Supplemental Report: Geologic Resources
Part of
Air, Soil, Water and Geologic Resources Assessment
Plan Revision
Nantahala and Pisgah National Forests

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Prepared by: Thomas K. Collins
Geologist
USDA – Forest Service

Geologic Resources

The Nantahala and Pisgah NFs are endowed with a wide range of geologic resources including, but not limited to, groundwater, groundwater-dependent ecosystems, springs, scenic and unusual landforms, waterfalls, minerals, field records of catastrophic events (floods and landslides), paleontological resources, and field records of climatic changes and Quaternary ecosystems. Geologic resources are geologic features or conditions (processes, materials, structures, landforms) that are significant to natural resource management or human health and safety or that have use or value to society. Geologic resources are identified and managed for scientific, ecological, scenic, recreational, public safety, historic, paleontological, educational, interpretative, provisioning services, and other values.

Geologic resources include not only soil and water but the whole range of Earth resources. Soil and surface waters are the thin skin of the Earth and occupy less than 1% of the Earth. Geologic resources include a wider range of surface resources as well as subsurface resources, such as caves, shallow and deep groundwater aquifers, and mineral resources. Mineral resources (including energy resources such as geothermal) are geologic resources, but are considered in the Energy and Minerals section of the Assessment. Similarly, the scenic mountains, streams, waterfalls, and other geologic resources that are the foundation for recreation are discussed in Recreation section of the Assessment. The following section focuses on the geologic resources that are the foundation for ecosystems and watersheds.

Geologic resources: four-dimensional foundation of ecosystems and watersheds

The geologic resources that are the foundation of ecosystems and watersheds on the Forest are the unique mix of geologic processes, materials, structures, and landforms on the Forest in the Blue Ridge of western North Carolina, including:

1. Geologic processes: fluvial, mass wasting (landslides), groundwater movement, weathering, climate change, etc.,

2. Geologic materials (Earth's solids, liquids, gases): variety of bedrock, surficial deposits including soils, surface water and groundwater, atmosphere, radon, methane, geothermal vapors, etc.,

3. Geologic structures: fractures, folds, faults, joints, strike and dip of planar surfaces, stratigraphy and the three dimensional distribution and arrangement of geologic materials, etc.,

4. Geologic landforms at all scales: waterfalls, exfoliation domes (Looking Glass Rock), Blue Ridge escarpment, landslides, dip slope mountains, stream cascades/riffles/pools, etc.

These geologic features and conditions control or influence a host of other ecological factors, such as slope aspect (solar radiation); slope steepness; the distribution and composition of soil, parent material and associated vegetation; the characteristics of flooding and floodplains, wetlands, riparian areas, and streams; the quantity and quality of surface water and groundwater; natural disturbance regimes such as flooding and landslides; the physical properties and chemical compositions of watersheds; and acid deposition sensitivity of soil and water due to air pollution, such as displayed in the acid deposition sensitivity map of the Southern Appalachian Assessment Area (Peper and others, 1995).

Different geologic processes operating on different geologic materials and structures at different time scales create different landforms and a variety of ecosystems. Geological diversity is the foundation of ecosystem diversity and biological diversity. Geologic science provides an in-depth, three dimension perspective and understanding of ecosystem and watersheds.

Geologic science also adds the comprehensive fourth dimension of time extending from the present to past decades, centuries, millennia, and longer. The comprehensive scope of geologic time and geologic processes extending from the present to the distant past is fundamental science required to understand the natural range of variation of ecosystems, watersheds, and climate change. Geologic processes operate every day, every year, and range from barely perceptible processes to catastrophic processes like the flooding and landslides in 2013 that affected the Forest and downslope private land.

In the following discussion, “geology” is shorthand for the multi-component “geologic resources (processes, materials, structures and landforms)” that is the foundation of ecosystems and watersheds.

Post-current Plan research and recognition of multi-faceted role of geology in ecosystems

Since the early 1990s the Forest Service has emphasized an ecosystem approach to management of the National Forests. Simultaneously, other federal agencies, state agencies, and universities also were emphasizing ecosystems and conducting research into the abiotic and biotic components of ecosystems. As a result, in regard to geology, the main trend since adoption of the current Forest Plan has been more research and recognition that 1) geology is the foundation of ecosystems, 2) geologic science is fundamental to science-informed management of ecosystems.

