



Appalachian National Scenic Trail

Geologic Resources Inventory Scoping Summary

Prepared by Rebecca Port, December 22, 2016

The Geologic Resources Inventory (GRI) is one of 12 natural resource inventories within the National Park Service (NPS). The Geologic Resources Division (GRD) of the NPS administers the inventory. The GRI provides each of the 270 identified natural area National Park System units with, first, a geologic scoping meeting and summary (this document), followed by a digital geologic map, and lastly a GRI report. The purpose of a GRI scoping meeting is to 1) evaluate the adequacy of existing geologic maps for resource management purposes, 2) discuss distinctive geologic features and processes, and 3) identify potential geologic management issues.

The NPS GRI scoping meeting for Appalachian National Scenic Trail was divided into three meetings, each held at a different location to facilitate attendance by participants spread over the wide geographical area covered by the trail. A site visit was not part of the scoping process. The first meeting was held on 2 May 2016 in Gatlinburg, Tennessee; the second meeting was held on 4 May 2016 at the National Conservation Training Center in Shepherdstown, West Virginia; the final meeting was held on 6 May 2016 at the University of Massachusetts in Amherst, Massachusetts. Participants included NPS staff from GRD, Appalachian National Scenic Trail, Great Smoky Mountains National Park, and Inventory and Monitoring Networks; GRI team members from Colorado State University; cooperators from state geological surveys and the US Geological Survey (USGS); staff from the USDA Forest Service and the Natural Resources Conservation Service; and faculty from the University of Massachusetts (table 1).

Each meeting began with an overview of the GRI program (Bruce Heise, National Park Service, GRI program coordinator) and an explanation of the GRI digital map products (Jim Chappell or Georgia Hybels, Colorado State University, GIS specialists). Meeting participants then had an opportunity to present the geologic maps available in their respective state/region. The remainder of the meeting involved a group discussion of map coverage and needs, geologic features and processes, and potential geologic resource management issues along the trail.

During the scoping meeting on 4 May 2016, Appalachian National Scenic Trail superintendent, Wendy Jansen, provided general information about the trail, including a brief history and description of resource management issues she and her staff are currently facing. The Appalachian National Scenic Trail's GIS specialist, Matt Robinson, also gave a presentation on 4 May 2016. He explained the dynamic nature of the Appalachian Trail boundary and how this affects resource management and trail maintenance.

This scoping summary highlights discussions that occurred during the GRI scoping meetings for the Appalachian National Scenic Trail and includes the following sections:

- Park Introduction
- Geologic Setting
- Status of Geologic Maps
- Geologic Features, Processes, and Issues
- Literature Cited

Table 1. Scoping meeting participants

Name	Affiliation	Position
Brian Carlstrom	NPS Natural Resources Stewardship and Science (NRSS)	Deputy Associate Director
Tim Connors	NPS NRSS Geologic Resources Division	Geologist
Bruce Heise	NPS NRSS Geologic Resources Division	Geologist
Rebecca Port	NPS NRSS Geologic Resources Division	Geologist
Hal Pranger	NPS NRSS Geologic Resources Division	Chief, Geologic Features and Systems Branch
Vincent L. Santucci	NPS NRSS Geologic Resources Division	Senior Paleontologist/GRD Liaison
Jim Chappell	Colorado State University	Geologist GIS Specialist
Georgia Hybels	Colorado State University	GIS Specialist
Wendy Janssen	NPS Appalachian National Scenic Trail	Superintendent
Matt Robinson	NPS Appalachian National Scenic Trail	GIS Specialist
Jim Von Haden	NPS Appalachian National Scenic Trail	Integrated Resources Manager
Brian Witcher	NPS Appalachian Highlands Network	Program Manager
Tom Remaley	NPS Great Smoky Mountains National Park	Inventory and Monitoring Coordinator
Fred Dieffenbach	NPS Northeast Temperate Network	Environmental Monitoring Coordinator
John Brock	US Geological Survey	Program Coordinator, National Cooperative Geologic Mapping Program
Jack Epstein	US Geological Survey	Emeritus Geologist
Randall Orndorff	US Geological Survey	Director, Eastern Geology and Paleoclimate Center
Melissa Reichert	USDA Forest Service	Recreation Program Manager
Susan Southard	USDA Natural Resources Conservation Service	Soil Scientist
Bart Cattanach	North Carolina Geological Survey	Geologist
Kenneth B. Taylor	North Carolina Geological Survey	State Geologist
Pete Lemiszki	Tennessee Geological Survey	Chief Geologist
Matt Heller	Virginia Division of Geology and Mineral Resources	Geologist Supervisor
Michael Hohn	West Virginia Geological Survey	Director
David K. Brezinski	Maryland Geological Survey	Geologist
Rebecca Kavage Adams	Maryland Geological Survey	Geologist
Richard Ort	Maryland Geological Survey	Director
Gale Blackmer	Pennsylvania Geological Survey	State Geologist
Gary M Fleeger	Pennsylvania Geological Survey	Geologist Supervisor
Bill Kelly	New York State Geological Survey	State Geologist (retired)
James Bogart	Connecticut Geological Survey	Intern
Margaret Thomas	Connecticut Geological Survey	State Geologist
Joe Kopera	Massachusetts Geological Survey	Geologist
Steve Mabee	Massachusetts Geological Survey	State Geologist
Don Wise	University of Massachusetts	Retired Geology Faculty
Marjorie Gale	Vermont Geological Survey	State Geologist
Rick Chormann	New Hampshire Geological Survey	State Geologist
Henry Berry	Maine Geological Survey	Bedrock Geologist

Note: Contact information is retained by the Geologic Resources Division.

Park Introduction

In 1921, Benton MacKaye—considered the founder of the Appalachian Trail—drafted the original plan for a greenway connecting local communities and wildlands running the length of the Appalachian Mountains. Under the coordination of the Appalachian Trail Conservancy (ATC), volunteer hiking clubs designed and constructed such a trail and by 1937 the Appalachian Trail was opened as a continuous trail from Georgia to Maine. In 1968, the National Trails System Act designated the Appalachian Trail as the first National Scenic Trail.

The Appalachian National Scenic Trail is roughly 2,180 miles long and passes through 14 states—Georgia, North Carolina, Tennessee, Virginia, West Virginia, Maryland, Pennsylvania, New Jersey, New York, Connecticut, Massachusetts, Vermont, New Hampshire, and Maine. It is the longest continuously marked footpath in the world; iconic white blazes adorn the trail (fig. 1). The southern terminus of the trail is Springer Mountain in Georgia and the northern terminus is Mount Katahdin in Maine. Virginia has the most trail miles (about 550 miles), while West Virginia contains the least (about 4 miles). Several million visitors hike at least a portion of the trail each year. A “thru-hiker” walks the entire trail continuously. Thousands attempt to thru-hike the trail each year; an average of one in four completes the journey. Most start in the south in the spring and end in fall (taking an average of 6 months).



Figure 1. White blazes mark the location of the Appalachian National Scenic Trail, Max Patch, North Carolina. NPS photograph by Matt Robinson.

The National Park Service has overall responsibility for the Appalachian National Scenic Trail; however, management is highly collaborative and depends substantially on volunteers due to the incredible length of the trail and number of private, federal, and state lands it intersects. The Appalachian Trail has more federal boundary (more than 1,200 miles of exterior federal boundary) than any other park except for Wrangell-St. Elias National Park in Alaska. And this figure does not include the 6 units of the National Park System, 8 national forests, 2 fish and wildlife refuges, and more than 70 state parks the trail traverses (Appalachian Trail Conservancy 2009). The trail is currently protected along more than 99 percent of its course by federal or state ownership of the land or by right-of-way. The ATC manages day-to-day operations under special agreements with the National Park Service and the Forest Service (Appalachian Trail Conservancy 2009). Annually, more than 6,000 volunteers contribute more than 200,000 hours on the Appalachian Trail, the second largest volunteer program in the NPS.

The Appalachian National Scenic Trail is unique among units of the National Park System because its legislative boundary is not fixed; the NPS has the authority to attempt to purchase land in order to reroute sections of the trail. Rerouting may be desired due to trail degradation—to find a more sustainable route—or in order to afford protection to a particular area and improve visitor

experience—to an area that deserves protection (Matt Robinson, Appalachian National Scenic Trail, GIS specialist, scoping meeting comment, 4 May 2016).

Geologic Setting

The Appalachian National Scenic Trail is a long-distance trail running along the backbone—the ridge crests and major valleys—of the Appalachian Mountains. The Appalachians are an ancient mountain chain (mountain-building ceased about 240 million years ago) that today are worn down and forested. Their current height is relatively stable; erosion and weathering, which lowers the mountains approximately 1 inch every 600 years, is balanced by uplift (Chew 1988). Though worn down from their former glory, the elevation change along the trail is not insignificant; the net elevation gain along the length of the trail is equivalent to 16 times that of Mount Everest.

The geologic story of the Appalachian Mountains is arguably one of the most interesting and relevant in all of the National Park System as it describes the formation of much of eastern North America. The history is long (beginning more than a billion years ago), complex (numerous mountain building episodes), and still not fully understood (research is active and often controversial) which presents both opportunities and challenges for those working to maintain, protect, and interpret the Appalachian National Scenic Trail. Geologic interpretations along the trail may quickly become outdated. Therefore, routine consultation of scientific literature and discussion with local experts is crucial for successful resource management and interpretation.

The geologic history of the Appalachian Mountains can be divided as follows:

- 1) Mesoproterozoic orogenic activity. Continental collisions, metamorphism, and igneous intrusions associated with the Grenville orogeny produced the oldest rocks found along the Appalachian Trail—roughly 1.3 billion year old gneiss and schist. These rocks make up the “basement” of much of northeastern America (Chew 1988). The Appalachian Trail crosses Grenville basement rocks in Vermont, Massachusetts, Connecticut, New York, New Jersey, Virginia, Tennessee, and North Carolina (Chew 1988). It is important to note that these basement rocks occur in places at the surface today only because much later tectonic activity (after the Mesoproterozoic Era) broke up and thrust slivers of Grenville rock westward and on top of younger rocks. Even older rocks, up to 1.8 billion years old, may occur at Roan High Knob and Round Bald on the Tennessee-North Carolina border (Chew 1988).
- 2) Neoproterozoic rifting. Rifting—pulling apart—split and stretched Earth’s crust, resulting in both sedimentation (in low places on the rift, atop Grenville rocks) and volcanism (along the newly formed continental margin of Laurentia). From Pennsylvania to Virginia lava spilled from volcanoes and flowed in sheets to form the rock basalt (Chew 1988). Ash also erupted and became a rock known as welded tuff (Chew 1988). This activity, roughly 800 million to 600 million years ago, produced the protoliths (parent rock) of the Central and Eastern Blue Ridge terranes and the sediments of the Western Blue Ridge Terrane (Bart Cattanach, North Carolina Geological Survey, geologist, scoping meeting presentation, 2 May 2016).
- 3) Paleozoic orogenic activity. In the beginning of the Paleozoic Era, prior to Paleozoic orogenic activity, most of the eastern United States was below sea level along a passive tectonic margin. Sandstone (and quartzite) and later limestone (and dolomite) formed in this offshore environment (Chew 1988). Some shale (originally mud) layers occur within the limestone and may display ripple marks (Chew 1988). Some of the limestone was later metamorphosed to marble

which is found today in the southern New England Valleys that the trail crosses in New York, Connecticut, and Massachusetts (Chew 1988). Orogenic activity began with continental collisions during the Ordovician Period. This activity metamorphosed the older rocks formed during the rifting of the Neoproterozoic Era, produced new igneous bodies, and created what we think of as the Appalachian Mountains (Bart Cattanach, North Carolina Geological Survey, geologist, scoping meeting presentation, 2 May 2016).

