in designated areas.	Shriver et al. (2005); NPS (2015a)
Disturbed lands and AML	Compile known mine features.	Port (2016)
Geologic and soil hazards	Apply handbook guidance to identify options to manage natural hazard and climate change risks throughout all levels of facility planning and design. Contact NPS GRD with hazards-checklist problems or questions.	NPS (2015b, 2023); Jarvis (2015)

Prior NRSS-Supported Work

- Geologic or soils research permits (some links require a DOI network login to access):
 - Northern Piscataquis County and Northern Somerset County Soil Survey (initial survey) <https://irma.nps.gov/RPRS/IAR/Profile/92500>,

- <https://irma.nps.gov/RPRS/Permit/Profile/15776>,
<https://irma.nps.gov/RPRS/IAR/Profile/49124>, <https://irma.nps.gov/RPRS/IAR/Profile/59016>
- Northern Piscataquis County Soil Survey (initial survey)
<https://irma.nps.gov/RPRS/IAR/Profile/52209>,
<https://irma.nps.gov/RPRS/IAR/Profile/44160>,
<https://irma.nps.gov/RPRS/IAR/Profile/38247>,
<https://irma.nps.gov/RPRS/IAR/Profile/35028>, <https://irma.nps.gov/RPRS/Permit/Profile/345>
 - Appalachian Trail MEGA-transect deposition effects study
<https://irma.nps.gov/RPRS/IAR/Profile/56334>,
<https://irma.nps.gov/RPRS/Permit/Profile/1578>
 - Palmerton Zinc Pile Superfund site Appalachian Trail degradation study
<https://irma.nps.gov/RPRS/Permit/Profile/15775>,
<https://irma.nps.gov/RPRS/IAR/Profile/53594>
 - Geographic parthenogenesis: a case study of the distribution of *Erigeron strigosus* (*Asteraceae*) in Georgia, US <https://irma.nps.gov/RPRS/IAR/Profile/40809>,
<https://irma.nps.gov/RPRS/IAR/Profile/34413>,
<https://irma.nps.gov/RPRS/IAR/Profile/34412>, <https://irma.nps.gov/RPRS/Permit/Profile/339>
 - Invasion ecology of Tree of Heaven (*Ailanthus altissima*)
<https://irma.nps.gov/RPRS/IAR/Profile/37060>, <https://irma.nps.gov/RPRS/Permit/Profile/337>
 - Study and recovery of glade spurge, *Euphoria purpurea*, in three populations
<https://irma.nps.gov/RPRS/IAR/Profile/59091>
 - Establishment of a temperate-climate monitoring site to constrain field-based basalt weathering rates in Cumberland County, PA <https://irma.nps.gov/RPRS/IAR/Profile/99338>,
<https://irma.nps.gov/RPRS/IAR/Profile/93814>,
<https://irma.nps.gov/RPRS/Permit/Profile/15792>,
<https://irma.nps.gov/RPRS/IAR/Profile/56846>
 - Past and outstanding geology of soils related STAR requests:
 - Assess rock containment systems and develop a treatment plan
<https://irma.nps.gov/STAR/Summary/ViewProfile/2772>
 - Past geology or soils related SIP (older GIP) or MOSAICS projects: two ecology assistance positions were filled (project IDs: 002406 and 003571)
 - Other inventory efforts related to soils:
 - Northeast Temperate Network rare plant monitoring:
<https://irma.nps.gov/DataStore/Reference/Profile/2191956>
 - Assessing the influence of sustainable trail design and maintenance on soil loss
<https://irma.nps.gov/DataStore/Reference/Profile/2243677>

- The influence of layout on Appalachian Trail soil loss, widening, and muddiness: implications for sustainable trail design and management
<https://irma.nps.gov/DataStore/Reference/Profile/2267321>

