National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

National Park Service Geologic Type Section Inventory

Appalachian Highlands Inventory & Monitoring Network

Natural Resource Report NPS/APHN/NRR—2021/2278

ON THE COVER
Cades Cove in Great Smoky National Park. Exposures located in the foothills near Cades Cove are the type locality of the Neoproterozoic Cades Sandstone (NPS/KEVIN NOON).

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

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Executive Summary

A fundamental responsibility of the National Park Service (NPS) is to ensure that park resources are preserved, protected, and managed in consideration of the resources themselves and for the benefit and enjoyment by the public. Through the inventory, monitoring, and study of park resources, we gain a greater understanding of the scope, significance, distribution, and management issues associated with these resources and their use. This baseline of natural resource information is available to inform park managers, scientists, stakeholders, and the public about the conditions of these resources and the factors or activities which may threaten or influence their stability.

There are several different categories of geologic or stratigraphic units (supergroup, group, formation, member, bed) which represent a hierarchical system of classification. The mapping of stratigraphic units involves the evaluation of lithologies, bedding properties, thickness, geographic distribution, and other factors. If a new mappable geologic unit is identified, it may be described and named through a rigorously defined process that is standardized and codified by the professional geologic community (North American Commission on Stratigraphic Nomenclature 2005). In most instances when a new geologic unit such as a formation is described and named in the scientific literature, a specific and well-exposed section of the unit is designated as the type section or type locality (see Definitions). The type section is an important reference section for a named geologic unit which presents a relatively complete and representative profile for this unit. The type or reference section is important both historically and scientifically, and should be recorded so that other researchers may evaluate it in the future. Therefore, this inventory of geologic type sections in NPS areas is an important effort in documenting these locations in order that NPS staff recognize and protect these areas for future studies.

The documentation of all geologic type sections throughout the 423 units of the NPS is an ambitious undertaking. The strategy for this project is to select a subset of parks to begin research for the occurrence of geologic type sections within particular parks. The focus adopted for completing the baseline inventories throughout the NPS was centered on the 32 inventory and monitoring networks (I&M) established during the late 1990s. The I&M networks are clusters of parks within a defined geographic area based on the ecoregions of North America (Fenneman 1946; Bailey 1976; Omernik 1987). These networks share similar physical resources (geology, hydrology, climate), biological resources (flora, fauna), and ecological characteristics. Specialists familiar with the resources and ecological parameters of the network, and associated parks, work with park staff to support network level activities (inventory, monitoring, research, data management).

Adopting a network-based approach to inventories worked well when the NPS undertook paleontological resource inventories for the 32 I&M networks. The network approach is also being applied to the inventory for the geologic type sections in the NPS. The planning team from the NPS Geologic Resources Division who proposed and designed this inventory selected the Greater Yellowstone Inventory and Monitoring Network (GRYN) as the pilot network for initiating this project. Through the research undertaken to identify the geologic type sections within the parks of the GRYN methodologies for data mining and reporting on these resources was established.

Methodologies and reporting adopted for the GRYN have been used in the development of this type section inventory for the Appalachian Highlands Inventory & Monitoring Network.

The goal of this project is to consolidate information pertaining to geologic type sections which occur within NPS-administered areas, in order that this information is available throughout the NPS to inform park managers and to promote the preservation and protection of these important geologic landmarks and geologic heritage resources. The review of stratotype occurrences for the APHN shows there are currently no designated stratotypes for BISO or OBED; BLRI has one type locality; and GRSM has one type section, five type localities, and three type areas.

This report concludes with a recommendation section that addresses outstanding issues and future steps regarding park unit stratotypes. These recommendations will hopefully guide decision-making and help ensure that these geoheritage resources are properly protected and that proposed park activities or development will not adversely impact the stability and condition of these geologic exposures.

Acknowledgments

Many individuals were consulted in the preparation of this report on the geologic type sections for the national parks of the Appalachian Highlands Inventory and Monitoring Network. We first want to extend our sincere appreciation to Randy Orndorff, David Soller, and Nancy Stamm (U.S. Geological Survey) for their assistance with this geologic type section inventory and other important NPS projects. Randy, Nancy and David manage the National Geologic Map Database for the United States (NGMDB, https://ngmdb.usgs.gov/ngm-bin/ngm_compsearch.pl?glx=1) and the U.S. Geologic Names Lexicon ("GEOLEX", https://ngmdb.usgs.gov/Geolex/search), critical sources of geologic map information for science, industry and the American public. We also extend our appreciation to Mark Carter (USGS) and Linda York (NPS) for their assistance with peer review of this inventory report.

We thank our colleagues and partners in the Geological Society of America (GSA) and Stewards Individual Placement Program for their continued support to the NPS with the placement of geologic interns and other ventures. Additionally, we are grateful to Rory O'Connor-Walston and Alvin Sellmer from the NPS Technical Information Center in Denver, Colorado for their assistance with locating hard-to-find publications.

Thanks to our NPS colleagues in the Appalachian Highlands Inventory and Monitoring Network and various network parks, including: Brian Witcher, Jim Hughes, Evan Raskin, and Tim Fotinos (APHN), Tom Blount (BISO and OBRI), Alexa Viets (BLRI), and Lisa McInnis, Tom Colson, and Paul Super (GRSM). Additional thanks to Darrell Echols and Linda York from the Southeast Region of the National Park Service.

This project is possible through the support from research associates and staff in the National Park Service Geologic Resources Division and we extend our thanks to Hal Pranger, Julia Brunner, Jason Kenworthy, and Jim Wood. We especially appreciate the dedicated assistance from Lima Soto, former Geoscientists-in-the-Parks Program (GIP) Coordinator, to ensure a highly qualified geology intern was hired for this project.

Dedication

This Appalachian Highlands Inventory and Monitoring Network Geologic Type Section Inventory is dedicated to geologist Trista L. Thornberry-Ehrlich. Trista spent many of her formative years in the shadow of majestic Glacier National Park, known locally as “the park”. After receiving a Master’s degree in Geosciences from Colorado State University (CSU) in 2001, Trista has dedicated her entire career to the support of the National Park Service’s (NPS) geologic resources. She continues to work for the parks as part of the NPS–CSU Geologic Resources Inventory crafting reports and graphics to foster science-informed resource management. Our team’s work on this report benefitted from the Geologic Resource Inventories Trista produced for Blue Ridge Parkway and Great Smoky Mountains National Park, and we are proud to dedicate the Appalachian Highlands Network Geologic Type Section Inventory report to Trista.

Trista Thornberry-Ehrlich at the Breitachklamm in Allgäu, southern Germany (photo courtesy of T. Thornberry-Ehrlich).

Introduction

The NPS Geologic Type Section Inventory Project ("Stratotype Inventory Project") is a continuation of and complements the work performed by the Geologic Resources Inventory (GRI). The GRI is funded by the NPS Inventory and Monitoring Program and administered by the Geologic Resources Division (GRD). The GRI is designed to compile and present baseline geologic resource information available to park managers, and advance science-informed management of natural resources in the national parks. The goals of the GRI team are to increase understanding and appreciation of the geologic features and processes in parks and provide robust geologic information for use in park planning, decision making, public education, and resource stewardship.