Paleozoic orogenic activity consists of several deformational events, of which the timing, number, and extent is not fully understood. For example, there is new evidence in Massachusetts for up to five Paleozoic deformational events, suggesting tectonic activity may be more continuous than previously thought (Steve Mabee, Massachusetts Geological Survey, state geologist, comment on scoping summary draft, 11 October 2016). In general, Paleozoic orogenic activity can be subdivided as follows:

1. Taconic orogeny. During the Ordovician Period, volcanic islands collided with the eastern edge of the limestone that was forming on the continental shelf in a shallow sea. Mud accumulated as the islands shed sediments on top of the limestone, forming shale. The volcanoes and the limestone and mud all became jumbled together. Today the Taconic Range in New England is the remains of this mass. Taconic mountain-building shoved rocks westward, up and over younger rocks, substantially shortening Earth's crust (probably by several hundred miles) (Chew 1988). During the Silurian Period, the Taconic Mountains eroded. Rivers flowing off the mountains deposited sand, gravel, and mud; iron ore is found in some of these deposits (Chew 1988).
2. Acadian orogeny. In the Late Devonian Epoch, an ancient microcontinent—Avalonia and Baltica landmasses—collided with North America, adding the coastal areas of Maine, Massachusetts, and Rhode Island. The collision raised New England above sea level; volcanoes formed, lava flowed, and plutons developed deep underground (some of which are now exposed due to erosion); and many pre-existing rocks were metamorphosed. Shortly after formation, the Acadian mountains began eroding. The coal and shale found in Virginia (west of the Appalachian Trail) formed at this time when eroded organic material and mud settled into the anoxic deep of the surrounding ocean (Chew 1988). The sediments eroded from these mountains accumulated in layers six to seven vertical miles deep (Chew 1988).
3. Alleghanian orogeny. In the Permian Period, the African continent collided with North America to form the supercontinent Pangea and the modern Appalachian Mountains. The collision metamorphosed the Proterozoic rocks—Grenville basement rocks, sediments, and basalt—and thrust them west and on top of younger rocks creating the Blue Ridge Mountains. To the west of the Blue Ridge, the Valley and Ridge Province formed where the early Paleozoic sedimentary rocks were folded westward and forced over massive thrust faults. In this province characterized by parallel valleys and ridges, erosion resistant sandstone and quartzite form ridges while limestone (a soluble rock) tends to form valleys. The majority of the Appalachian Trail is along the Blue Ridge and Valley and Ridge provinces.

In the Mesozoic Era, after the formation of the Appalachian Mountains, Pangea began to separate, breaking apart North America and Africa, and creating the Atlantic Ocean basin between the two continents. Similar to the Neoproterozoic rifting, molten material rose from deep within the Earth to fill the cracks between the separating plates; sediment also accumulated in the spaces (Chew 1988). The Appalachian Mountains began eroding at this time. Erosion has removed an estimated 1 ½ miles of rock since the end of the Cretaceous Period, 66 million years ago (Chew 1988).

In the Cenozoic Era, the most significant geologic activity in the Appalachian region was Pleistocene glaciations. Glaciers repeatedly extended south and then retreated over the course of roughly 2 million years. The most recent cycle occurred 20,000 years ago; thousands of feet of ice reached as far south as Pennsylvania and the Ohio River Valley (Chew 1988).

Georgia

In Georgia, the Appalachian Trail is entirely within the Chattahoochee National Forest. The trail follows the rises and falls of the eastern ridge of the Blue Ridge Province and summits several of the state's highest peaks. Views from the trail are of the Blue Ridge and Piedmont Plateau. The trail primarily traverses late Proterozoic gneiss in this state.

North Carolina and Tennessee

The majority of the Appalachian Trail in North Carolina and Tennessee runs along the state border (fig. 2). Along this stretch, the trail passes through Great Smoky Mountains National Park where it reaches the summit of Clingmans Dome (6,643 ft), marking the highest point along its journey from Georgia to Maine. Thornberry-Ehrlich (2008) produced a geologic resources inventory report for Great Smoky Mountains National Park. Moore (1988) wrote a roadside guide to the geology of park. These reports may be useful to resource managers and in the production of the geologic resources inventory report for Appalachian National Scenic Trail.

The Blue Ridge Parkway runs roughly parallel to and east of the trail in North Carolina; the trail does not cross the parkway in this state. Carter et al. (1999) produced a report of the geology along the Blue Ridge Parkway which may be useful for understanding the geology along the trail nearby and in the production of the geologic resources inventory report for Appalachian National Scenic Trail.

Throughout North Carolina, the trail is in the Blue Ridge Province. The Hayesville Fault and Murphy Syncline cross the trail in North Carolina. The trail leaves the border with North Carolina in northeastern Tennessee, leaving the Blue Ridge Province and entering the Valley and Ridge Province.

Terrane Map of North Carolina



Figure 2. Map of the Appalachian Trail and physiographic provinces in North Carolina. The trail (blue line) runs through the Blue Ridge Province and along the North Carolina-Tennessee border for a considerable distance where it also crosses Great Smoky Mountains National Park. Graphic by Bart Cattanaach (North Carolina Geological Survey).

Virginia

The Appalachian Trail snakes from the Blue Ridge Mountains out into the valley and back, providing a variety of geology and landscapes for hikers to enjoy. In the south, the trail begins in the Blue Ridge where it summits Mount Rogers and passes briefly through a corner of Grayson Highlands State Park. The trail then crosses into the Valley and Ridge; near Blackhorse Gap the trail returns to the Blue Ridge province.

The state of Virginia contains the most Appalachian Trail-miles, the bulk of which are through Jefferson and George Washington National Forests; the trail crosses the Blue Ridge parkway twice while in the national forests. The trail then proceeds through the long axis of Shenandoah National Park, with extraordinary views. Thornberry-Ehrlich (2008) completed the geologic resources inventory report for Shenandoah National Park. The trail continues northeast, passing through G. R. Thompson State Wildlife Management Area and Sky Meadows State Park before exiting the state into Harper's Ferry, West Virginia.

West Virginia

Appalachian National Scenic Trail meanders back and forth across the Virginia-West Virginia border for several miles before it reaches Harper's Ferry—the confluence of the Shenandoah and Potomac Rivers. The rivers carved a notch in the mountains, providing passage west. The trail crosses both rivers. In 1783, Thomas Jefferson described the view of the Shenandoah and Potomac rivers confluence from a cliff at Harper's Ferry, which today is along the trail, as a scene “worth a voyage across the Atlantic”. The rock from which Thomas Jefferson made this observation became known as “Jefferson's Rock.” Around 1860, supports were placed around the rock because the risk of it falling was a threat to people and property below (fig. 3).



Figure 3. Photograph of Jefferson's Rock. Thomas Jefferson described the view of the Shenandoah and Potomac Rivers from this location in 1783. The supports were placed around the rock in 1860 to prevent it from falling. NPS photograph by Rebecca Port.

Maryland

The trail overlaps with the Chesapeake & Ohio Canal National Historical Park towpath after crossing the Potomac River from West Virginia into Maryland. As it continues, Appalachian National Scenic Trail follows the ridge crest of South Mountain. South Mountain is the western limb of the South Mountain anticline; it is made up of the Late Precambrian–Cambrian Weverton Formation quartzite (formerly quartz sandstone, metamorphosed during Appalachian mountain-building). Hagerstown Valley (to the west) and Middletown Valley (to the east) are on either side of the South Mountain ridge.

In some places the South Mountain limb is overturned (David Brezinski, Maryland Geological Survey, geologist, scoping meeting presentation, 4 May 2016). South of Crampton's Gap the anticline limb is overturned and the Weverton Formation rocks dip steeply southeast. The overturned limb places Blue Ridge rocks over younger Great Valley rocks. North of Crampton's Gap the anticline limb is not overturned. In this section, Monument Knob is the "right-side-up" limb of the fold that has been raised by thrust sheets. Where the limb is not overturned the ridge becomes less obvious due to cross-faults. Interstate 70 follows a cross-fault where it crosses the Appalachian Trail south of South Mountain State Park. North of this area the limb becomes overturned again and the ridge becomes more prominent. The ridge is terminated at the Pennsylvania border by the Triassic Antietam Cove Fault.

Pennsylvania

The mid-point of the Appalachian National Scenic Trail occurs in Pennsylvania. Pennsylvania is probably the state with the most geologic diversity along the trail. It is where the trail crosses from glaciated to unglaciated terrain (Gary Fleegeer, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016).

The Appalachian Trail in Pennsylvania follows the ridges east of the Allegheny Mountains, crosses Cumberland Valley, and follows the northernmost extension of the Blue Ridge. From south to north the trail passes through the following physiographic regions: (1) South Mountain; (2) Great Valley Section—a broad open valley underlain by intensely folded and faulted bedrock shale and limestone (Wilshusen 1983); (3) Appalachian Mountain Section; and (4) runs along the border of the Great Valley and Appalachian Mountain sections (fig. 4). The trail leaves Pennsylvania at Delaware Water Gap National Recreation Area along Kittatinny Mountain, which is actually a long ridge (see Thornberry-Ehrlich 2013). The ridge is composed of 440 million year old quartzite and conglomerate of the Shawangunk and Tuscarora formations (Wilshusen 1983).

Wilshusen (1983) prepared a report on the geology of the Appalachian Trail in Pennsylvania. The report describes geologic features which can be seen from the trail and contains geologic sketches, cross sections, photographs, and a geologic map. A presentation prepared by Gary Fleegeer of the Pennsylvania Geological Survey for the GRI scoping meeting is saved on the GRD network drive (available by request). There is a wealth of information in these two resources. The information will not be summarized here because it is beyond the scope of this summary document.