State-Specific Guidance for Resource Management

- Association of American State Geologist (AASG): <https://www.stategeologists.org>
- Maine Geology and Geological Surveys and Societies
 - Maine Geological Survey: <https://www.maine.gov/dacf/mgs/>
 - Maine's geology: <https://www.gsmmaine.org/maines-geology/>
 - New England Intercollegiate Geological Conference: <https://neigc.info/>
- New Hampshire Geology and Geological Surveys and Societies
 - New Hampshire Geological Survey: <https://www.des.nh.gov/land/geology>
 - Geological Society of New Hampshire: <http://www.gsnh.org/geo-links.html>
 - New Hampshire environmental science interactive map:
<https://www.americangeosciences.org/critical-issues/maps/interactive-map-environmental-information-new-hampshire>
 - New England Intercollegiate Geological Conference: <https://neigc.info/>
- Vermont Geology and Geological Surveys and Societies
 - Vermont Geological Survey: <https://dec.vermont.gov/geological-survey>
 - Geology resources: <https://www.uvm.edu/perkins/geology-resources>
 - Interactive map of Vermont's geology: <https://www.americangeosciences.org/critical-issues/maps/interactive-map-vermonts-geology-and-natural-resources>
 - New England Intercollegiate Geological Conference: <https://neigc.info/>
- Massachusetts Geology and Geological Surveys and Societies
 - Massachusetts Geological Survey: <https://mgs.geo.umass.edu/>
 - US Geological 1:24,000 surficial geology of Massachusetts: <https://www.mass.gov/info-details/massgis-data-usgs-124000-surficial-geology>
 - Interactive map of Massachusetts' geology: <https://www.americangeosciences.org/critical-issues/maps/interactive-map-massachusetts-geology-and-natural-resources>
 - New England Intercollegiate Geological Conference: <https://neigc.info/>
- Connecticut Geology and Geological Surveys and Societies
 - Connecticut Geological Survey: <https://portal.ct.gov/DEEP/Geology/Geological-Survey>
 - Explore Connecticut geology: <https://explorect.org/geology/>

- Connecticut geology: <https://www.easternct.edu/cunninghamw/connecticut-geology/connecticutgeologyphotos.html>
- Geological Society of Connecticut: <https://www.geologicalsocietyct.org/>
- New England Intercollegiate Geological Conference: <https://neigc.info/>
- New York Geology and Geological Surveys and Societies
 - Geology Department and New York State Geological Survey: <http://www.nysm.nysed.gov/research-collections/geology>
 - Geoscience in New York: <https://www.americangeosciences.org/critical-issues/states/new-york>
 - New England Intercollegiate Geological Conference: <https://neigc.info/>
- New Jersey Geology and Geological Surveys and Societies
 - New Jersey Geological and Water Survey: <https://www.nj.gov/dep/njgs/>
 - Interactive map of New Jersey's geology: <https://www.americangeosciences.org/critical-issues/maps/interactive-map-new-jerseys-geology-and-natural-resources>
- Pennsylvania Geology and Geological Surveys and Societies
 - Department of Conservation and Natural Resources Bureau of Geological Survey: <https://www.dcnr.pa.gov/Geology/Pages/default.aspx>
 - Pennsylvania geology: <https://libraries.psu.edu/about/collections/pennsylvania-geology>
 - Interactive map of Pennsylvania's geology and natural resources: <https://www.americangeosciences.org/critical-issues/maps/interactive-map-pennsylvanias-geology-and-natural-resources>
 - Geology of the Appalachian Trail in Pennsylvania: Wilshusen (1983)
 - Pennsylvania geology publication 1969–2023: http://elibrary.dcnr.pa.gov/GetDocument?docId=1751958&DocName=Hyperlinks_PaGeoMagazine.pdf
- Maryland Geology and Geological Surveys and Societies
 - Maryland Geological Survey: <http://www.mgs.md.gov/>
 - Maryland Geological Survey historic resources: https://dnr.maryland.gov/pages/md-conservation-history/mgs_historical_sources.aspx
- West Virginia Geology and Geological Surveys and Societies
 - West Virginia Geological and Economic Survey: <http://www.wvgs.wvnet.edu/>
 - Geologic map of West Virginia: <http://wvgis.wvu.edu/data/dataset.php?ID=43>
 - Geoscience in your state—West Virginia: <https://www.americangeosciences.org/critical-issues/states/west-virginia>

- Virginia Geology and Geological Surveys and Societies
 - Virginia Department of Mines, Minerals, and Energy (Virginia Energy): <https://www.energy.virginia.gov/geology/geologymineralresources.shtml>
 - Interactive map of Virginia's geology and natural resources: <https://www.americangeosciences.org/critical-issues/maps/interactive-map-virginias-geology-and-natural-resources>
 - Guide to Virginia Geological Survey historic records: <https://ead.lib.virginia.edu/vivaxtf/view?docId=lva/vi01007.xml>
- Tennessee Geology and Geological Surveys and Societies
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 - Geoscience in your state—Tennessee: <https://www.americangeosciences.org/critical-issues/states/tennessee>
- North Carolina Geology and Geological Surveys and Societies
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