Documentation of stratotypes (i.e., type sections/type localities/type areas) that occur within national park boundaries represents a significant component of a geologic resource inventory, as these designations serve as the standard for defining and recognizing geologic units (North American Commission on Stratigraphic Nomenclature 2005). The importance of stratotypes lies in the fact that they store information, represent important comparative sites where knowledge can be built up or reexamined, and can serve as teaching sites for students (Brocx et al. 2019). The geoheritage significance of stratotypes is analogous to that of libraries and museums, in that they are natural reservoirs of Earth history spanning ~4.5 billion years and record the prodigious forces and evolving life forms that define our planet and our understanding as a contributing species.

The goals of this project are to systematically report the assigned stratotypes that occur within national park boundaries, provide detailed descriptions of the stratotype exposures and their locations, and reference the stratotype assignments from published literature. It is important to note that this project cannot verify a stratotype for a geologic unit if one has not been formally assigned and/or published. Additionally, numerous stratotypes are located geographically outside of national park boundaries, but only those within 48 km (30 mi) of park boundaries will be mentioned in this report.

This geologic type section inventory for the parks of the Appalachian Highlands Inventory & Monitoring Network (APHN) follows standard practices, methodologies, and organization of information introduced in the Greater Yellowstone I&M Network type section inventory (Henderson et al. 2020). All network-specific reports are prepared, peer-reviewed, and submitted to the Natural Resources Stewardship and Science Publications Office for finalization. A small team of geologists and paleontologists from the NPS Geologic Resources Division and the NPS Paleontology Program have stepped up to undertake this important inventory for the NPS.

This inventory fills a current void in basic geologic information not currently compiled by the NPS either at most parks or at the servicewide level. This inventory requires some intensive and strategic data mining activities to determine instances where geologic type sections occur within NPS areas. Sometimes the lack of specific locality or other data presents limitations in determining if a particular type section is geographically located within or outside NPS administered boundaries. Below are the primary considerations warranting this inventory of NPS geologic type sections.

- Geologic type sections are a part of our national geologic heritage and are a cornerstone of the scientific value used to define the societal significance of geoheritage sites (https://www.nps.gov/articles/scientific-value.htm);
- Geologic type sections are important geologic landmarks and reference locations which define important scientific information associated with geologic strata. Geologic formations are commonly named after geologic features and landmarks that are recognizable to park staff;
- Geologic type sections are both historically and scientifically important components of earth sciences and mapping;
- Understanding and interpretation of the geologic record is largely dependent upon the stratigraphic occurrences of mappable lithologic units (formations, members). These geologic units are the foundational attributes of geologic maps;
- Geologic maps are important tools for science, resource management, land use planning, and other areas and disciplines;
- Geologic type sections are similar in nature to type specimens in biology and paleontology, serving as a "gold standard" which help to define characteristics used in classification;
- The documentation of geologic type sections in NPS areas has not been previously inventoried and there is a general absence of baseline information for this geologic resource category.
- In general, NPS staff in parks are not aware of the concept of geologic type sections and therefore may not understand the significance or occurrence of these natural landmarks in parks;
- Given the importance of geologic type sections as geologic landmarks and geologic heritage resources, these locations should be afforded some level of preservation or protection when they occur within NPS areas;
- If NPS staff are unaware of geologic type sections within parks, the NPS would not proactively monitor the stability, condition, or potential impacts to these locations during normal park operations or planning. The lack of baseline information pertaining to the geologic type sections in parks would limit the protection of these localities from activities which may involve ground disturbance or construction. Therefore, considerations need to be addressed about how the NPS may preserve geologic type sections and better inform NPS staff about their existence in the park.
- There may be an important conversation that needs to be addressed regarding whether or not geologic type sections rise to the level of national register documentation. The NPS should consider if any other legal authorities (e.g., National Historic Preservation Act), policy, or other safeguards currently in place can help protect geologic type sections which are established on NPS administered lands. Through this inventory, the associated report, and close communication with park and I&M Network staff, the hope is there will be an increased awareness about these important geologic landmarks in parks. In turn, the awareness of these resources and their significance may be recognized in park planning and operations, to ensure that geologic type sections are preserved and available for future study.

Geology and Stratigraphy of the Appalachian Highlands I&M Network Parks

The Appalachian Highlands Network (APHN) consists of four national park areas in Kentucky, North Carolina, Tennessee, and Virginia including: Big South Fork National River and Recreation Area (BISO), Blue Ridge Parkway (BLRI), Great Smoky Mountains National Park (GRSM), and Obed Wild and Scenic River (OBRI) (Figure 1). The network parks are divided between two ecologically distinct physiographic regions: the Cumberland Plateau of Kentucky and Tennessee, and the Southern Appalachian Mountains of Georgia, North Carolina, Tennessee, and Virginia. Both these regions are characterized by high levels of biological diversity and endemism (Santucci et al. 2008).