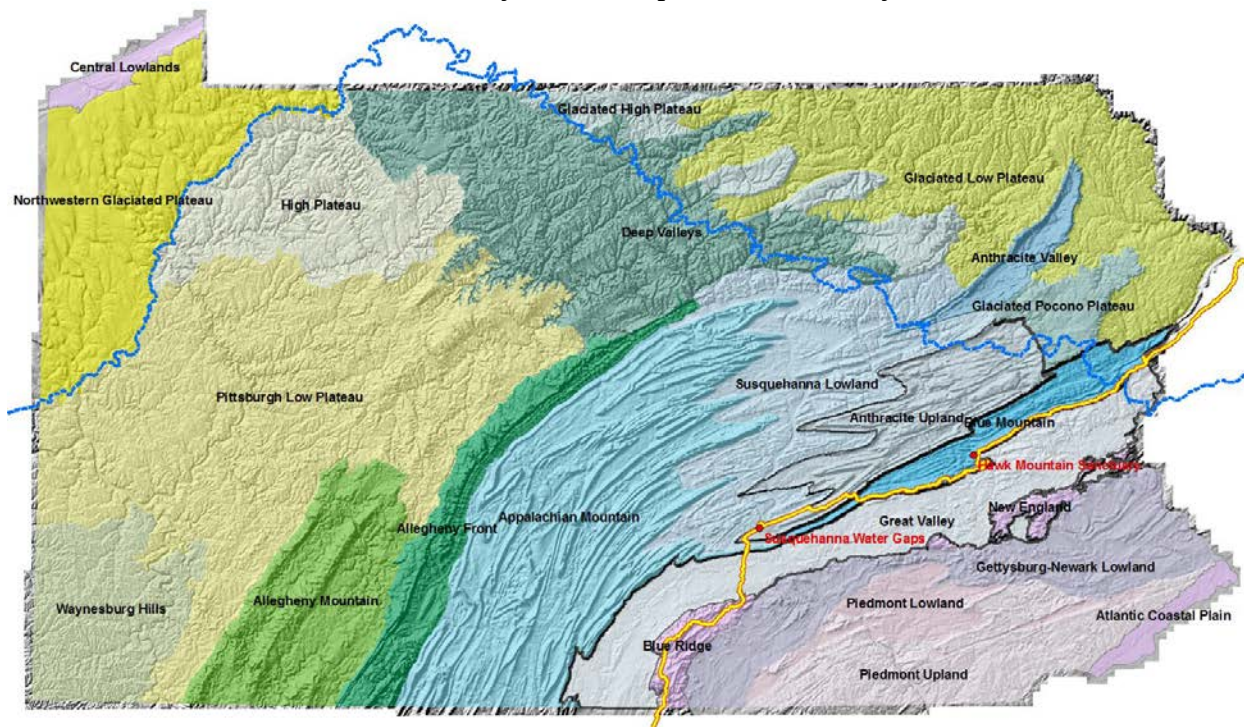


Figure 4. Physiographic map of the extent of Pleistocene glaciation in Pennsylvania. The Appalachian Trail (yellow line) crosses four physiographic sections in Pennsylvania and passes through or near two National Natural Landmarks (red text). The Blue dashed line is the boundary between glaciated and unglaciated terrain. Graphic by Gary Fleegeer (Pennsylvania Geological Survey).

New Jersey

The Appalachian Trail terrain is less wild in New Jersey than other states. The most rugged area in New Jersey is around Kittatinny Mountain. The Appalachian Trail passes from the Valley and Ridge to the New England Province in New Jersey (Gary Fleege, Pennsylvania Geological Survey, geologist, email communication, 12 October 2016)

New York

The Appalachian Trail crosses the Hudson River in New York at the Bear Mountain Bridge. The trail passes through Bear Mountain State Park and Harriman State Park. The New York landscape around the trail consists of rolling hills with dense suburban development. Rocks are primarily Precambrian marble and granite, gneiss, and some leucogranite; very few Taconic rocks occur in New York because Appalachian deformation removed them (Bill Kelly, New York Geological Survey, state geologist, scoping meeting presentation, 6 May 2016).

Connecticut

The Appalachian Trail in Connecticut goes through the western highlands—worn down remnants of a much loftier mountain range. Here, the deep Housatonic Valley is underlain by marble (metamorphosed early Paleozoic carbonate shelf sediments) and bordered by steep-sided, high plateaus of Proterozoic schist and gneiss of the Taconic and Berkshire ranges. More detailed geologic information was presented by James Bogart (Connecticut Geological Survey) at the scoping meeting on 6 May 2016. This presentation is saved on the GRD network drive (available by request) and should be consulted during the GRI report writing phase. The information will not be summarized here because it is beyond the scope of this summary document.

Approximately 30 years ago, a section of the trail in Connecticut was rerouted. The old route, though no longer officially part of the trail, is still used by hikers, has some geologic points of interest, and may have cultural significance (James Bogart, Connecticut Geological Survey, intern, scoping meeting presentation, 6 May 2016).

Massachusetts

The Appalachian Trail traverses the Berkshire Hills in Massachusetts. The Berkshires consist of wooded areas and valleys; the shape of the landscape is largely controlled by Taconic-age thrust sheets and carbonate valleys underlain by the Stockbridge Marble (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting presentation, 6 May 2016). Taconic orogenic activity thrust allochthonous—originating elsewhere—metamorphic rocks (e.g., gneiss) up and over younger, autochthonous—originating locally—marble (former shelf sediments). The trail also crosses an area of igneous intrusive rocks. High points along the trail include Mount Greylock (3491 ft [1064 m]) and Mount Everett (2602 ft [793 m]).

Geologic points of interest along the trail include a food-grade marble quarry situated within a small syncline which produces calcium for antacid medication and paper coating. Also, vegetation changes along the trail can be linked to changes in rock type. For example, 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).

Field trip guide books by the New England Intercollegiate Geological Conference will be a good resource during preparation of the final GRI report. However, there are potentially a lot of sites

along the Appalachian Trail where one can see fascinating geology, not all of which are listed in the guides (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting presentation, 6 May 2016).

Vermont

Appalachian National Scenic Trail runs north from Massachusetts through Green Mountain National Forest to Killington, Vermont along the west limb of the Green Mountain Anticlinorium. The Green Mountains are a high, rugged country of abandoned and overgrown farmlands and woods. After Killington, the trail turns east toward New Hampshire. Through its course in Vermont, the Appalachian Trail crosses Proterozoic- through Devonian-age rocks.

Between mountain-building events (when little crustal movement was occurring) the Appalachian Mountains eroded substantially and a relatively flat surface called a peneplain formed. Several peneplains are visible in the Appalachians, each correlated to a different episode of erosion and lack of tectonic activity. This peneplain layering is probably best illustrated in Vermont (Don Wise, University of Massachusetts, retired geology faculty, scoping meeting comment, 6 May 2016). The high points along the trail—Stratton Mountain, Prospect Peak, Spruce Peak, Bromley Mountain, Styles Peak, Peru Peak—are monadnocks (survivors of erosion) of the oldest peneplain.

Marjorie Gale (Vermont Geological Survey) presented more detailed geologic information at the scoping meeting on 6 May 2016. Her presentation is saved on the GRD network drive (available by request) and should be consulted during preparation of the GRI report.

New Hampshire

Some of the youngest rocks at the surface along the trail occur in New Hampshire; they are primarily Jurassic-age granite (Chew 1988). In New Hampshire, the Appalachian Trail crosses deep notches (e.g., Franconia Notch) which are surrounded by high mountains (e.g., the Presidential Range). Parts of the trail in the White Mountains are at elevations above tree line (the altitude above which timber ceases to grow). Logging is a big part of the cultural story on this part of the Appalachian Trail; in many places the trail follows old railroad beds that were built by lumber companies (Rick Chormann, New Hampshire Geological Survey, state geologist, scoping meeting presentation, 6 May 2016).

Maine

The northern terminus of the Appalachian Trail is in Maine on Mount Katahdin in Baxter State Park. The longest wilderness section of the trail is in Maine—100 miles (161 km). On 24 August 2016, Katahdin Woods and Waters National Monument was established by presidential proclamation. It borders Baxter State Park to the east; the trail does not enter the monument.

Maine is known for its world-class pegmatite minerals; watermelon tourmaline—green tourmaline with a red center—is popular among collectors. A gem and mineral museum is planned to open near the trail. Illegal mineral collection may be occurring along the trail in Maine. This section of the trail is monitored closely because it is where most thru-hikers end their journey and there have been issues with trash and celebratory activity. Illegal mineral collection may be more difficult due to the heightened surveillance in this area (Fred Dieffenbach, NPS Northeast Temperate Network, environmental monitoring coordinator, scoping meeting and email comment, 6 May 2016 and 12 September 2016).

Status of Geologic Maps

GRI's digital geologic maps reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of being GIS compatible. The NPS GRI Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation for the GRI and allows for rigorous quality control. Staff members digitize maps or convert digital data to the GRI digital geologic map model using ESRI ArcGIS software. Final digital geologic map products include data in geodatabase and shapefile format, layer files complete with feature symbology, Federal Geographic Data Committee (FGDC)-compliant metadata, a PDF help file that captures ancillary map data, and a document that displays the map. Final data products are posted at <https://irma.nps.gov/Portal>. The data model is available at <http://science.nature.nps.gov/im/inventory/geology/GeologyGISDataModel.cfm>.

When possible, the GRI provides large scale (1:24,000) digital geologic map coverage for each National Park System unit's area of interest, which is often composed of the 7.5-minute quadrangles that contain parklands. Maps at a scale of 1:24,000 (and larger) are useful for resource management because they capture most geologic features of interest and are spatially (horizontally) accurate to within 12 m (40 ft).

Geologic map coverage for the area of interest of Appalachian National Scenic Trail is not complete. The following subsections discuss the completeness of geologic map coverage by state. Existing maps are listed in the tables below and are also viewable on a web map at <http://nps.maps.arcgis.com/home/webmap/viewer.html?webmap=b60414ea949f43638110fe6a9b52b650>.

Geologic map coverage discussions focused on bedrock geology, however, scoping meeting participants communicated the need for both bedrock and surficial (including glacial) maps of Appalachian National Scenic Trail. At a minimum, the GRI team will compile a bedrock geologic map. Surficial map coverage is less complete and has more variable nomenclature than bedrock maps, making it more of a challenge to produce a compiled map for the entire trail. The state by state discussions below are focused on bedrock map coverage. Surficial map coverage will not be assessed in this document but should be revisited. At this time, Jim Chappell has fairly decent documentation of surficial maps for the southern half of the trail. Additionally, meeting participants expressed a willingness to assist with surficial map discovery and compilation.