For example, to implement its science strategy “Geology for a changing world 2010–2020”, — the U.S. Geological Survey notes:

“A comprehensive understanding of the Earth’s geologic framework is needed to inform the critical decisions the Nation and the world will make about resource utilization, environmental quality, and hazard mitigation…”

“The science of geology has the power to help us understand the processes that link the physical and biological world so that we can model and forecast changes in the system…”

“Studies of the Earth’s crust… provide the foundation for understanding most geological processes of societal significance. Life occurs upon or within the Earth and is sustained by its interactions with water, the atmosphere, and sunlight. Moreover, the nature of available geological materials has been a primary influence on the rise and fall of past civilizations. Soils that are derived from the weathering and erosion of surficial geologic materials are the foundation of agriculture…Thus, a geological understanding of how the Earth works is vital to improving our understanding of energy, mineral, soil, and water resources, how our climate is changing, where and when hazards will occur, and the sustainability of life itself." (Gunderson and other, 2011)

Geologic science is an interdisciplinary and overarching earth science that investigates the influences and interrelationships of climate, geomorphic processes, topography, bedrock, surficial deposits, soils, plants and animals, surface and groundwater, and other abiotic and biotic components of ecosystems. Geologic science is fundamental to management of soil and water resources as well as watersheds and ecosystems. Conversely, resource management without geologic science would be skin deep and superficial and not informed by basic science, let alone best available science. Since the current Nantahala and Pisgah Forest Plan was adopted, there has been more research and information about integrating geologic science in watershed and ecosystem management that prompt a "need for change" for Plan Revision. More examples of this research and information are in the following sections.

Geologic foundation of ecosystems on Nantahala & Pisgah NFs

The relationship of geology to site fertility is a basis for the Ecological Zones in the Southern Appalachians: first approximation by Simon and other (2005). Western North Carolina including the Nantahala & Pisgah NFs occupies most of the Ecological Zones area. Some relevant highlights from this Southern Research Station Research Paper are:

> "Forest environments of the Southern Appalachian Mountains and their characteristic plant communities are among the most varied in the Eastern United States. Considerable data are available on the distribution of plant communities relative to temperature and moisture regimes, but not much information on fertility as an environmental influence has been published... Our objectives were to identify predominant ecological units, develop a grouping of geologic formations related to site fertility, and model and map ecological zones of the Southern Appalachians…Eight lithologic groups were identified by rock mineral composition that upon weathering would result in soils of low or high availability of base cations. The presence or absence of ecological zones (large areas of similar environmental conditions consisting of temperature, moisture, and fertility, which are manifested by characteristic vegetative communities) were modeled as multivariate logistic functions of climatic, topographic, and geologic variables…The most important model variables were elevation, precipitation amount, and lithologic group… Results of this project suggest that bedrock geology is an important factor affecting the distribution of vegetation. The developed map is a realistic depiction of ecological zones that can be used by resource managers for purposes ranging from broad-scale assessment to local-scale project planning." (Simon and other, 2005).

The geologic foundation of ecosystems was investigated by Pittillo and others (1998) who reported:

> "The Southern Blue Ridge Province of the Appalachian Mountains is defined by its geographic distribution, geology, soils, and vegetation… The long history of the Southern Blue Ridge is expressed, often cryptically, in its rocks, soils, and vegetative cover. Geological processes that have given rise to the diverse mixture of rocks are complex and geological interpretations require continuous revision with the appearance of new data. These rocks are dominantly metamorphic and were derived from recrystallization of a variety of sedimentary, volcanic, or igneous rocks. They provide a variety of parent materials for soil development. The long-term interactions of climate, topography, and vegetation on these materials have produced regional soil complexes that are generally acidic and nutrient poor. Vegetation of the Province is similarly complex and ancient."