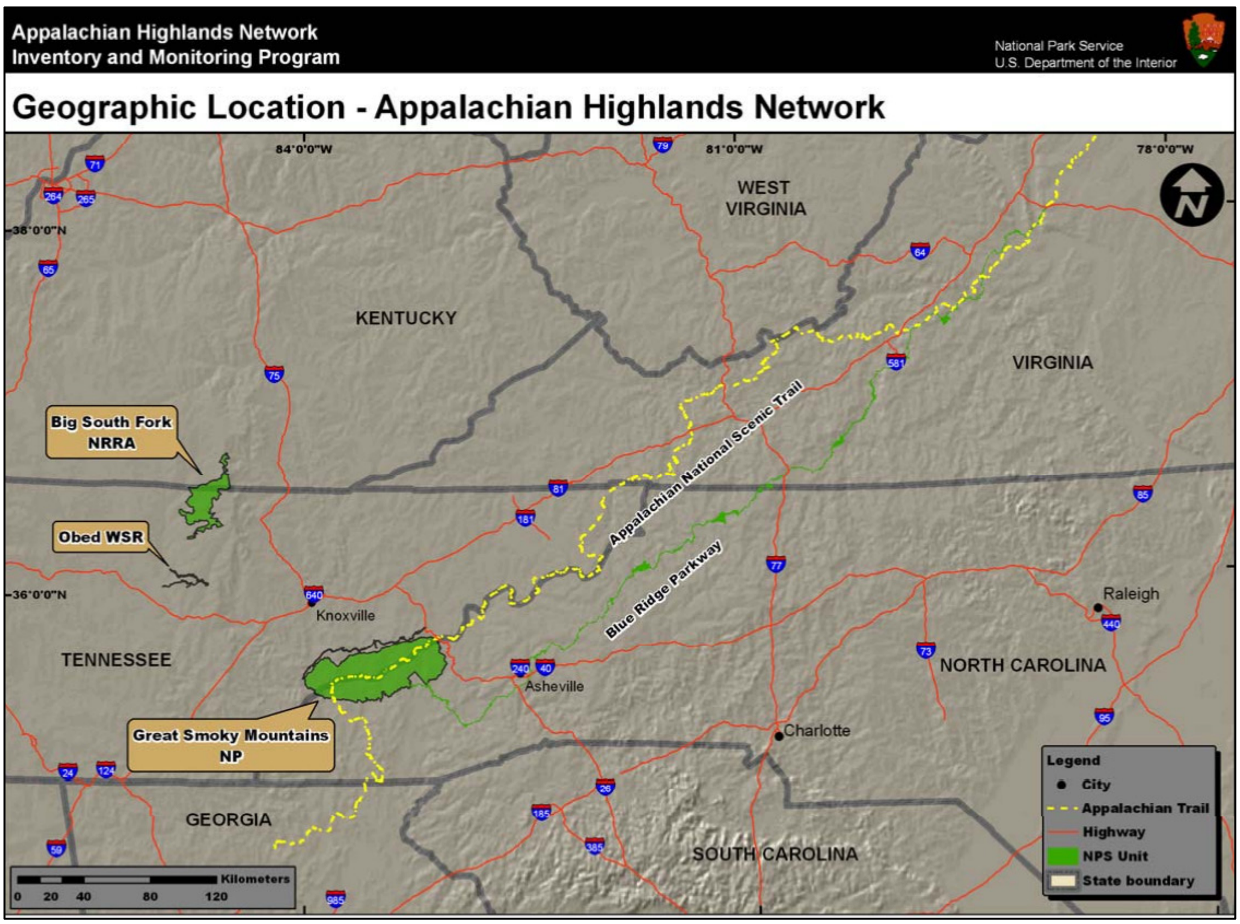


Figure 1. Map of Appalachian Highlands Network parks including: Big South Fork National River and Recreation Area (BISO), Blue Ridge Parkway (BLRI), Great Smoky Mountains National Park (GRSM), and Obed Wild and Scenic River (OBED) (NPS). Also shown is the location of the Appalachian National Scenic Trail in the southern Appalachian highlands.

The Appalachian Mountains are one of the oldest mountain ranges in the world. The long stability of the Appalachian Mountains, combined with its great variation in geology, landforms, and climate, have supported the evolution of a rich diversity of fauna and flora, especially in the southern regions which were not directly impacted by glacial activity. Within the Southern Appalachians, the Blue Ridge Mountains (Blue Ridge Province) rise abruptly above the rolling Piedmont to the east and form the backbone of the Appalachians in this region. The Southern Appalachians ecoregion is one of the most biologically diverse terrestrial ecosystems in the world.

To the west of the Blue Ridge Mountains are the Valley and Ridge Province and the Cumberland Plateau. The Valley and Ridge Province consists of folded and unmetamorphosed Paleozoic sedimentary rocks that include sandstones, shales, and limestones, with some Pennsylvanian-age coal beds (see Appendix B for a geologic time scale). These sedimentary units are underlain by large thrust faults generated by intercontinental collisions during the late Paleozoic. The Cumberland Plateau is an extensive tableland of sandstone and shale carved by water into a labyrinth of rocky ridges and deep gorges. The Cumberland River system includes the Big South Fork and Obed rivers.

Precambrian

Precambrian geology is well represented at BLRI and GRSM. The oldest rocks in the network are igneous and metamorphic units which date to the Mesoproterozoic. At least seven Neoproterozoic units are mapped at BLRI and 16 Neoproterozoic units are documented in GRSM. The Blue Ridge Province and Mountains represent the backbone of the central and southern Appalachians and have an important geologic history during the Precambrian. The Blue Ridge Mountains were significantly influenced by multiple mountain-building events (orogenies), beginning with the Grenville Orogeny that occurred approximately 1.1 billion years ago.

Paleozoic

The Appalachian Mountains were significantly uplifted and deformed during the Paleozoic due to a series of orogenies that include the Taconic Orogeny (475–405 million years ago), Acadian Orogeny (390–350 million years ago), and Alleghenian Orogeny (300–245 million years ago). Paleozoic rocks occur in all four of the APHN parks. The Cambrian is represented by seven units in BLRI and seven units in GRSM. The only Cambrian unit to occur in both parks is the Shady Dolomite. Lower and Middle Ordovician units (Jonesboro Limestone and Chickamauga Group) are mapped in GRSM. The only Devonian formation occurring in any of the APHN parks is the Chattanooga Shale, which is present in GRSM.

The Upper Mississippian is most extensively exposed at BISO in the form of a sandstone belt of cliffs and steep-sided, narrow-crested valleys. Terrestrial Mississippian sandstones and siltstones are the result of a great influx of mud, silts, and sands brought in by rivers and streams from uplands many miles to the northeast and deposited as a great delta. The Mississippian limestones of the region were deposited 350 million years ago in the bottom of a warm, shallow sea. Mississippian rocks also occur in limited exposures in GRSM.

At the end of the Mississippian (approximately 320 million years ago) the seas receded and were overlain by Pennsylvanian-aged sediments. The warm climate of the Pennsylvanian allowed extensive forests to grow and great coastal swamps to develop at the edges of water bodies. Marine waters advanced and receded many times, which produced many layers of sandstone, shale, and coal. Pennsylvanian-age plants were buried under blankets of sediments, which over long geologic time were compressed into coal.

At BISO the Pennsylvanian rocks are predominantly sandstone and shale, and include siltstone, conglomerate, and coal. A dendritic drainage pattern resulted in narrow and V-shaped gorges. The weathering processes on these rocks have produced an impressive array of geologic features, including arches, mesas, chimneys, cracks, and rock shelters. Lower and Middle Pennsylvanian units, including sandstone, shale, conglomerate and coal, dominate the bedrock at OBED and large portions of BISO.

Mesozoic

The Mesozoic is not well represented in the APHN parks. The only Mesozoic rocks are Jurassic diabase mapped in narrow dikes that intrude older geologic units in BLRI. Diabase is exposed just south of Roanoke River near MP 118 and MP 125, north of James River near MP 56, and in the vicinity of Afton near MP 3 and north of MP 0 (Carter et al. 2016).

Cenozoic

With the exception of Quaternary surficial deposits, the only Cenozoic strata in the APHN network parks is an unknown unit which may date between Pleistocene to as old as Miocene in age in Great Smoky Mountains National Park (Thornberry-Ehrlich 2008).

National Park Service Geologic Resource Inventory

The Geologic Resources Inventory (GRI) provides digital geologic map data and pertinent geologic information on park-specific features, issues, and processes to support resource management and science-informed decision-making in more than 270 natural resource parks throughout the National Park System. The GRI is one of 12 inventories funded by the National Park Service (NPS) Inventory and Monitoring Program. The Geologic Resources Division (GRD) of the NPS Natural Resource Stewardship and Science Directorate administers the GRI. The GRI team consists of a partnership between the GRD and the Colorado State University Department of Geosciences to produce GRI products.

GRI Products

The GRI team undertakes three tasks for each park in the Inventory and Monitoring program: (1) conduct a scoping meeting and provide a summary document, (2) provide digital geologic map data in a geographic information system (GIS) format, and (3) provide a GRI report. These products are designed and written for non-geoscientists.

Scoping meetings bring together park staff and geologic experts to review and assess available geologic maps, develop a geologic mapping plan, and discuss geologic features, processes, and resource management issues that should be addressed in the GRI report. Scoping sessions were held on the following dates for the APHN parks: GRSM on May 8–9, 2000; BLRI on May 10–12, 2000; and BISO/OBED on June 4–5, 2000.

Following the scoping meeting, the GRI map team converts the geologic maps identified in the mapping plan to GIS data in accordance with the GRI data model. After the map is completed, the GRI report team uses these data, as well as the scoping summary and additional research, to prepare the GRI report. As of 2020, GRI reports have been completed for BLRI and GRSM. The GRI team conducts no new field work in association with their products.

The compilation and use of natural resource information by park managers is called for in the 1998 National Parks Omnibus Management Act (§ 204), 2006 National Park Service Management Policies, and the Natural Resources Inventory and Monitoring Guideline (NPS-75). Additional information regarding the GRI, including contact information, is available at https://www.nps.gov/subjects/geology/gri.htm.