Georgia

At the scoping meeting, Kenneth Taylor (North Carolina Geological Survey) offered to compile a list of professors and students that have done mapping along the Appalachian Trail in Georgia and to provide an opinion about the maps' accuracy. Substantial mapping may have already been completed by graduate students.

Table 2. Map coverage for Appalachian National Scenic Trail in Georgia

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1983	Geologic Map of the Blood Mountain Roadless Area, Union and Lumpkin Counties	Nelson	USGS	MF-1503-A	1:30000	paper	b/w map; digitize and combine with other roadless area maps
1983	Geologic Map of the Catta-hoochee Roadless Area, Towns, Union, and White Counties	Nelson	USGS	MF-1502-A	1:30000	paper	b/w map; digitize and combine with other roadless area maps
1982	Geologic Map of the Tray Mountain Roadless Area	Nelson	USGS	MF-1347-A	1:30000	paper	b/w map; digitize and combine with other roadless area maps
1913	Ellijay folio, Georgia-North Carolina-Tennessee	La Forge and Phalen	USGS	GF-187	1:125000	paper	bedrock only; could be better than state dataset; digitize
1991	Geology, geochemistry, and mineral resource assessment of the southern Nantahala Wilderness and adjacent roadless areas	Peper et al.	USGS	Bulletin 1883	1:48000	paper	digitize and integrate with adjacent maps
1976	Geologic map of Georgia	Lawton et al.	Georgia Department of Natural Resources	NA	1:500000	paper	digitize; use to fill in gaps between more detailed maps

North Carolina

In addition to the maps listed below, the North Carolina Geological Survey produced a compiled state map at 1:100,000 scale that is now outdated but could be used to fill in any gaps in the GRI GIS data. The state survey completed a detailed hazards map for Blue Ridge Parkway; a similar map would be very useful for the Appalachian Trail.

Table 3. Map coverage for Appalachian National Scenic Trail in North Carolina

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1980	Geologic map and mineral resources summary of the Prentiss quadrangle	Hatcher	North Carolina Geological Survey	GM 167-SW	1:24000	paper	b/w; digitize and integrate with adjacent maps
2003	Bedrock Geologic Map of the Spring Creek 7.5-Minute Quadrangle	Cattanach et al.	North Carolina Geological Survey	GMS - 12	1:24000	paper	digitize
1985	Geologic map of North Carolina	?	North Carolina Geological Survey	General Geologic Map	1:500000	paper	digitize; use to fill in gaps between more detailed maps
2012	Geologic Map of Great Smoky Mountains National Park Region	Southworth et al.	USGS	SIM-2997	1:100000	GRI GIS	In GRI format; derived from and same as USGS SIM-2997
2000	Geology of the Mount Le Conte 7.5-minute quadrangle	Schultz et al.	USGS	OF-2000-261	1:24000	paper	Southworth map; probably referenced in SIM-2997; capture if not
2002	Bedrock Geologic Map of the Lemon Gap 7.5-Minute Quadrangle	Merschatt et al.	North Carolina Geological Survey	GMS - 11	1:24000	paper	digitize

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1996	Bedrock Geologic Map of the Hot Springs 7.5-Minute Quadrangle	Carter	North Carolina Geological Survey	OF-1996-05	1:24000	paper	digitize
2002	Bedrock Geologic Map of the Sams Gap 7.5-Minute Quadrangle	Merschat et al.	North Carolina Geological Survey	OF-2000-09	1:24000	paper	digitize
1997	Bedrock Geologic Map of the Bald Creek 7.5-Minute Quadrangle	Merschat	North Carolina Geological Survey	OF- 1997-05	1:24000	paper	digitize
1965	Geology of the Linville quadrangle, North Carolina-Tennessee	Bryant	USGS	GQ-364	1:62500	paper	digitize

Tennessee

A 1:100,000 scale compiled map is not available for Tennessee to fill in gaps on the Appalachian Trail map. The quadrangles that intersect the trail are not currently on the state survey's list of upcoming mapping projects (Pete Lemiszki, Tennessee Geological Survey, chief geologist, scoping meeting comment, 2 May 2016). A gap in geologic map data occurs along the trail from the Lemon Gap 7.5' quadrangle to the Chestoa 7.5' quadrangle. The North Carolina Geological Survey may have mapped some of these quads. Additionally, "geologic map packet" information may be requested from the Tennessee Geological Survey. Packets exist for the Hot Springs, Greystone, Flag Pond, Sams Gap, Unicoi, Iron Mountain Gap, Bakersville, and Elk Park 7.5' quadrangles. Thesis and/or dissertation information exists for the Hartford, Lemon Gap, Paint Rock, Hot Springs, Greystone, Flag Pond, Iron Mountain Gap, and White Rocks Mountain 7.5' quadrangles. If the information in the packets is from the University of Tennessee Knoxville, the state survey may have higher quality data available that NPS staff could request (Pete Lemiszki, Tennessee Geological Survey, chief geologist, scoping meeting comment, 2 May 2016).

Table 4. Map coverage for Appalachian National Scenic Trail in Tennessee

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1962	Geology and ground-water resources of the Elizabethton - Johnson City area	Maclay	USGS	Water-Supply Paper 1460-J	1:31680	paper	overlaps slightly with USGS id:4294; digitize and incorporate if significant increase in detail
1966	Geologic map of Tennessee	Hardeman et al.	Tennessee Division of Geology	State Geologic Map	1:250000	paper	digitize; use to fill in gaps between more detailed maps

Virginia

The Appalachian Trail intersects ~64 7.5' quadrangles in Virginia. Geologic quadrangle maps were done by the state survey. According to Matt Heller, there are a lot of draft/in progress maps available in the area of interest for the Appalachian Trail (Virginia Division of Geology and Mineral Resources, geologist supervisor, email communication, 22 September 2016). Maps that are in draft form should have draft GIS available. Almost all of the maps done by state survey are bedrock and surficial combined, though the surficial data may be minimal (Matt Heller, Virginia Division of Geology and Mineral Resources, geologist supervisor, scoping meeting comments, 4 May 2016).

Table 5. Map coverage for Appalachian National Scenic Trail in Virginia

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1960	Geology of northeasternmost Tennessee	King et al.	USGS	PP 311	1:48000	paper	digitize
1993	The volcanogenic Mount Rogers Formation and the overlying glaciogenic Konnarock Formation	Rankin	USGS	Bulletin 2029	1:100000	paper	specific to Mt. Rogers and Konnarock Formations; consider using if no other map is available and it will work better than state map
2005	Geology of the Damascus and Laurel Bloomery quadrangles	Whitlock and Derby	Virginia Division of Mineral Resources	Publication 172	1:24000	paper	digitize; only covers VA part of Laurel Bloomery quad
1986	Geologic map of Giles County	Schultz et al.	Virginia Division of Mineral Resources	Publication 69	1:50000	paper	digitize; only covers VA part of Laurel Bloomery quad
1974	Geology of the Salem quadrangle	Amato	Virginia Division of Mineral Resources	Report of Investigations 37	1:24000	paper	digitize
1976	Geology of the Daleville quadrangle	McGuire	Virginia Division of Mineral Resources	Report of Investigations 42	1:24000	paper	digitize
2000	Geology of the Glasgow and Buena Vista quadrangles	Spencer	Virginia Division of Mineral Resources	Publication 154	1:24000	paper	digitize
1968	Geology of the Natural Bridge, Sugarloaf Mountain, Buchanan and Arnold Valley quadrangles	McGuire	Virginia Division of Mineral Resources	Report of Investigations 42	1:24000	paper	digitize Buchanan and Arnold Valley quads
1981	Geology of the Villamont and Montvale quadrangles	Henika	Virginia Division of Mineral Resources	Publication 35	1:24000	paper	digitize
1978	Geology of the Crimora quadrangle	Gathright et al.	Virginia Division of Mineral Resources	Publication 13	1:24000	paper	digitize; covered by SHEN dataset at 100K; only use if provides significantly more detail
1977	Geology of the Greenfield and Sherando quadrangles	Bartholomew	Virginia Division of Mineral Resources	Publication 4	1:24000	paper	digitize
1977	Geology of the Waynesboro East and Waynesboro West quadrangles	Gathright et al.	Virginia Division of Mineral Resources	Publication 3	1:24000	paper	digitize; covered by SHEN dataset at 100K; only use if provides significantly more detail
2001	Geologic Map of the Virginia portion of the Peterstown quadrangle	Gathright and Rader	Virginia Division of Mineral Resources	Publication 156	1:24000	paper	digitize; covered by Giles County map (USGS id: 39822); use if provides more detail
2001	Geologic map of the Virginia portion of the Lindsie quadrangle	Schultz and Stanley	Virginia Division of Mineral Resources	Publication 160	1:24000	paper	digitize; covered by Giles County map (USGS id: 39822); use if provides more detail
2012	Geologic map of the Swift Run Gap quadrangle	Bailey et al.	Virginia Division of Geology and Mineral Resources	Publication 179	1:24000	paper	digitize; covered by SHEN dataset at 100K; only use if provides significantly more detail
1975	Geology of the Front Royal quadrangle	Rader, and Biggs	Virginia Division of Mineral Resources	Report of Investigations 40	1:24000	paper	digitize; covered by SHEN dataset at 100K; only use if provides significantly more detail
1976	Geology of the Linden and Flint Hill quadrangles	Lukert and Nuckols	Virginia Division of Mineral Resources	Report of Investigations 44	1:24000	paper	digitize; covered by SHEN dataset at 100K; only use if provides significantly more detail

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1997	Geology of the Upperville 7.5-minute quadrangle	Nelson	USGS	OF-97-708	1:24000	paper	digitize
1974	Geology of the Ashby Gap quadrangle	Gathright and Nystrom	Virginia Division of Mineral Resources	Report of Investigations 36	1:24000	paper	digitize
1994	Geologic map of the Bluemont quadrangle	Southworth	USGS	GQ-1739	1:24000	paper	digitize
1995	Geologic map of Warren County, Virginia	Rader and Conley	Virginia Division of Mineral Resources	Publication 138	1:50000	paper	covered by SHEN data and more detailed quads; only use if it provides better integration with surrounding maps and/or features not present on coincident maps
1993	Geologic map of Virginia	?	Virginia Division of Mineral Resources	NA	1:500000	GIS data?	use to fill in gaps; NGMDB page mentions 2003 digital rendition

West Virginia

Approximately four miles of trail run through West Virginia. Map coverage in this state is complete.