An example of the geologic foundation of ecosystems is the ultramafic rock found in Buck Creek area on the Nantahala NF, described by Pittillo and others (1998) as:

> "Ultramafic bodies produce unique environments worldwide, regardless of climate. Dark red, relatively fertile soils like Ellijay (fine-loamy, mixed, mesic Rhodic Kanhapludalfs) are commonly present at these locales. These soils contain high quantities of magnesium and often nickel and chromium, but are potassium-poor (Mansberg and Wentworth 1984). The largest dunite (>90 percent olivine, [Mg,Fe]2 SiO4) body in the Appalachians occurs along Buck Creek west of Franklin, North Carolina. Numerous smaller dunite and other ultramafic bodies (e.g., the Webster-Addie body near Sylva) are present throughout the eastern Blue Ridge and western Piedmont (Hatcher 1970, Hatcher et al. 1984, Misra and McSween 1984). The Buck Creek body supports a plant assemblage of pitch pine-oak/prairie grasses instead of the surrounding oak or oak-mixed hardwoods (Mansberg and Wentworth 1984). Often the species living on these potassium-deficient soils have different physical appearance and may be evolving to different species, as indicated by the dense tomentum characterizing *Senecio aureus* at the Buck Creek site."

Another example of the geologic foundation of ecosystems is from a study of the Linville Gorge Wilderness on the Pisgah National Forest. Newell and Peet (1998) reported:

> "Montane Oak Forests and Rich Cove and Slope Forests are present, but are limited in distribution. The atypical concentrations of the latter class on high-elevation ridgelines results from underlying nutrient-rich bedrock…
>
> "Much of our understanding of vegetation of the southern Appalachian Mountains is based on information from a few key research areas. However, the climatic, topographic, and geologic complexity of this region suggests that those areas represent only a small subset of the variation in vegetation and underlying environmental conditions across the region…
>
> "In Linville Gorge, textural variation corresponds closely with differences in soil fertility and surficial geology. Soils underlain by Lower Quartzite tend to be less fertile and more silty in comparison to the nutrient-rich soils of gneiss, metaarkose, phyllite and Upper Quartzite (Table 2). A multiple analysis of variance indicated statistically significant differences in soil chemistry and soil texture among the six surficial geology types (Newel1 1997)."