Geologic Map Data

A geologic map in GIS format is the principal deliverable of the GRI program. GRI GIS data produced for the APHN parks follows the selected source maps and includes components such as: faults, mine area features, mine point features, geologic contacts, geologic units (bedrock, surficial, glacial), geologic line features, structure contours, and so forth. These are commonly acceptable geologic features to include in a geologic map.

Posters display the data over imagery of the park and surrounding area. Complete GIS data are available at the GRI publications website: https://www.nps.gov/subjects/geology/geologic-resources-inventory-products.htm.

Geologic Maps

A geologic map is the fundamental tool for depicting the geology of an area. Geologic maps are two-dimensional representations of the three-dimensional geometry of rock and sediment at, or beneath the land surface (Evans 2016). Colors and symbols on geologic maps correspond to geologic map units. The unit symbols consist of an uppercase letter indicating the geologic age and lowercase letters indicating the formation's name. Other symbols depict structures such as faults or folds, locations of past geologic hazards that may be susceptible to future activity, and other geologic features. Anthropogenic features such as mines or quarries, as well as observation or collection locations, may be indicated on geologic maps. The American Geosciences Institute website (https://www.americangeosciences.org/environment/publications/mapping) provides more information about geologic maps and their uses.

Geologic maps are typically one of two types: surficial or bedrock. Surficial geologic maps typically encompass deposits that are unconsolidated and which formed during the past 2.6 million years (the Quaternary Period). Surficial map units are differentiated by geologic process or depositional environment. Bedrock geologic maps encompass older, typically more consolidated sedimentary, metamorphic, and/or igneous rocks. Bedrock map units are differentiated based on age and/or rock type. GRI has produced various maps for the APHN parks.

Source Maps

The GRI team does not conduct original geologic mapping. The team digitizes paper maps and compiles and converts digital data to conform to the GRI GIS data model. The GRI GIS dataset includes essential elements of the source maps such as map unit descriptions, a correlation chart of units, a map legend, map notes, cross sections, figures, and references. These items are typically included in a master geology document (PDF) for a specific park. The GRI team uses a unique "GMAP ID" value for each geologic source map, and all sources used to produce the GRI GIS datasets for the APHN parks can be found in Appendix A.

GRI GIS Data

The GRI team standardizes map deliverables by using a data model. The most recent GRI GIS data for BISO and GRSM was compiled using data model version 2.3, which is available at https://www.nps.gov/articles/gri-geodatabase-model.htm; the BLRI and OBED data are based on older data model version 2.2 and need to be upgraded to the most recent version. This data model dictates GIS data structure, including layer architecture, feature attribution, and relationships within ESRI ArcGIS software. The GRI website (https://www.nps.gov/subjects/geology/gri.htm) provides more information about the program's products.

GRI GIS data are available on the GRI publications website (https://www.nps.gov/subjects/geology/geologic-resources-inventory-products.htm) and through the NPS Integrated Resource Management Applications (IRMA) Data Store portal (https://irma.nps.gov/DataStore/Search/Quick). Enter “GRI” as the search text and select BISO, BLRI, GRSM, or OBED from the unit list.

The following components are part of the dataset:

- A GIS readme file that describes the GRI data formats, naming conventions, extraction instructions, use constraints, and contact information;
- Data in ESRI geodatabase GIS format;
- Layer files with feature symbology;
- Federal Geographic Data Committee (FGDC)-compliant metadata;
- An ancillary map information document that contains information captured from source maps such as map unit descriptions, geologic unit correlation tables, legends, cross-sections, and figures;
- ESRI map documents that display the GRI GIS data; and
- A version of the data viewable in Google Earth (.kml / .kmz file)

GRI Map Posters

Posters of the GRI GIS draped over shaded relief images of the park and surrounding area are included in GRI reports. Not all GIS feature classes are included on the posters. Geographic information and selected park features have been added to the posters. Digital elevation data and added geographic information are not included in the GRI GIS data, but are available online from a variety of sources. Contact GRI for assistance locating these data.

Use Constraints

Graphic and written information provided in this report is not a substitute for site-specific investigations. Ground-disturbing activities should neither be permitted nor denied based upon the information provided. Please contact GRI with any questions.

Minor inaccuracies may exist regarding the locations of geologic features relative to other geologic or geographic features on the posters. Based on the source map scales (1:100,000, 1:62,500, and 1:24,000) and US National Map Accuracy Standards, geologic features represented in the geologic map data are expected to be horizontally within 51 m (167 ft), 32 m (104 ft), and 12 m (40 ft), respectively, of their true locations.

Methods

This section of the report presents the methods employed and definitions adopted during this inventory of geologic type sections located within the administrative boundaries of the parks in the APHN. This report is part of a more extensive inventory of geologic type sections throughout the National Park System. Therefore, the methods, definitions, and challenges identified here pertain not only to the parks of the APHN, but also to other inventory and monitoring networks and parks.

There are a number of considerations to be addressed throughout this inventory. The most up-to-date information available is necessary, either found online or in published articles and maps. Occasionally, there is a lack of specific information that limits the information contained in the final report. The inventory does not include any field work and is dependent on the existing information related to individual park geology and stratigraphy. Additionally, this inventory does not attempt to resolve any unresolved or controversial stratigraphic interpretations, which is beyond the scope of the project.

Stratigraphic nomenclature may change over time with refined stratigraphic field assessments and discovery of information through the expansion of stratigraphic mapping and measured sections. One important observation regarding stratigraphic nomenclature relates to differences in use of geologic names for units which transcend state boundaries. Geologic formations and other units which cross state boundaries may be referenced with different names in each of the states the units are mapped. An example would be the Triassic Chugwater Formation in Wyoming, which is equivalent to the Spearfish Formation in the Black Hills of South Dakota.

The lack of a designated and formal type section, or inadequate and vague geospatial information associated with a type section, limits the ability to capture precise information for this inventory. The available information related to the geologic type sections is included in this report.

Finally, it is worth noting that this inventory report is intended for a wide audience, including NPS staff who might not have a background in geology. Therefore, this document has been developed as a reference document that supports science, resource management, and a historic framework for geologic information associated with NPS areas.

Methodology

The process of determining whether a specific stratotype occurs in an NPS area involves multiple steps. The process begins with an evaluation of the existing park-specific GRI map to prepare a full list of recognized map units (Figure 2).