Table 6. Map coverage for Appalachian National Scenic Trail in West Virginia

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1992	Geologic map of the Round Hill quadrangle	McDowell and Milton	USGS	GQ-1702	1:24000	paper	digitize; partially covered by Berryville map (USGS id: 40185); used both for complete coverage
1987	Geology of the Hedgesville, Keedysville, Martinsburg, Shepherdstown, and Williamsport Quadrangles	Dean et al.	West Virginia Geological and Economic Survey	Map-WV 31	1:24000	GIS data?	need to acquire pub; covers only small part of QOI so probably won't need it
1990	Geology of the Berryville, Charles Town, Harpers Ferry, Middleway, and Round Hill quadrangles	Dean et al.	West Virginia Geological and Economic Survey	Map-WV 35	1:24000	paper	overlaps with Round Hill quad map; will need to use both for complete coverage
1968	Geologic map of West Virginia	Cardwell et al.	West Virginia Geological and Economic Survey	Map 1	1:250000	paper	newer maps exist but this one might be most detailed

Maryland

Map coverage in Maryland is nearly complete. It should be noted that the 1:24,000 quadrangle maps are not edge mapped because they are different generations. The Hagerstown Valley map is in progress; within the next year or so a geologic map of Maryland parks should be available (compiled at 1:62.5 but mapped at 1:24000) (David Brezinski, Maryland Geological Survey, geologist, scoping meeting presentation, 4 May 2016). In Maryland, the trail almost intersects the Funkstown 7.5' quadrangle; this quad should be included in the mapping plan otherwise the park would not receive geologic information on one side of the trail in this state.

Table 7. Map coverage for Appalachian National Scenic Trail in Maryland

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
2009	Geologic map of the Keedysville and parts of Shepherdstown, Harpers Ferry and Charles Town quadrangles	Brezinski	Maryland Geological Survey	Quadrangle Geologic Map	1:24000	GIS data	convert to GRI GIS model; overlaps with Harpers Ferry quad; will need to use both for complete coverage
2005	Geologic map of the Middletown quadrangle	Brezinski and Fauth	Maryland Geological Survey	Quadrangle Geologic Map	1:24000	GIS data	convert to GRI GIS model
2009	Geologic Map of the Funkstown Quadrangle	Brezinski and Bell	Maryland Geological Survey	Quadrangle Geologic Map	1:24000	GIS data	convert to GRI GIS model
2009	Geologic map of the Myersville quadrangle and Maryland portion of the Smithsburg quadrangle	Brezinski and Fauth	Maryland Geological Survey	Quadrangle Geologic Map	1:24000	GIS data	convert to GRI GIS model; only covers Maryland part of Smithsburg quad
1977	Geologic map of the Catocin Furnace and Blue Ridge Summit	Fauth	Maryland Geological Survey	Quadrangle Geologic Map	1:24000	paper	digitize; only covers Maryland part of Blue Ridge Summit quad
1968	Geologic map of Maryland	Cleaves et al.	Maryland Geological Survey	NA	1:250000	paper	state survey says to not use?
1996	Geology of the Harpers Ferry quadrangle	Southworth, and Brezinski	USGS	Bulletin 2123	1:24000	paper	digitize; overlaps with Keedysville map (USGS id: 87560); will need to use both for complete coverage

Pennsylvania

A 1:250,000 scale compiled map is available for Pennsylvania to fill in gaps on the Appalachian Trail map. Gaps in map coverage exist for the following 7.5' quadrangles: Auburn, Dickinson, Dillsburg, Enders, Fredericksburg, Friedensburg, Grantville, Halifax, Walnut Bottom. The state survey does not have plans to map these quadrangles; however, they are covered in the coarser scale, Map 61, developed for the 1981 state geologic map compilation (Gale Blackmer, Pennsylvania Geological Survey, state geologist, email communication, 24 June 2016).

Table 8. Map coverage for Appalachian National Scenic Trail in Pennsylvania (continues on next two pages)

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1978	Geology and mineral resources of the Iron Springs area	Fauth	Pennsylvania Geological Survey	Atlas 129c	1:24000	paper	digitize; partially covered by Fairfield 15' folio; will need to use both
1968	Geology of the Caledonia Park quadrangle area	Fauth	Pennsylvania Geological Survey	Atlas 129a	1:24000	paper	digitize; missing se corner of calcedonia quad; missing west 1/3 of scotland quad; overlaps with Fairfield 15' folio; need to determine which provides best detail and fit
1967	Geology of a portion of the Mount Holly Springs quadrangle	Freedman	Pennsylvania Geological Survey	Progress Report 169	1:24000	paper	missing se part of quad
1978	Geology and mineral resources of the Carlisle and Mechanicsburg quadrangles	Root	Pennsylvania Geological Survey	Atlas 138ab	1:24000	paper	digitize; just bedrock

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1968	Geologic map of the Tower City quadrangle	Wood	USGS	GQ-698	1:24000	paper	digitize
1968	Geologic map of the Pine Grove quadrangle	Wood and Kehn	USGS	GQ-691	1:24000	paper	digitize
1968	Geologic map of the Swatara Hill quadrangle	Wood and Kehn	USGS	GQ-689	1:24000	paper	digitize
1987	Geologic map of the Hamburg quadrangle	Lash	USGS	GQ-1637	1:24000	paper	digitize; just bedrock
1993	Geology of the New Tripoli quadrangle	Epstein and Lytle	USGS	Bulletin 1994	1:24000	paper	digitize
1986	Geologic map of the Slatedale quadrangle	Lytle et al.	USGS	GQ-1598	1:24000	paper	digitize
1974	Geology and mineral resources of the Lehigh and Palmerton quadrangles	Epstein et al.	Pennsylvania Geological Survey	Atlas 195cd	1:24000	paper	digitize; surf and map of slate quarries and dumps in Martinsburg Fm on different plates
1978	Preliminary geologic map and sections of the Kunkletown 7 1/2-minute quadrangle	Epstein and Sevon	USGS	OF-78-392	1:24000	paper	preliminary; b&w; digitize; north part covered by Monroe County map
1990	Geologic map of the Wind Gap quadrangle	Epstein	USGS	GQ-1645	1:24000	paper	digitize; nw part covered by Monroe County map
1990	Geologic map of the Saylorsburg quadrangle	Epstein	USGS	GQ-1638	1:24000	GRI GIS	extract from DEWA data
1973	Geologic map of the Stroudsburg quadrangle	Epstein	USGS	GQ-1047	1:24000	GRI GIS	extract from DEWA data
1997	Geology and groundwater resources of Monroe County	Carswell and Lloyd	Pennsylvania Geological Survey	Water Resource Report 47	1:48000	paper	part in DEWA data
1989	Groundwater resources of Pike County	Davis	Pennsylvania Geological Survey	Water Resource Report 65	1:50000	paper	parts in DEWA data; other pub for county is PA C52 (1989)
1909	Folio of Chambersburg 15' quadrangle	Stose	USGS	GF-170	1:62500	paper	digitize and incorporate with adjacent/overlapping map data
1929	Folio of Fairfield 15' quadrangle	Stose et al.	USGS	GF-225	1:62500	paper	digitize and incorporate with adjacent/overlapping map data
1980	Geologic map of Pennsylvania (2nd ed.)	Berg et al.	Pennsylvania Geological Survey	Map 1	1:250000	GIS data	use for gaps in coverage
1963	Geology and mineral resources of the northern half of the New Bloomfield quadrangle	Dyson	Pennsylvania Geological Survey	Atlas 137ab	1:24000	paper	digitize east half of map (Duncannon quad)
1967	Geology and mineral resources of the southern half of the New Bloomfield quadrangle, Pennsylvania	Dyson	Pennsylvania Geological Survey	Atlas 137cd	1:24000	paper	digitize east half of map (Wertzeville quad)

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1968	Geology and mineral resources of southeastern Franklin County, Pennsylvania	Root	Pennsylvania Geological Survey	Atlas 119cd	1:24000	paper	digitize Waynesboro quad part and PA part of Smithsburg quad; intergrate with overlapping folio sheet
1981	Atlas of preliminary geologic quadrangle maps of Pennsylvania	Berg and Dodge	Pennsylvania Geological Survey	Map 61	1:62500	paper	digitize b&w maps; use where not covered by more detailed mapping

New Jersey

Geologic map coverage (at 1:24k) in New Jersey is nearly complete except for the Port Jervis South 7.5' quadrangle. The Flatbrookville and Milford quadrangle maps are complete and awaiting final corrections prior to publication. Also, many of the New Jersey maps have complementary surficial maps (Jack Epstein, US Geological Survey, emeritus geologist, scoping meeting comment, 4 May 2016).

Table 9. Map coverage for Appalachian National Scenic Trail in New Jersey

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1992	Bedrock geologic map of the Branchville quadrangle	Drake and Monteverde	USGS	Geologic Quadrangle Map GQ-1700	1:24000	GRI GIS	extract from DEWA data
1992	Bedrock geologic map of the Newton West quadrangle	Drake	USGS	Geologic Quadrangle Map GQ-1703	1:24000	GRI GIS	extract from DEWA data
1992	Bedrock Geologic Map of the Sussex County, New Jersey Portions of the Culvers Gap and Lake Maskenzha Quadrangles	Monteverde	New Jersey Geological Survey	Geologic Map Series GMS 92-1	1:24000	GRI GIS	extract from DEWA data
2014	Bedrock geologic map of the Hamburg quadrangle	Dalton et al.	New Jersey Geological Survey	Geologic Map Series GMS 14-3	1:24000	paper	digitize; need to determine if GIS data is available
2015	Bedrock geologic map of the New Jersey parts of the Greenwood Lake and Sloatsburg quadrangles	Volkert	New Jersey Geological Survey	Open-file Map OFM 106	1:24000	paper	digitize; need to determine if GIS data is available
2004	Bedrock geology of New Jersey	Pristas	New Jersey Geological Survey	Digital Geodata Series DGS 04-6	1:100000	GIS data	use to fill gaps; used for parts of DEWA dataset
1992	Bedrock geologic map of the Unionville quadrangle	Drake and Monteverde	USGS	Geologic Quadrangle Map GQ-1699	1:24000	paper	digitize
2014	Bedrock geologic map of the Wawayanda quadrangle and the New Jersey part of the Pine Island quadrangle	Volkert	New Jersey Geological Survey	Open-file Map OFM 104	1:24000	paper	digitize; need to determine if GIS data is available

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1986	Geologic map of the eastern parts of the Belvidere and Portland quadrangles	Drake et al.	USGS	Miscellaneous Investigations Series Map I-1530	1:24000	GRI GIS	extract from DEWA data
1969	Geologic map and sections of parts of the Portland and Belvidere quadrangle	Drake et al.	USGS	Miscellaneous Geologic Investigations Map I-552	1:24000	GRI GIS	extract from DEWA data

New York

US Geological Survey, emeritus geologist, Nick Ratcliffe has done a lot of mapping in the New York Hudson Valley and highlands areas (Randy Orndorff, US Geological Survey, Director - Eastern Geology and Paleoclimate Center, scoping meeting comment, 4 May 2016). There is likelihood that any gaps in coverage could be filled with some of his unpublished maps.