Geology: wide-ranging, multiple component foundation of ecosystems

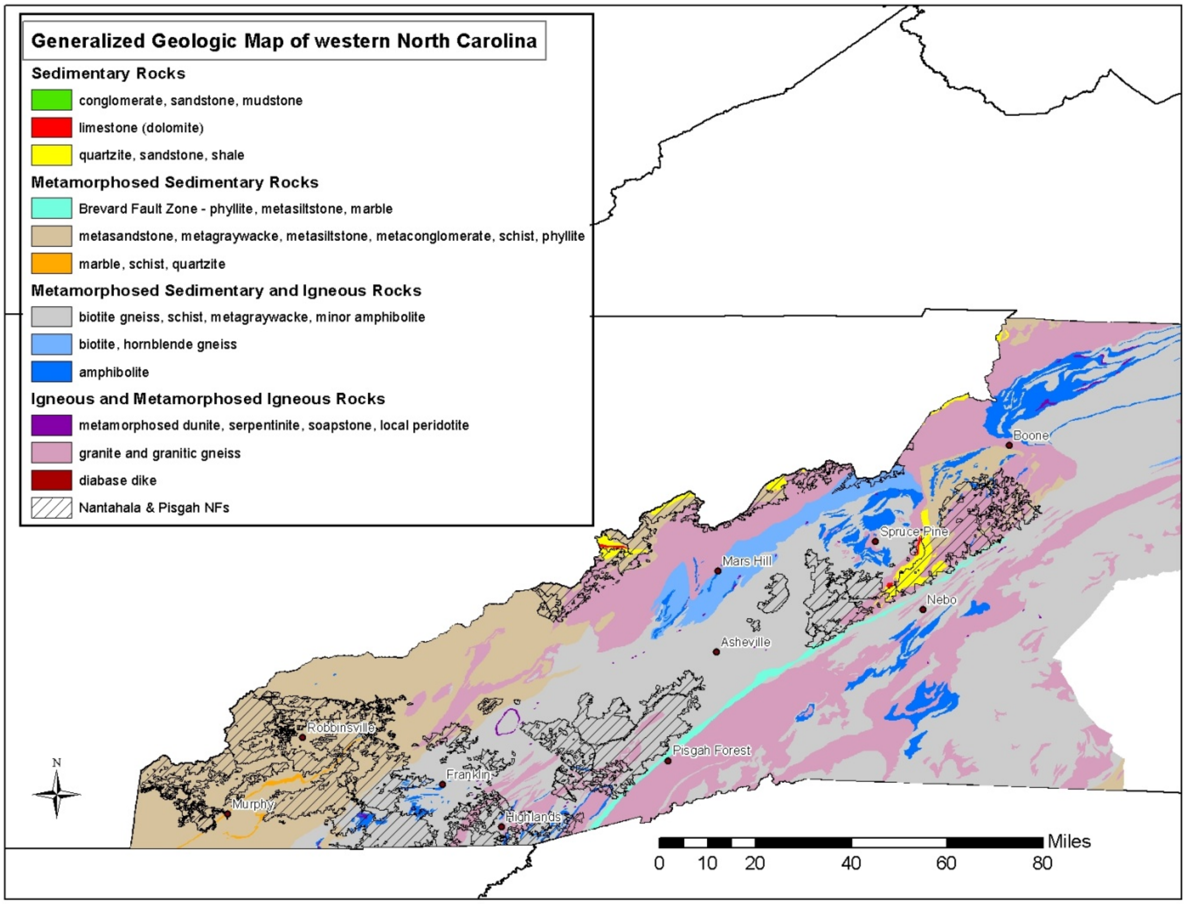
Lithology is one component of geology and is one geologic component of ecosystems. But geology is a wide-ranging, multiple-component foundation of ecosystems that encompasses much more than lithology. For example, geomorphology, groundwater, and geologic hazards are examples of other components of geology and ecosystems. Geology includes not just lithology or solid materials like bedrock and surficial deposits like soil, colluvium and alluvium but also the fluids like surface water and groundwater. Geology also includes geologic processes (such as weathering, flooding, mass wasting (landslides), surface water and groundwater movement, etc.), geologic structures (fracture systems, bedding, folds, faults), and geologic (geomorphic) landforms. Multiple components of geology control or influence multiple components of ecosystems.

Multiple components of geology in ecosystems are included in the Western North Carolina Vitality Index (http://www.wncvitalityindex.org/) developed and funded by the Mountain Resources Commission in partnership with the Blue Ridge National Heritage Area and the USDA Forest Service. The Mountain Resources Commission was established during the 2009 North Carolina General Assembly legislative session. The Western North Carolina Vitality Index assesses components of the vitality of 27 counties in western North Carolina through the perspectives of their natural, social, built, and economic environments. The Index is made to allow planners and decision makers the information necessary to inspire quality discussion and craft informed decisions on issues affecting western North Carolina's abundant natural resources and its potential for sustainable growth (North Carolina Mountain Resources Commission, 2012a,b).

The 18 counties where the Nantahala and Pisgah NFs are located are part of the 27 counties covered by the Western North Carolina Vitality Index. The Index draws on information from various State agencies including the North Carolina Department of Environment and Natural Resources, North Carolina Geological Survey, and Land Quality Section.

A Generalized Geologic Map of bedrock provides a broad overview of the sedimentary, metamorphic and igneous bedrock on the Nantahala and Pisgah NFs (Figure 1).