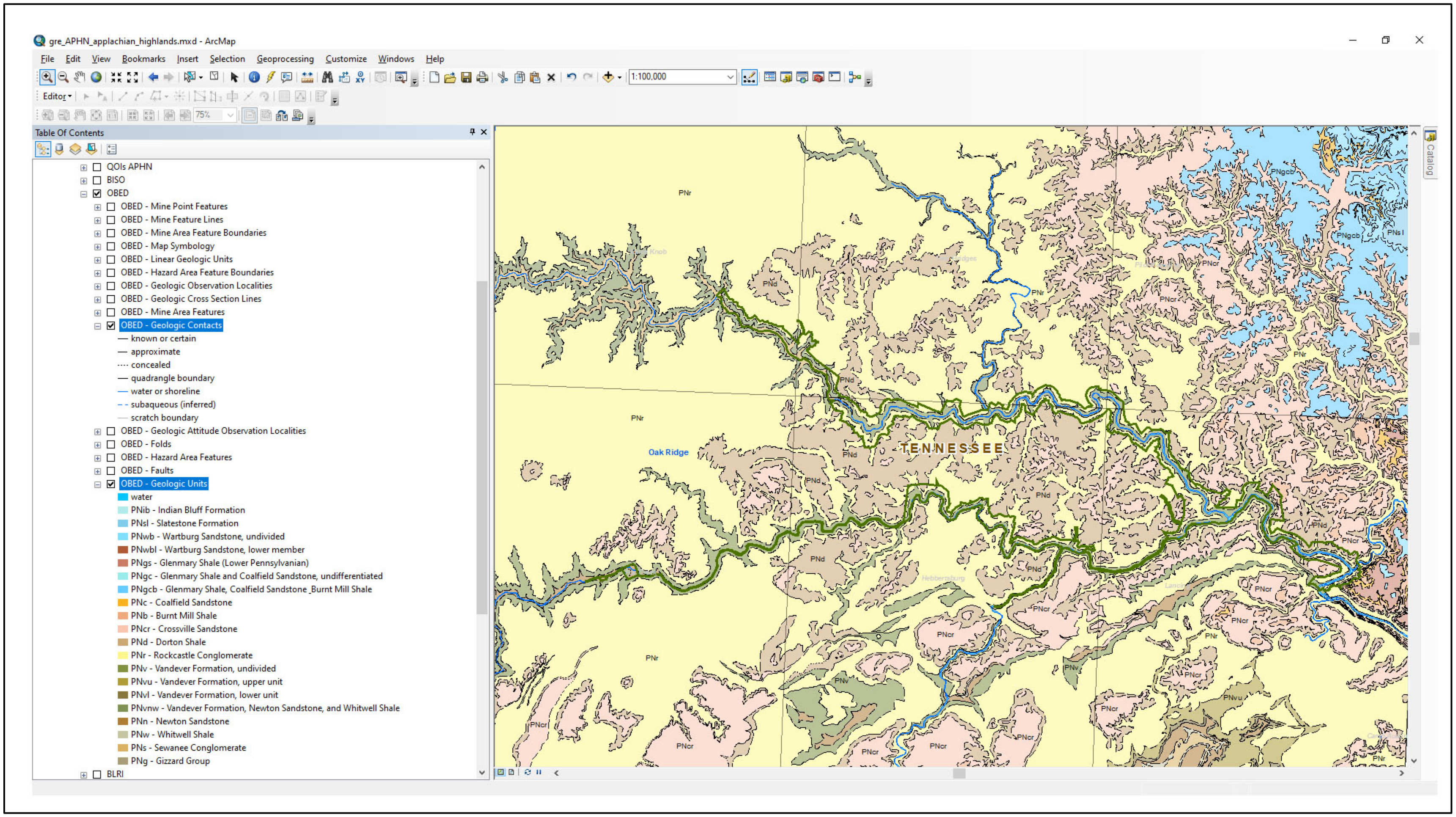


Figure 2. Screenshot of digital bedrock geologic map of Obed Wild and Scenic River showing mapped units.

Each map unit name is then queried in the U.S. Geologic Names Lexicon online database ("GEOLEX", a national compilation of names and descriptions of geologic units) at https://ngmdb.usgs.gov/Geolex/search. Information provided by GEOLEX includes unit name, stratigraphic nomenclature usage, geologic age, published stratotype location descriptions, and the database provides a link to significant publications as well as the USGS Geologic Names Committee Archives (Wilmarth 1938; Keroher et al. 1966). Figure 3 below is taken from a search on the Rich Butt Sandstone.

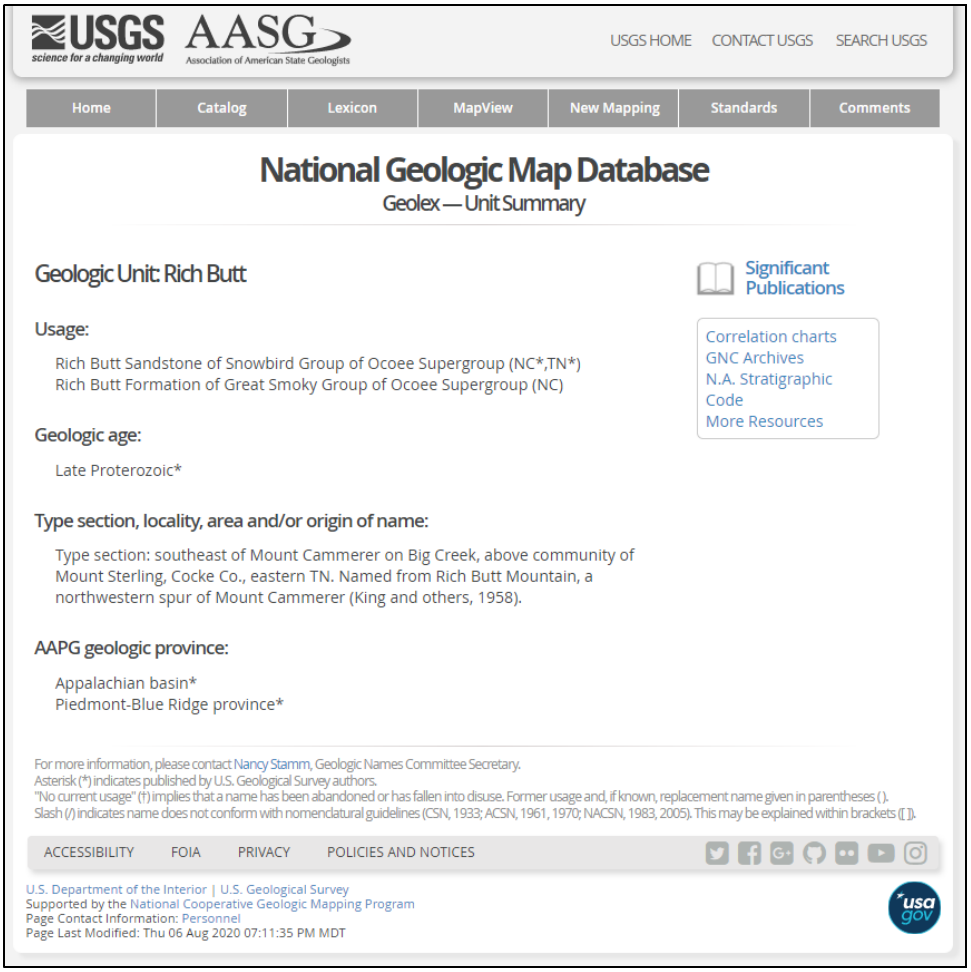
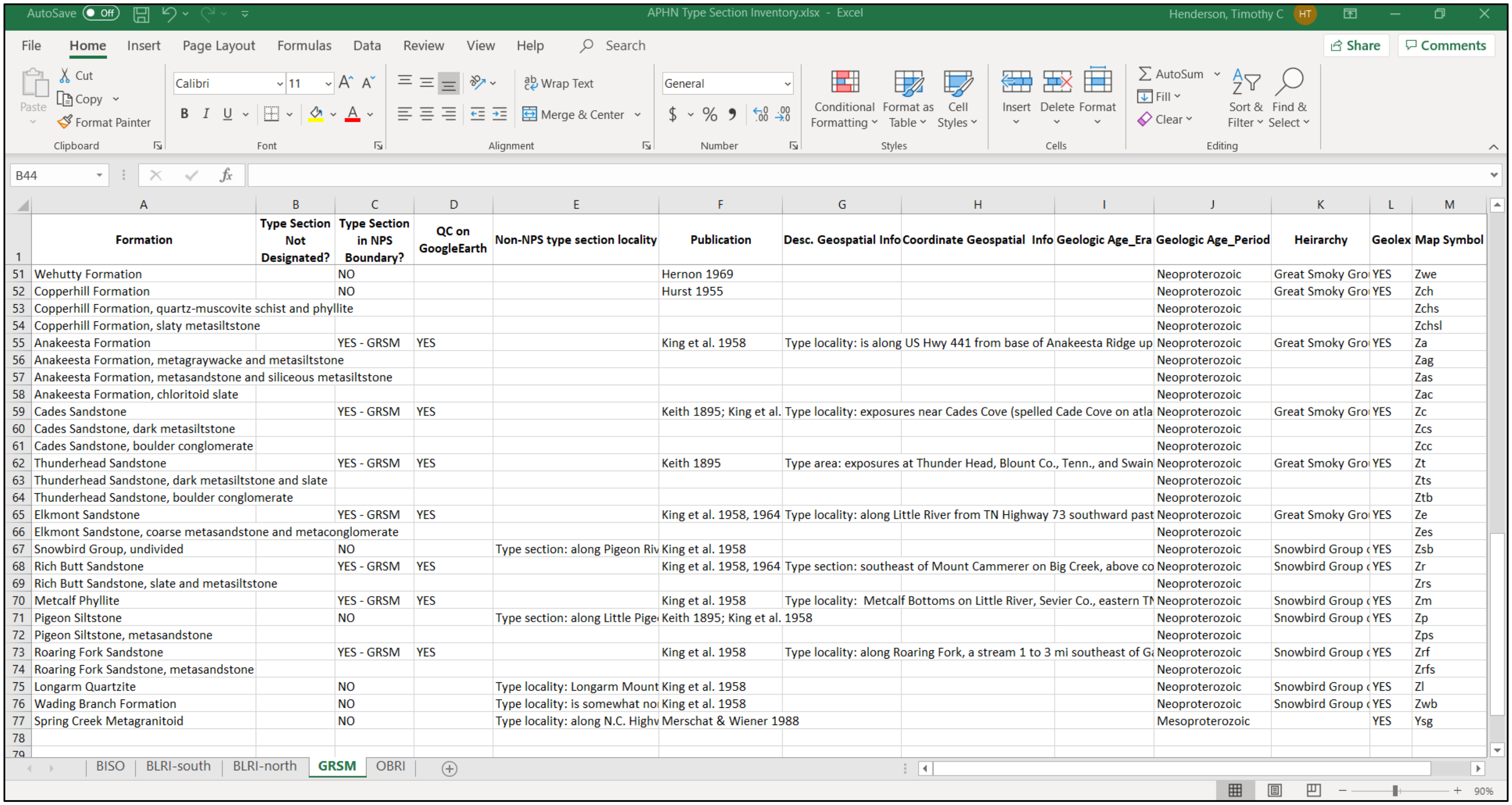