Table 10. Map coverage for Appalachian National Scenic Trail in New York

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1992	Bedrock geologic map of the Unionville quadrangle, Orange County, New York, and Sussex County, New Jersey	Drake and Monteverde	USGS	Geologic Quadrangle Map GQ-1699	1:24000	digital and paper	convert digital data
?	Bedrock Map of the Greenwood Lake and Warwick 7.5 Minute Quadrangles, Orange County, New York, 1:24,000 Series	Gates and Valentino	New York State Geological Survey	OF number 1g1781	1:24000	paper	obtain scan and digitize
2001	Bedrock Geologic Map of the Monroe, New York 7.5 Minute Quadrangle	Gates and Valentino	New York State Geological Survey	OF number 1g1436	1:24000	paper	obtain scan and digitize
?	Geologic Map of the Popolopen Lake	Gates and Pagano	New York State Geological Survey	OF number 1g1784	1:24000	paper	obtain scan and digitize
?	Draft Geologic Map of the Popolopen Lake Quadrangle	Ratcliffe	USGS	OF number 1g1753	1:24000	paper	obtain draft scan (if you can) and compare with OF 1g1784
?	Draft Map of Peekskill 7 1/2' quadrangle. 1:24,000	Offield	New York State Geological Survey	OF number 1gB1337	1:24000	paper	obtain scan and digitize
?	Draft Map of Peekskill Quadrangle, 1:24,000 Series	Ratcliffe	USGS	OF number 1g1757	1:24000	paper	obtain draft scan (if you can) and compare with OF 1g1784
1968	Preliminary Geologic Map of the West Point 7.5 minute Quadrangle, New York	Murray	New York State Geological Survey	Open File Map 1g1436	1:24000	paper	obtain scan and digitize
1992	Bedrock geology and seismotectonics of the Oscawana Lake quadrangle, New York	Ratcliffe	USGS	Bulletin 1941	1:24000	paper	?

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1911	Geologic Map of the Poughkeepsie (15') Quadrangle	Gordon	New York State Museum	Bulletin 148	1:62500	paper	obtain scan and digitize (covers Hopewell Junction quad.)
1990	Bedrock geologic map of the Poughquag quadrangle, New York	Ratcliffe and Burton	USGS	Geologic Quadrangle Map GQ-1662	1:24000	paper	obtain scan and digitize
?	Draft Geologic Map of the Pawling Quadrangle, 1:24,000 series	Fisher and McLelland	New York State Geological Survey	OF number 1g1261	1:24000	paper	obtain scan and digitize
?	Geologic map of Dover Plains 7 1/2'	Carroll	New York State Geological Survey	OF number 1g050	1:24000	paper	obtain scan and digitize (compare with unpublished from CT)
1970	Geologic map of New York - lower Hudson sheet	Rickard et al.	New York State Museum and Science Service	Map and Chart Series 15	1:250000	GIS data	use to fill gaps; used for parts of DEWA dataset

Connecticut

Geologic map coverage over the six 7.5' quadrangles the Appalachian Trail crosses is complete. Although some maps are listed as unpublished, they may have actually been peer reviewed and assigned an open file number.

Table 11. Map coverage for Appalachian National Scenic Trail in Connecticut

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1975	Bedrock geology of the South Canaan quadrangle, Connecticut	Gates	Connecticut Geological and Natural History Survey	Quadrangle Report 32	1:24000	paper	digitize entire quad
1979	Bedrock geologic map of the Sharon quadrangle, Connecticut	Gates	Connecticut Geological and Natural History Survey	Quadrangle Report 38	1:24000	paper	digitize entire quad
1985	Bedrock Geological Map of Connecticut	Rodgers	State of Connecticut, Department of Environmental Protection	?	1:50000	digital	might use to fill in the gaps at Ellsworth and Dover Plains
1998	Bedrock Geologic Map of the Kent Quadrangle, CT	Jackson	Connecticut Geological and Natural History Survey	Open File OF-98-1	1:24000	digital and paper	convert digital data
1966	Geologic map of the Bashbish Falls quadrangle, Massachusetts, Connecticut, and New York	Zen and Hartshorn	USGS	Geologic Quadrangle Map GQ-507	1:24000	paper	digitize entire quad
?	Unpublished Dover Plains from Connecticut Geological and Natural History Survey	Jackson	Connecticut Geological and Natural History Survey	Unpublished	?	?	possible gap. There is a 1x2 that covers the area

Massachusetts

Geologic map coverage of the Appalachian Trail in Massachusetts is complete. A statewide slope stability map (1:125,000 scale) also exists.

Table 12. Map coverage for Appalachian National Scenic Trail in Massachusetts

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1971	Bedrock geologic map of the Egremont quadrangle and adjacent areas, Berkshire County, Massachusetts, and Columbia County, New York	Zen and Ratcliffe	USGS	Miscellaneous Geologic Investigations Map I-628	1:24000	paper	digitize entire quad
1966	Geologic map of the Bashbish Falls quadrangle, Massachusetts, Connecticut, and New York	Zen and Hartshorn	USGS	Geologic Quadrangle Map GQ-507	1:24000	paper	digitize entire quad
1974	Bedrock geologic map of the Great Barrington quadrangle, Berkshire County, Massachusetts	Ratcliffe	USGS	Geologic Quadrangle Map GQ-1141	1:24000	paper	digitize entire quad
1984	Bedrock geologic map of the Monterey quadrangle, Berkshire County, Massachusetts	Ratcliffe	USGS	Geologic Quadrangle Map GQ-1572	1:24000	paper	digitize entire quad
1985	Bedrock geologic map of the East Lee quadrangle, Berkshire County, Massachusetts	Ratcliffe	USGS	Geologic Quadrangle Map GQ-1573	1:24000	paper	digitize entire quad
1984	Bedrock geologic map of the Pittsfield East quadrangle, Berkshire County, Massachusetts	Ratcliffe	USGS	Geologic Quadrangle Map GQ-1574	1:24000	paper	digitize entire quad
1993	Bedrock geologic map of the Williamstown and North Adams quadrangles, Massachusetts and Vermont, and part of the Cheshire quadrangle, Massachusetts	Ratcliffe et al.	USGS	Miscellaneous Investigations Series Map I-2369	1:24000	paper	digitize entire quad
1958	Bedrock geology of the Cheshire quadrangle, Massachusetts	Herz	USGS	Geologic Quadrangle Map GQ-108	1:24000	paper	crop out missing section of Cheshire

Vermont

Vermont has 1:24,000-scale bedrock maps but they are not all considered published and available digitally. The GRI map team should contact the Vermont Geological Survey to determine access to the maps for the following quadrangles: Hanover, Quechee, Woodstock North, Delectable Mountain, Pico Peak, Killington Peak, Rutland, Wallingford, Danby, Peru, Stratton Mountain, Sunderland, Woodford, and Stamford.

Table 13. Map coverage for Appalachian National Scenic Trail in Vermont

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
2011	Bedrock geologic map of Vermont	Ratcliffe et al.	USGS	Scientific Investigations Map SIM-3184	1:100000	digital and paper	convert digital data (only APPA QOI's)

New Hampshire

Map coverage in New Hampshire exists at 1:62,500-scale for all but the Jackson 7.5' quadrangle. Mapping this area would be an ideal project for a student. In addition to the maps listed in the table below, a Mount Washington map and Mount Dartmouth maps have been completed at 1:3,000-scale.

Table 14. Map coverage for Appalachian National Scenic Trail in New Hampshire

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
2015	Bedrock Geologic Map of the Hanover 7.5 minute Quadrangle	Thompson	New Hampshire Geological Survey	Map Geo-091-024000-BMOF	1:24000	digital and paper	convert digital data
2014	Geologic Map of the Enfield, NH 7.5 Minute Quadrangle	Thompson	New Hampshire Geological Survey	Open-File Reports Geo-092-024000-BMOF	1:24000	digital and paper	convert digital data
2008	Bedrock Geology map of the Lyme 7.5 Minute Quadrangle	Thompson	New Hampshire Geological Survey	Digital Geodata Series Geo-080-024000-BMOF	1:24000	digital	convert digital data
2008	Bedrock Geologic map of the Smarts Mountain Quadrangle, Grafton County, New Hampshire	Thompson	New Hampshire Geological Survey	Map Geo-081-024000-BMOF	1:24000	digital and paper	convert digital data
2015	Bedrock Geology of the Mt. Dartmouth 7.5 minute Quadrangle	Eusden et al.	New Hampshire Geological Survey	Map Geo-046-024000-BMOF	1:24000	digital and paper	convert digital data
1958	Geologic Map and Structure Sections of the Hanover Quadrangle	Lyons	New Hampshire Geological Survey	Map Geo-029-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)
1938	Geologic Map and Structure Sections of the Mascoma Quadrangle, New Hampshire	Chapman	Geological Society of America	Map and Chart Series Geo-030-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)
1938	Geologic Map and Structure Sections of the New Hampshire Portions of the Mt. Cube Quadrangle	Hadley	New Hampshire Geological Survey	Map Geo-023-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1940	Geologic map and Structure Sections of the Rumney Quadrangle, New Hampshire	Page	New Hampshire State Planning and Development Commission	Geologic Maps Geo-024-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)
1935	Geologic map and structure sections of the Moosilauke quadrangle, Grafton County, New Hampshire	Billings	New Hampshire Department of Environmental Services	Geologic Quadrangle Map Geo-018-062500-BMA	1:62500	paper	digitize (coarser scale than above maps to fill in any missing areas)
1935	Bedrock Geologic map of the Franconia Quadrangle, New Hampshire	Billings, and Williams	New Hampshire Geological Survey	Map Geo-019-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)
1977	Geology of the Crawford Notch Quadrangle, New Hampshire	Henderson et al.	New Hampshire Geological Survey	Map Geo-020-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)
1945	Geologic Map and Structure Sections of the Mt. Washington Quadrangle, New Hampshire	Billings et al.	New Hampshire Geological Survey	Map Geo-015-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)
1975	Geology of the Gorham Quadrangle, New Hampshire	Billings and Fowler-Billings	New Hampshire Geological Survey	Map Geo-016-062500-BMAP	1:62500	digital and paper	convert digital data (coarser scale than above maps to fill in any missing areas)

Maine

The only map with seamless and digitized coverage of the Appalachian Trail in Maine is a compiled 1:500,000-scale state bedrock geologic map (available at <http://maine.gov/dacf/mgs/explore/bedrock/index.shtml>). Detailed mapping exists at various scales, but it is not compiled and may not be digitized yet. A gap in detailed maps occurs over the Greenville and Barren Mountain East and West quadrangles. The quadrangles only have surficial materials maps available (just points on a map) which could not feed into the GRI data model. The surficial geologic map of the Millinocket quadrangle covers these areas but is the same data that is on the state 1:500,000-scale map.