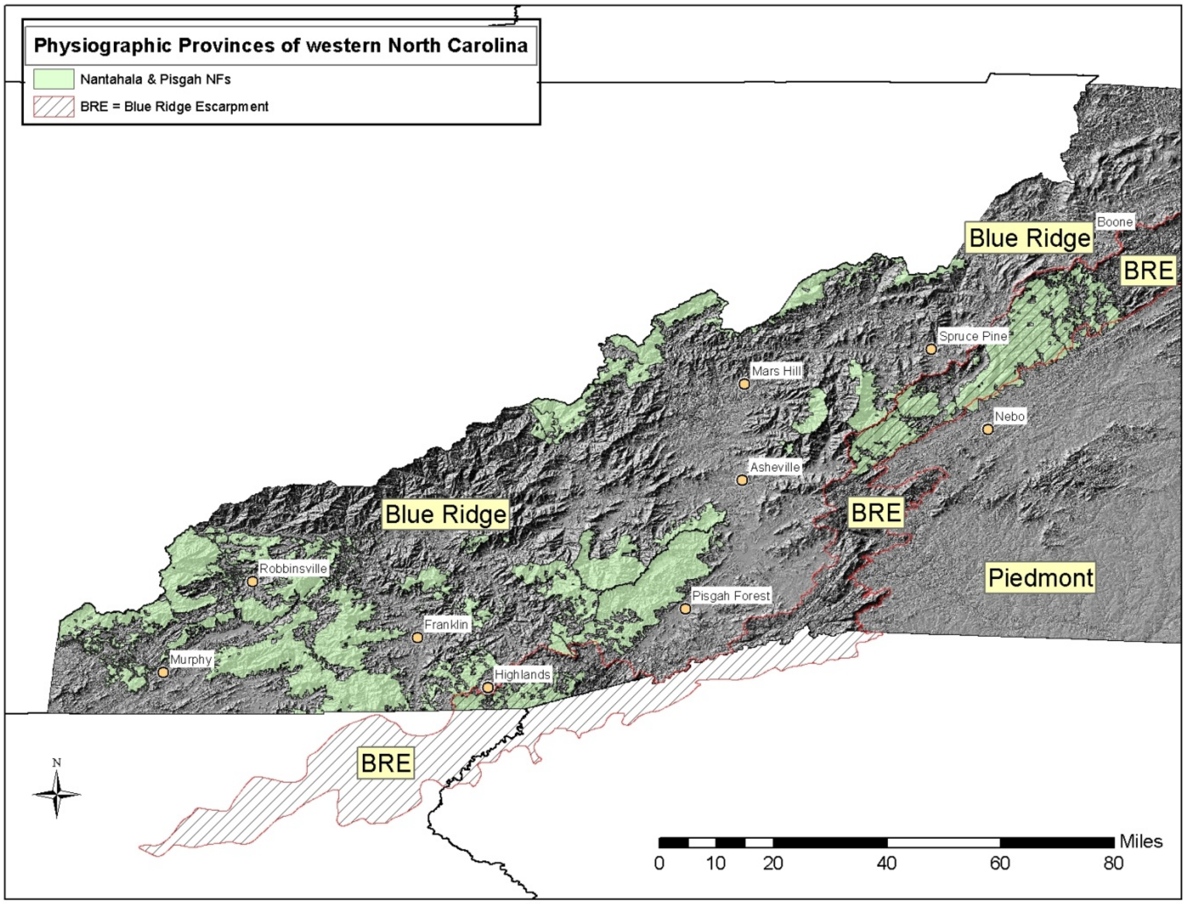
Figure 1. Generalized Geologic Map of bedrock on Nantahala and Pisgah NFs in western North Carolina. Map modified from Generalized Geologic Map produced by North Carolina Geologic Survey for Western North Carolina Vitality Index (North Carolina Mountain Resources Commission, 2012a).



The Nantahala and Pisgah NFs are located in the Blue Ridge Physiographic Province of the Southern Appalachian Mountains (Figure 2). The Blue Ridge forms a southwest to northeast mountain range through western North Carolina with many areas over 4,000 feet in elevation. The Nantahala & Pisgah NFs generally occupy the upper slopes of dissected, steep terrain and narrow, mountain valleys.

Surface geologic processes are an important part of the natural disturbance regime in the Forest. These processes include: the erosion, transport and deposition of sediment; mass wasting or landslides; flooding; stream processes; groundwater movement. The processes are part of the natural disturbance regime in the mountains and affect the Forest in varying degrees every year. Some processes are geologic hazards that create risks to the public. The interaction of the surface geologic processes with the different geologic materials and geologic structures produced different landforms at different scales, from a site specific scale, like at a waterfall, to a physiographic province scale (Figure 2).