Figure 3. GEOLEX search result for Rich Butt Sandstone unit.

Published GEOLEX stratotype spatial information is provided in three formats: (1) descriptive, using distance from nearby points of interest; (2) latitude and longitude coordinates; or (3) Township/Range/Section (TRS) coordinates. TRS coordinates are based on subdivisions of a single 93.2 km^2 (36 mi^2) township into 36 individual 2.59 km^2 (1 mi^2) sections, and were converted into Google Earth (.kmz file) locations using Earth Point (https://www.earthpoint.us/TownshipsSearchByDescription.aspx). The most accurate GEOLEX descriptions using TRS coordinates can help locate features within 0.1618 km^2 (0.0625 mi^2). Once stratotype locality information provided for a given unit is geolocated using Google Earth, a GRI digital geologic map of the national park is draped over it. This step serves two functions: to improve accuracy in locating the stratotype, and validating the geologic polygon for agreement with GEOLEX nomenclature. Geolocations in Google Earth are then converted into an ArcGIS format using a "KML to Layer" conversion tool in ArcMap.

After this, a Microsoft Excel spreadsheet is populated with information pertinent to the geologic unit and its stratotype attributes. Attribute data recorded in this way include: (1) is a stratotype officially designated; (2) is the stratotype on NPS land; (3) has it undergone a quality control check in Google Earth; (4) reference of the publication citing the stratotype; (5) description of geospatial information; (6) coordinates of geospatial information; (7) geologic age (era, period, epoch, etc.); (8) hierarchy of nomenclature (supergroup, group, formation, member, bed, etc.); (9) was the geologic unit found in GEOLEX; and (10) a generic notes field (Figure 4).



	Formation	Type Section Not Designated?	Type Section in NPS Boundary?	QC on GoogleEarth	Non-NPS type section locality	Publication	Desc. Geospatial Info	Coordinate Geospatial Info	Geologic Age_Era	Geologic Age_Period	Heirarchy	Geolex	Map Symbol
51	Wehutty Formation		NO			Hernon 1969				Neoproterozoic	Great Smoky Gro	YES	Zwe
52	Copperhill Formation		NO			Hurst 1955				Neoproterozoic	Great Smoky Gro	YES	Zch
53	Copperhill Formation, quartz-muscovite schist and phyllite									Neoproterozoic			Zchs
54	Copperhill Formation, slaty metasiltstone									Neoproterozoic			Zchsl
55	Anakeesta Formation		YES - GRSM	YES		King et al. 1958	Type locality: is along US Hwy 441 from base of Anakeesta Ridge up			Neoproterozoic	Great Smoky Gro	YES	Za
56	Anakeesta Formation, metagraywacke and metasiltstone									Neoproterozoic			Zag
57	Anakeesta Formation, metasandstone and siliceous metasiltstone									Neoproterozoic			Zas
58	Anakeesta Formation, chloritoid slate									Neoproterozoic			Zac
59	Cades Sandstone		YES - GRSM	YES		Keith 1895; King et al.	Type locality: exposures near Cades Cove (spelled Cade Cove on atla			Neoproterozoic	Great Smoky Gro	YES	Zc
60	Cades Sandstone, dark metasiltstone									Neoproterozoic			Zcs
61	Cades Sandstone, boulder conglomerate									Neoproterozoic			Zcc
62	Thunderhead Sandstone		YES - GRSM	YES		Keith 1895	Type area: exposures at Thunder Head, Blount Co., Tenn., and Swain			Neoproterozoic	Great Smoky Gro	YES	Zt
63	Thunderhead Sandstone, dark metasiltstone and slate									Neoproterozoic			Zts
64	Thunderhead Sandstone, boulder conglomerate									Neoproterozoic			Ztb
65	Elkmont Sandstone		YES - GRSM	YES		King et al. 1958, 1964	Type locality: along Little River from TN Highway 73 southward past			Neoproterozoic	Great Smoky Gro	YES	Ze
66	Elkmont Sandstone, coarse metasandstone and metaconglomerate									Neoproterozoic			Zes
67	Snowbird Group, undivided		NO		Type section: along Pigeon Riv	King et al. 1958				Neoproterozoic	Snowbird Group (	YES	Zsb
68	Rich Butt Sandstone		YES - GRSM	YES		King et al. 1958, 1964	Type section: southeast of Mount Cammerer on Big Creek, above co			Neoproterozoic	Snowbird Group (	YES	Zr
69	Rich Butt Sandstone, slate and metasiltstone									Neoproterozoic			Zrs
70	Metcalf Phyllite		YES - GRSM	YES		King et al. 1958	Type locality: Metcalf Bottoms on Little River, Sevier Co., eastern TN			Neoproterozoic	Snowbird Group (	YES	Zm
71	Pigeon Siltstone		NO		Type section: along Little Pige	Keith 1895; King et al. 1958				Neoproterozoic	Snowbird Group (	YES	Zp
72	Pigeon Siltstone, metasandstone									Neoproterozoic			Zps
73	Roaring Fork Sandstone		YES - GRSM	YES		King et al. 1958	Type locality: along Roaring Fork, a stream 1 to 3 mi southeast of Ga			Neoproterozoic	Snowbird Group (	YES	Zrf
74	Roaring Fork Sandstone, metasandstone									Neoproterozoic			Zrfs
75	Longarm Quartzite		NO		Type locality: Longarm Mount	King et al. 1958				Neoproterozoic	Snowbird Group (	YES	Zl
76	Wading Branch Formation		NO		Type locality: is somewhat no	King et al. 1958				Neoproterozoic	Snowbird Group (	YES	Zwb
77	Spring Creek Metagranitoid		NO		Type locality: along N.C. Highw	Merschat & Wiener 1988				Mesoproterozoic		YES	Ysg
78													