Table 15. Map coverage for Appalachian National Scenic Trail in Maine

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1985	Bedrock geology of the Pierce Pond 15' quadrangle, Maine	Boone	Maine Geological Survey	Open-File Map 85-86	1:62,500	pdf	digitize entire quad
1981	Reconnaissance bedrock geology of the The Forks [15-minute] quadrangle, Maine	Burroughs and Marvinney	Maine Geological Survey	Open-File Map 81-10	1:62500	pdf	digitize entire quad
1973	Metamorphic stratigraphy, petrology, and structural geology of the Little Bigelow Mountain map area, western Maine	Boone	Maine Geological Survey	Bulletin 24	1:62500	?	digitize entire quad

Year	Title	Author	Organization	Series	Scale	Format	GRI Action
1977	Geology of the Oquossoc 15' quadrangle, west-central Maine	Guidotti	Maine Geological Survey	Open-File Report 77-2	1:62500	pdf	digitize entire quad
1971	Geologic map of the Rangeley and Phillips quadrangles, Franklin and Oxford Counties, Maine	Moench	USGS	Miscellaneous Geologic Investigations Map I-605	1:62500	pdf	digitize entire quad
1976	Geologic map of the Rumford quadrangle, Oxford and Franklin Counties, Maine	Moench and Hildreth	USGS	GQ-1272	1:62500	pdf	digitize entire quad
1967	Geology and petrology of the Greenville quadrangle, Piscataquis and Somerset Counties, Maine	Espenshade and Boudette	USGS	Bulletin 1241-F	1:62500	digital and paper	convert digital data
1972	Geology of the Moxie pluton in the Moosehead Lake - Jo-Mary Mountain area, Piscataquis County, Maine	Espenshade	USGS	Bulletin 1340	1:62500	digital and paper	convert digital data
2010	A guide to the geology of Baxter State Park and Katahdin	Rankin et al.	Maine Geological Survey	Bulletin 43, 80 p., 2 color maps	1:100000	paper	digitize APPA portion
1985	Bedrock geology of the Pierce Pond 15' quadrangle, Maine	Boone	Maine Geological Survey	Open-File Map 85-86	1:62,500	pdf	digitize entire quad
1981	Reconnaissance bedrock geology of the The Forks [15-minute] quadrangle, Maine	Burroughs and Marvinney	Maine Geological Survey	Open-File Map 81-10	1:62500	pdf	digitize entire quad

Geologic Features, Processes, and Issues

The GRI scoping meeting for Appalachian National Scenic Trail provided an opportunity to develop a list of significant geologic features and processes along and/or adjacent to the trail. During the meeting, scoping participants identified and discussed the following features and processes, some of which may have associated resource management issues. Participants also discussed research and monitoring needs related to these features and processes. Management needs at Appalachian National Scenic Trail will extend beyond the park boundaries.

The geologic features, processes, and issues discussed in this section are not only relevant to park management and decision making, but could become important interpretive themes. Jim Von Haden (Appalachian National Scenic Trail, integrated resources manager, scoping meeting comment, 2 May 2016) pointed out the importance of sharing meaningful interpretive stories with park visitors and hikers because what the public values will ultimately “influence how park staff manages resources and which resources become priorities.” The following list could serve as a good starting point for discussion between park staff and NPS network staff to determine management and data needs (Brian Witcher, NPS Appalachian Highlands Network, program manager, scoping meeting comment, 2 May 2016).

Fluvial (River) Features and Processes

Active fluvial processes are not a major resource management issue. However, fluvial processes are significant from an interpretive standpoint because active processes are creating interesting geologic landforms and ancient fluvial processes are preserved in the rock record. Water gaps are a common feature along the trail, especially in Pennsylvania. Water gaps form where a river creates an opening through a weak spot in a mountain ridge. These weak spots are typically because of a fault or maybe an igneous intrusion. The gap opened by the river often exposes excellent cross sections of geologic strata. On a smaller scale, weathered rock particles that are swirling in eddies can erode bedrock producing large potholes, such as those near Thoreau Falls, New Hampshire (Chew 1988).

Paleontological Resources

All paleontological resources are nonrenewable and subject to science-informed inventory, monitoring, protection, and interpretation as outlined by the 2009 Paleontological Resources Preservation Act. As of August 2016, Department of the Interior regulations associated with the Act were being developed. Though not formally documented within the boundaries of the trail, Appalachian National Scenic Trail has great potential for fossils, most likely from the early Paleozoic Era (Vincent Santucci, NPS Geologic Resource Division, scoping meeting comment, 4 May 2016).

Skolithos—fossilized tube-shaped burrows of a worm-like organism—are possible in at least North Carolina, Tennessee, Virginia, and Pennsylvania (fig. 5). Skolithos have been documented in these states, though not directly on the trail. In Virginia, an undescribed Silurian-aged unit in the Garden Mountain area contains marine invertebrate fossils and skolithos (Chew 1988; Vincent Santucci, NPS Geologic Resource Division, scoping meeting comment, 4 May 2016). A variety of fossils are documented from the Valley and Ridge Province, which the trail passes through in several states.

Adjacent to the trail in Pennsylvania, the Swatara Gap Quarry was a popular Silurian-age trilobite collecting location that was shut down when excavations made by collectors started to undermine the roadway (Gary Fleeger, Pennsylvania Geological Survey, geologist, scoping meeting

presentation, 4 May 2016). Silurian-age trilobite trace fossils also occur at the pinnacle overlook in Pennsylvania but far removed from the trail (Vincent Santucci, NPS Geologic Resource Division, scoping meeting comment, 4 May 2016)

Additionally, plant fossils have been recovered from DeHart Reservoir in Pennsylvania (Vincent Santucci, NPS Geologic Resource Division, scoping meeting comment, 4 May 2016). Fossil fish scales occur where the trail crosses the Delaware River (Jack Epstein, US Geological Survey, emeritus geologist, scoping meeting comment, 4 May 2016). Conodonts and/or graptolites may occur in rocks along the trail in Vermont.



Figure 5. Photograph of skolithos fossils. Skolithos are common in the quartzites of South Mountain, Pennsylvania. Photograph by Gary Fleegeer (Pennsylvania Geological Survey).

Glacial Record

The northern half of the Appalachian Trail shows evidence of Pleistocene glaciation while the southern half does not because glaciers never extended that far south. The transition from glaciated to unglaciated terrain occurs along the trail in Pennsylvania (fig. 4). Bedrock in Pennsylvania shows striations from Wisconsinian glaciation (fig. 6). Glacial polish on bedrock also occurs at Eph's Lookout near the Pine Cobble Trail in northern Massachusetts (Chew 1988). Also in Massachusetts, near the Appalachian Trail but not directly on it, is Natural Bridge State Park. This is the location of an old commercial marble quarry. The park hosts a deep gorge, produced by glacial meltwater streams, that cuts deeply into the marble along joint sets creating a natural marble arch (Joe Kopera,

Massachusetts Geological Survey, geologist, scoping meeting comment, 6 May 2016). The Appalachian Trail crosses the former location of an ancient glacial lake, Lake Albany, near Bear Mountain. Glacial erratics occur near the trail in Connecticut (fig. 7); the Roger's ramp section of the trail passes through a glacial erratic that has split in half. In New Hampshire, relict rock glaciers and patterned ground occur in the presidential range on Mount Washington. A glacial cirque is present on Mount Washington (Chew 1988). In Maine, Mahoosuc Mountain and Mount Katahdin exhibit classic alpine glacier-formed features such as cirques, eskers, and moraines.

South of the Wisconsin glacial border, periglacial features—related to areas at the edge of glaciers—are present but glacial features are absent. Boulder fields, which formed in response to repeated freezing and thawing cycles, occur in Tennessee, West Virginia, and Pennsylvania. These areas may provide habitat for bats.

Geologic features along the Appalachian Trail also show evidence of pre-Pleistocene Glaciation. Lithified glacial lake deposits and till occur in Virginia. A glacier formed in the Mount Rogers area of Virginia sometime near the end of the Precambrian (more than 500 million years ago). Glacial till deposited at this time hardened into a rock called tillite or diamictite. Where the glacier ended in water, varve deposits—light colored sand in summer and dark mud in winter—settled under the surface of the ice and are now preserved in rock in the valley on the north side of Mount Rogers (Chew 1988). Dropstones which fell from melting icebergs are also in the rock (Chew 1988).



Figure 6. Photograph of striated bedrock. Rocks along the trail near Lake Lenape exhibit glacial striations. Photograph by Gary Fleeger (Pennsylvania Geological Survey).



Figure7. Photograph of a glacial erratic. Giant's thumb is an 8-ft-tall glacial erratic near the trail in Connecticut. Photograph courtesy of James Bogart (Connecticut Geological Survey).

Caves and Karst

Cave features are nonrenewable resources. The Federal Cave Resources Protection Act of 1988 requires the identification of “significant caves” in NPS areas, the regulation or restriction of use as needed to protect cave resources and inclusion of significant caves in land management planning. The act also imposes penalties for harming a cave or cave resources and exempts park managers from releasing specific location information for significant caves in response to a FOIA request.

A cave inventory has not been completed for Appalachian National Scenic Trail. Caves are documented in the Shady Valley Dolomite of North Carolina and Tennessee, though they are not abundant and not directly on the trail. In Maryland, quadrangles to the west of the trail were mapped for karst (David Brezinski, Maryland Geological Survey, geologist, scoping meeting comment, 4 May 2016). In Pennsylvania, karst occurs where the trail crosses the Cumberland Plateau and in the Great Valley. The Pennsylvania Geological Survey indicated at the scoping meeting that they may have karst maps available in the area of the trail. Caves do not occur near the trail in Connecticut. Ice caves are located in Stockbridge, Massachusetts (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting comment, 6 May 2016). Talus caves occur in the Mahoosuc Range on the border between Maine and New Hampshire.