Figure 2. Physiographic Provinces and Geomorphic Features Map of Nantahala & Pisgah NFs in western North Carolina. Map based on Physiographic Provinces and Geomorphic Features Map produced by North Carolina Geologic Survey for Western North Carolina Vitality Index (North Carolina Mountain Resources Commission, 2012b).



An example of geologic control on streams and rivers is described in the Western North Carolina Vitality Index:

> "In the Blue Ridge Province, erosion of uplifted mountains of resistant metamorphic and igneous rocks has produced a rugged landscape. The overall southwest to northeast trend of the landscape results from a similar pattern in the underlying rocks and structures imparted during Paleozoic mountain building events. Streams and rivers cut down through the mountains along less resistant rock types, and along faults and fracture zones. A prime example is the long, linear topography along the Brevard fault zone. Many streams that flow northwest or southeast follow trends of post-Paleozoic fracture zones in the bedrock that favor preferential down cutting and erosion by water." (North Carolina Mountain Resources Commission, 2012b)

The Blue Ridge Escarpment extends along the east side of the Blue Ridge and includes most of the Grandfather Ranger District and portions of the Nantahala and Pisgah Ranger Districts along the NC/SC Stateline. The Blue Ridge Escarpment has several significant effects, as described in the Western North Carolina Vitality Index:

> "The transition zone between the Blue Ridge and Piedmont provinces is the Blue Ridge Escarpment, an abrupt change in elevation with a vertical relief that ranges from about 1,300 to 2,500 feet. Its upper boundary generally coincides with the Eastern Continental Divide, which separates river systems that flow westward into the Gulf of Mexico from those that flow eastward into the Atlantic Ocean…Streams flowing eastward to the Atlantic Ocean generally are shorter, straighter, and more energetic than those flowing westward across the Blue Ridge into the Mississippi River system and into the Gulf of Mexico. Consequently, the Escarpment and Eastern Continental Divide are slowly migrating westward by headward erosion…
>
> "The Escarpment influences weather patterns, tourism, and transportation, among others. The region's highest annual rainfall is in Transylvania County, where weather systems collide with the Escarpment, thereby enhancing rainfall. Higher amounts of rainfall fell along the Escarpment during the storms of July 15-16, 1916, and August 10-17, 1940, that impacted much of the MRC region. The record rainfall for North Carolina of 22 inches in 24 hours fell during the July 15-16, 1916, storm at Alta Pass, near the crest of the Escarpment in Mitchell County. Many waterfalls are present along the Escarpment, including the much-visited Whitewater Falls in Transylvania County…" (North Carolina Mountain Resources Commission, 2012b)

The Nature Conservancy (Anderson and other, 2013) used geology to develop Ecological Land Units in the Southern Blue Ridge, including the Nantahala and Pisgah NFs, and noted,

"The Southern Blue Ridge is a forested landscape of steeps slopes, high mountains, deep ravines, and wide valleys. The combination of intact temperate forest over a diversity of landforms, elevation zones, and bedrock geologies, makes it one of the most biologically diverse areas in North America." The Nature Conservancy developed a four-step analysis process to assess, prioritize, and direct conservation strategies to protect the Southern Blue Ridge matrix forest system. One of the steps is:
Classify the candidate matrix forest blocks into multiple groups that reflect similar combinations of elevation, geology, and landforms (Ecological Land Units).

In addition, "… local lithology is usually the principle determinant of soil chemistry, texture, and nutrient availability… We grouped bedrock units on the bedrock geology maps of Virginia, North Carolina, Tennessee, South Carolina, and Georgia into nine general classes, designed to have particular relevance to vegetation distributions."

The "geology" in these Ecological Land Units is bedrock geology, also referred to as "lithology". As discussed earlier in this Assessment, the "landforms" are a subset of geology, just as lithology is a subset of geology. The "elevation" in these Ecological Land Units is another characteristic or derivative of the landforms which are a result of geologic processes acting on geologic materials embedded with geologic structures (geomorphology).