Figure 4. Stratotype inventory spreadsheet of the APHN displaying attributes appropriate for geolocation assessment.

Definitions

In order to clarify, standardize, and consistently reference stratigraphic concepts, principles, and definitions, the North American Stratigraphic Code is recognized and adopted for this inventory. This code seeks to describe explicit practices for classifying and naming all formally defined geologic units. An important designation for a geologic unit is known as a ***stratotype***—the standard (original or subsequently designated) for a named geologic unit or boundary and constitutes the basis for definition or recognition of that unit or boundary (North American Commission on Stratigraphic Nomenclature 2005). There are several variations of stratotype referred to in the literature and this report, and they are defined as following:

(1) Unit stratotype: the **type section** for a stratified deposit or the **type area** for a non-stratified body that serves as the standard for recognition and definition of a geologic unit (North American Commission on Stratigraphic Nomenclature 2005). Once a unit stratotype is assigned, it is never changed. The term “unit stratotype” is commonly referred to as “type section” and “type area” in this report.

(2) **Type locality**: the specific geographic locality encompassing the unit stratotype of a formally recognized and defined unit. On a broader scale, a type area is the geographic territory encompassing the type locality. Before development of the stratotype concept, only type localities and type areas were designated for many geologic units that are now long- and well-established (North American Commission on Stratigraphic Nomenclature 2005).

(3) **Reference sections**: for well-established geologic units for which a type section was never assigned, a reference section may serve as an invaluable standard in definitions or revisions. A principal reference section may also be designated for units whose stratotypes have been destroyed, covered, or are otherwise inaccessible (North American Commission on Stratigraphic Nomenclature 2005). Multiple reference sections can be designated for a single unit to help illustrate heterogeneity or some critical feature not found in the stratotype. Reference sections can help supplement unit stratotypes in the case where the stratotype proves inadequate (North American Commission on Stratigraphic Nomenclature 2005).

(4) **Lithodeme**: the term “lithodeme” is defined as a mappable unit of plutonic and highly metamorphosed or pervasively deformed rock and is a term equivalent in rank to “formation” among stratified rocks (North American Commission on Stratigraphic Nomenclature 2005). The formal name of a lithodeme consists of a geographic name followed by a descriptive term that denotes the average modal composition of the rock (example: Cathedral Peak Granodiorite). Lithodemes are commonly assigned type localities, type areas, and reference localities.

Big South Fork National River and National Recreation Area

Big South Fork National River and Recreation Area (BISO) is located in the Cumberland Plateau in parts of southeastern Kentucky (McCreary County) and north-central Tennessee (Fentress, Morgan, Pickett, and Scott Counties) (Figure 5). Encompassing approximately 50,051 hectares (123,679 acres), BISO protects and preserves the free-flowing Big South Fork of the Cumberland River and its tributaries (Anderson 2017). Authorized as a park unit on May 7, 1974, BISO was designated as both a national river and national recreation area to preserve the area and offer recreational opportunities. BISO offers miles of scenic gorges, sandstone bluffs, arches, mesas, and a variety of natural and historic features.

The geology of BISO predominantly consists of sedimentary rocks that date back to the Pennsylvanian and Mississippian (~360–300 million years ago) (Figure 6). Pennsylvanian rocks are predominantly sandstone and shale, and include also siltstone, conglomerate, and coal. The rocks have been weathered to form an impressive array of formations, including arches, chimneys, cliffs, coves, cracks, and mesas. Underlying Mississippian-age units consist predominantly of limestones that contain oil and gas deposits both within and outside the boundaries of BISO. The landscape of BISO is characterized by a dendritic river drainage pattern and narrow, V-shaped gorges with river valleys dotted by huge boulders that have broken from the cliff faces. The rivers and streams at BISO consist of stretches of rugged, whitewater rapids and quiet pools. A focal point of the recreation area is the Big South Fork River gorge with its sheer cliffs towering over forested talus slopes.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of BISO. However, the Pennsylvanian Burnt Mill Shale was named by Wilson et al. (1956) for exposures within or near the park boundaries and lacks proper stratotype designation (see "Recommendations"' section). There are eight identified stratotypes located within 48 km (30 mi) of BISO boundaries, for the Mississippian Kidder Limestone Member of the Monteagle Formation (type section), and the Pennsylvanian Crooked Fork Group (type section and type locality), Glenmary Shale (type locality), Slatestone Formation (type section), Coalfield Sandstone (type locality), Dorton Shale (type locality), and Rockcastle Sandstone Member of the Bee Rock Formation (type locality).