Caves provide habitat for wildlife, including some which are federally listed threatened or endangered species. For example, boulder fields create small caves which are known to be inhabited by small-footed bats (Brian Witcher, NPS Appalachian Highlands Network, program manager, scoping meeting comment, 2 May 2016). The GRI geologic map data could be used to help identify potential small-footed bat habitat.

Geothermal Features and Springs

The Geothermal Steam Act of 1970, as amended in 1988 (see Appendix B), 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. Appalachian National Scenic Trail is not included on the list of 16 parks that are designated under the act as having significant thermal features.

There is a hot spring in the Shady Valley Dolomite in North Carolina. The spring is 105° Fahrenheit—just barely able to be called a “hot” spring. The spring is not heated geothermally and is not related to fracking. Rain water infiltrates the subsurface along inactive faults where it is heated as a result of the natural thermal gradient and therefore returns to the surface warm (Kenneth Taylor, North Carolina Geological Survey, state geologist, scoping meeting comment, 2 May 2016). Manganese is present in spring water at this location.

Boiling springs is a spring in Pennsylvania, but it is not a geothermal spring. The water is not hot or even warm. It gets its name from the boiling appearance of water that is forced to the surface as a result of a Jurassic-age diabase dike which forms a barrier (fig. 8; Gary Fleeger, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016).

In Connecticut, Marble Springs is a natural underground spring which can be seen at ground surface just southeast of the “Limestone Spring Lean-to” official shelter. The spring water is considered to be very clean and drinkable (Margaret Thomas, Connecticut Geological Survey, state geologist, scoping meeting comment, 6 May 2016).

In Massachusetts, a 72° Fahrenheit “hot” spring occurs which may be considered a historical resource related to geology on the Appalachian Trail (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting comment, 6 May 2016). These are meteoric waters that infiltrate and are heated by the natural geothermal gradient before returning to the surface. The Sand Spring Recreational Center is located just west of the Appalachian Trail in Williamstown, Massachusetts (Stephen Mabee, Massachusetts Geological Survey, state geologist, scoping meeting comment, 6 May 2016).



Figure 8. Photograph of Boiling springs. Boiling springs in Pennsylvania is not actually boiling, it gets its name from the appearance that the water is boiling. Photograph by Gary Fleege (Pennsylvania Geological Survey).

Slope Movements

Anywhere steep slopes and/or loose rock or soil occur there is the potential for slope movements. Additionally, trail construction and maintenance has the potential to trigger slope movements. Trails should not be cut on slopes such that bedding planes (surfaces separating layers of rock) dip down and toward the trail. Large debris flows occurred in Great Smoky Mountains National Park a couple years ago, but these did not impact the Appalachian Trail (Bart Cattnach, North Carolina Geological Survey, geologist, scoping meeting comment, 2 May 2016). In Pennsylvania, a large rockfall occurred at Lehigh Gap (Jack Epstein, US Geological Survey, emeritus geologist, scoping meeting comment, 4 May 2016). A debris flow occurred in Shenandoah National Park in the mid-1990s; Dave Steensen of the NPS Geologic Resources Division was involved in the response and should be consulted during the preparation of the GRI report. In Massachusetts, landslide scars on Mount Greylock are visible on Lidar maps and on mountain viewing from the east (Joe Kopera, Massachusetts Geological Survey, geologist, scoping meeting comment, 6 May 2016).

In New Hampshire, the Willey slide of 1827 killed 9 people and restricted travel in and out of Crawford Notch. Curious tourists came up to see the White Mountains following the event. The Carter Dome quadrangle geologic map has one landslide deposit mapped right on the Appalachian Trail, which is unusual for a bedrock map (Rick Chormann, New Hampshire Geological Survey,

state geologist, scoping meeting presentation, 6 May 2016). Rock slides were documented in King Ravine, New Hampshire (Chew 1988).

Seismic Activity

Appalachian National Scenic Trail is not in a very seismically active area, however, earthquakes do occur. The Southern Appalachian Seismic Zone, which runs from Alabama to West Virginia, activates periodically every 40–60 years and we are coming up on the peak of it (Kenneth Taylor, North Carolina Geological Survey, state geologist, scoping meeting comment, 2 May 2016). The Federal Emergency Management Agency placed the Lancaster Seismic Zone in Pennsylvania in the moderate risk category. Earthquakes occur in New York and Vermont every once in a while, 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). Following an earthquake in 2011, a USGS team documented slides along the Blue Ridge Parkway because it was suspected the two were related (Matt Heller, Virginia Division of Geology and Mineral Resources, geologist supervisor, scoping meeting comment, 4 May 2016). The Weston Observatory at Boston College monitors seismic activity in New England; shaking occurs but almost never causes damage or is strong enough to be felt.

Abandoned Mineral Lands

Acid producing rocks probably occur along the trail in North Carolina; further investigation is required to pinpoint locations (fig. 9; Bart Cattanach, North Carolina Geological Survey, geologist, scoping meeting comment, 2 May 2016).

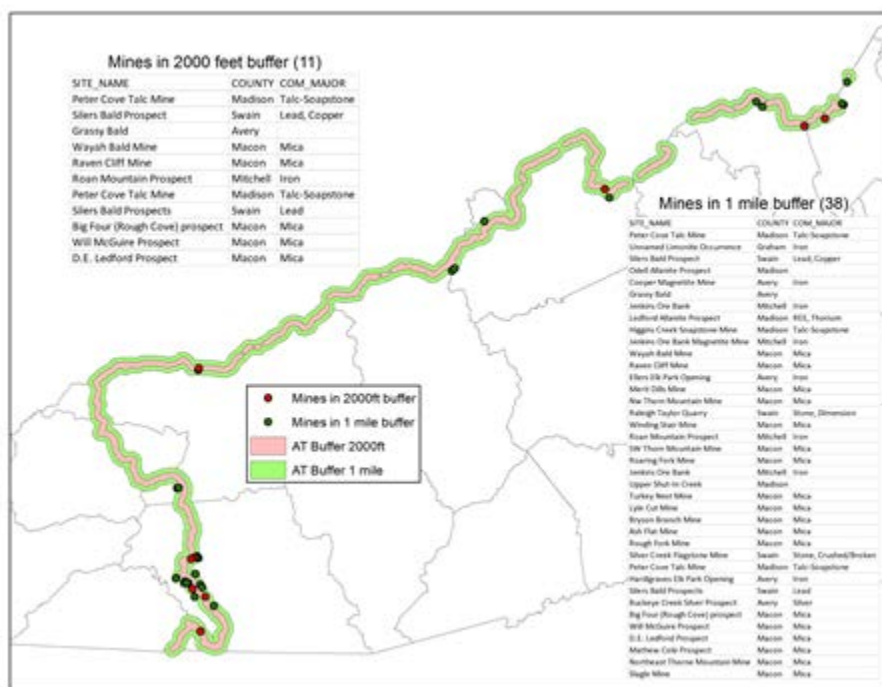


Figure 9. Map of mines near the Appalachian Trail in North Carolina. Acid producing rocks probably occur along the trail in North Carolina. Further investigation is required to pinpoint locations. Graphic by Bart Cattanach (North Carolina Geological Survey).

Anthracite coal mining and coal towns are part of the history of Pennsylvania and acid mine drainage occurs along the Appalachian Trail (Gary Fleege, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016). The “Palmerton Zinc Superfund Site” at

Lehigh Gap is devoid of vegetation due to zinc smelting in Palmerton; it is currently a superfund site and remediation is ongoing. For the few miles where the Appalachian Trail approaches Lehigh Gap there is little vegetation on Blue Mountain (fig. 10). There is a slate belt to the south of the trail in Pennsylvania and slate dumps and abandoned quarries occur near the trail. The Appalachian Trail passes several coal mining ghost towns, such as Rausch Gap and Yellow Springs. Just after passing through Rausch Gap, the trail passes a long abandoned strip mine situated on the Mammoth coal seam (Gary Fleeger, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016). The trail passes near Fuller Lake in Pine Grove Furnace State Park. It is an abandoned 90-ft-deep iron ore pit (Gary Fleeger, Pennsylvania Geological Survey, geologist, scoping meeting presentation, 4 May 2016).



Figure 10. Photograph of the Appalachian Trail approaching Lehigh Furnace Gap. Lehigh Gap is devoid of vegetation due to zinc smelting in Palmerton. Photograph by Gary Fleeger (Pennsylvania Geological Survey).

Many abandoned mines exist in New York, some near Appalachian National Scenic Trail. The Phillips mine may be an issue along the Appalachian Trail due to acid mine drainage, the potential for radioactive uraninite, and the close proximity to hikers on the trail (Bill Kelly, New York Geological Survey, state geologist, scoping meeting presentation, 6 May 2016).

Northwest Connecticut was the foremost iron producer for the country for over 200 years starting in the mid 18th century. Civil War Landmarks remain at many points along the Appalachian Trail in Connecticut. Iron furnace ruins are located at Great Falls and Bull's Bridge sites, as well as charcoal

pits lining the trail from the base of Bear Mountain to the Riga campsite (James Bogart, Connecticut Geological Survey, intern, scoping meeting presentation, 6 May 2016). Iron ore deposits come from the Walloomsac Schist near the contact with the underlying Stockbridge Marble. Iron deposits are “bog ore” type, where iron precipitated from iron rich waters of the ancient Iapetus Ocean. The hazard potential of former iron operations in Connecticut in relation to the Appalachian Trail is not known at this time. The Connecticut Geological Survey could do site visits for mines/quarries and assess their hazard level (Margaret Thomas, Connecticut Geological Survey, state geologist, scoping meeting comment, 6 May 2016).

In New Hampshire, the Appalachian Trail passes an old lead, copper, and zinc mine that may be a superfund site now (Rick Chormann, New Hampshire Geological Survey, state geologist, scoping meeting presentation, 6 May 2016). The mine was abandoned in 1915. The owners left several piles of tailings and waste rock on site. When water ran through the tailings and waste rock it 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).

External Energy Development

The potential exists for energy development adjacent to or within the viewshed of Appalachian National Scenic Trail which may impact the quality of resources along the trail. Renewable energy operations, specifically wind turbines, are proposed in Main and Vermont. Wind turbine designs are getting progressively taller, increasing their potential to impact the trail and its resources. NPS staff at the park is already working with GRD staff to address these issues. There are currently around ten proposals for gas pipelines to cross the trail (Wendy Janssen, Appalachian National Scenic Trail, superintendent, scoping meeting comment, 6 May 2016). Mining operations near the trail could 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 in Maine; and glacial till gravel pits.

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