Climate Change

The Nature Conservancy (Anderson and Ferree, 2010) explains the importance of incorporating geology into climate change strategies:

"Current recommendations for addressing climate change in conservation planning largely focus on predicting future habitat for individual species based on climatic envelope models [2]. Although these models have helped catalyze attention, and clarify the thinking about climate change effects, their utility has come under question because they are hindered by large uncertainties, and often unrealistic assumptions…From the perspective of our results, adding geology, elevation, and landforms to the models might allow for more realistic results and in many cases narrower predictions of suitable habitat…For instance, it is unrealistic to expect the species comprising a limestone valley bottom ecosystem to simply move up on to granite slopes, and thus it is necessary to consider how to prevent their isolation from other limestone settings, and how to maintain the flow of processes and species between like settings."

In investigating the underpinnings of species diversity, the researchers Anderson and Ferree (2010), stated:

> "We chose to focus on geology because geology defines the available environments, determines the location of key habitats, and stimulates diversification [7]… In essence, geology directly shapes species diversity patterns through its influence on the chemical and physical properties of soil and water, and by creating topography that redistributes climatic effects creating predictable weather patterns and microclimates." The researchers reported, "Our results suggest that geological diversity, elevation range and latitude explain regional species diversity patterns within eastern temperate North American…Thus, as we head into a period of dramatic climate-driven rearrangement of species distribution patterns, we assert that conserving a full spectrum different geology classes stratified across elevation zones and latitudes, may offer an approach to conservation that protects diversity under both current and future climates."

Paleontological Resources (Fossils)

North Carolina Geological Survey Bulletin 89 "Fossil Collecting in North Carolina" provides information on where to find fossils and how to collect and identify fossils in North Carolina (Carter and others, 1988). Bulletin 89 notes:

"Fossil collecting is enjoyed by a large number of amateur and professional paleontologists in North Carolina. The popularity of this pursuit reflects the aesthetic and scientific value of fossils, plus the fact that eastern North Carolina has some of the richest fossil localities in eastern North America…The selected fossil localities are restricted to eastern North America (see back cover). The rocks comprising the mountains of western North Carolina generally lack fossils, or their fossils are poorly preserved and difficult to collect."

The Nantahala and Pisgah NFs are located in western North Carolina, and so, fit into this assessment of "generally lack fossils, or their fossils are poorly preserved and difficult to collect".

Congress passed the Paleontological Resources Preservation Act of 2009 (Public Law 111-11) which establishes a framework for management and protection of paleontological resources on federal lands. In the Act, the term 'paleontological resource' means "any fossilized remains, traces, or imprints of organisms, preserved in or on the earth's crust, that are of paleontological interest and that provide information about the history of life on earth, except that the term does not include--

(A) any materials associated with an archaeological resource (as defined in section 3(1) of the Archaeological Resources Protection Act of 1979 (16 U.S.C. 470bb(1)); or

(B) any cultural item (as defined in section 2 of the Native American Graves Protection and Repatriation Act (25 U.S.C. 3001))."

The Act requires a permit to collect paleontological resources on federal lands except no permit is required for casual collecting where such collection is consistent with the laws governing the management of the federal land and the Act. In the Act, the term 'casual collecting' means "the collecting of a reasonable amount of common invertebrate and plant paleontological resources for non-commercial personal use, either by surface collection or the use of non-powered hand tools resulting in only negligible disturbance to the Earth's surface and other resources."

Link to Paleontological Resources Preservation Act of 2009 (Public Law 111-11)
http://www.fs.fed.us/geology/PaleoResourcePres.pdf

In 2013 the Forest Service issued for public comment a proposed rule to implement the Act. The Forest Service is analyzing the public comments on the proposed rule, and is expecting to issue a final rule in the last half of 2014.

USDA – Forest Service, 2013, Paleontological Resources Preservation: Proposed Rule. Federal Register,Vol. 78, No. 100, Notice of Proposed Rule; Request for Comment, May 23, 2013. p.30810-30828
http://www.fs.fed.us/geology/paleo%20rule.pdf

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