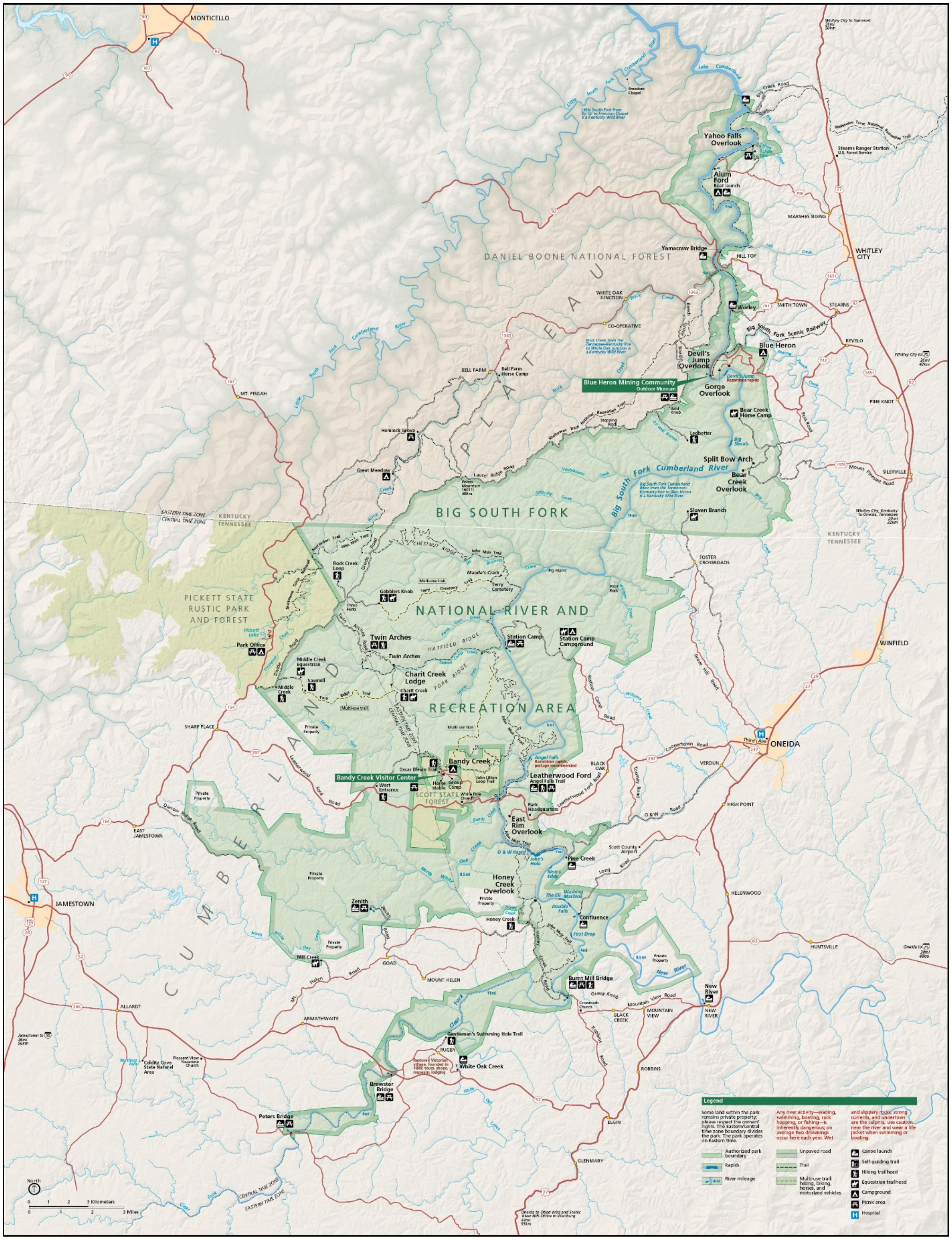


Figure 5. Park map of BISO, Kentucky–Tennessee (NPS).

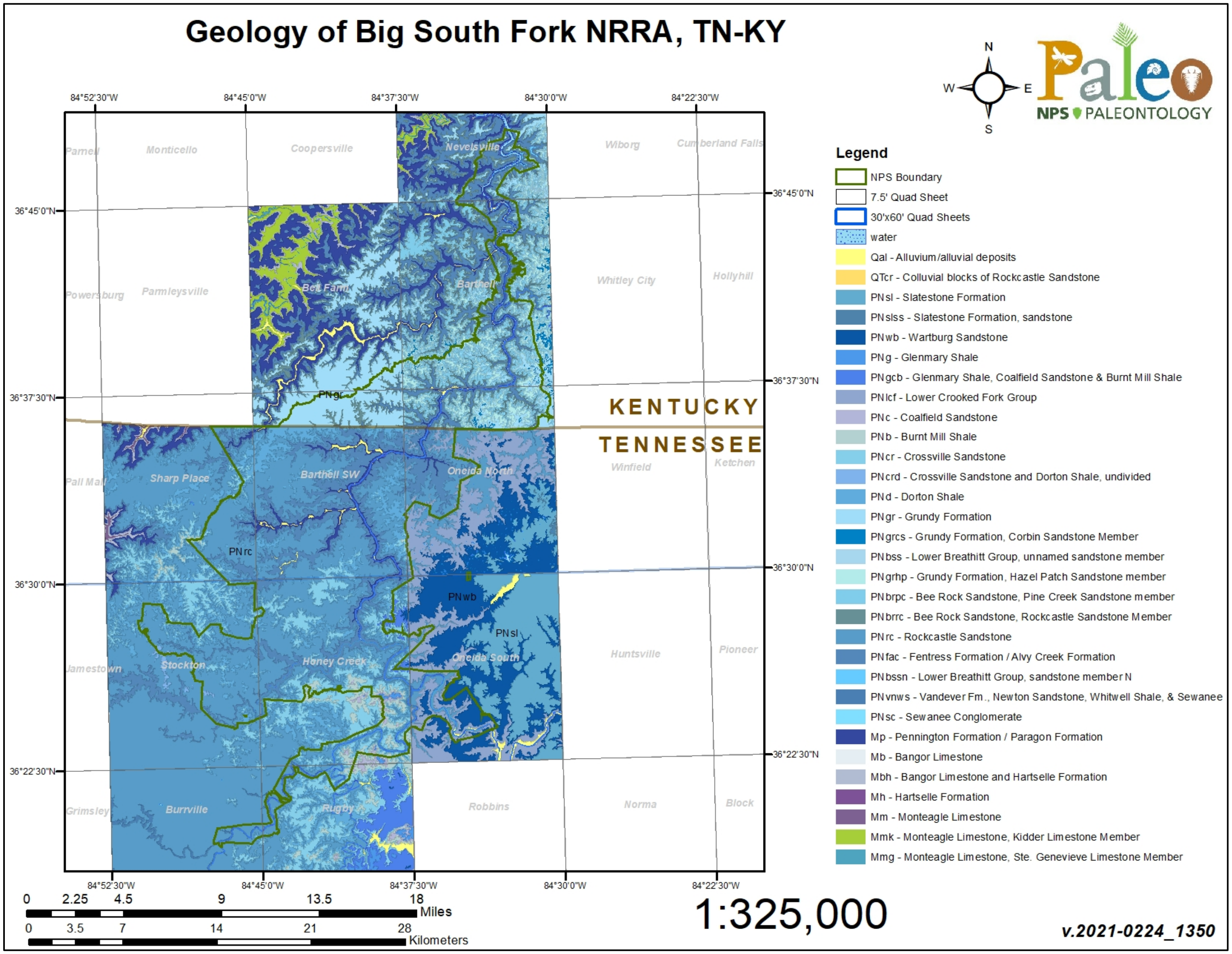


Figure 6. Geologic map of BISO, Kentucky–Tennessee.

Blue Ridge Parkway

Blue Ridge Parkway (BLRI) is the longest road to be designated as a single park unit in the United States and stretches a scenic 756 km (470 mi) through North Carolina (Allegheny, Ashe, Avery, Buncombe, Burke, Haywood, Henderson, Jackson, McDowell, Mitchell, Surry, Swain, Transylvania, Watauga, Wilkes, and Yancey Counties) and Virginia (Amherst, Augusta, Bedford, Botetourt, Carroll, Floyd, Franklin, Grayson, Nelson, Patrick, Roanoke, and Rockbridge Counties) (Figure 7). Authorized as an NPS unit on June 30, 1936, BLRI connects Great Smoky Mountains National Park with Shenandoah National Park and ties together a diverse landscape that includes high passes, lush vegetation, waterfalls, water and wind gaps, forests, and upland meadows (Thornberry-Ehrlich 2020). Construction began on the parkway during the Great Depression to create jobs in an impoverished area. The parkway is regarded as an engineering marvel that includes 26 tunnels and 168 bridges designed in harmony with the local bedrock (Thornberry-Ehrlich 2020).

The geology of BLRI consists of ancient rocks that form the core of the Appalachian Mountains and date back more than one billion years. The long geologic history recorded in the rocks along BLRI involves an early supercontinent (Rodinia), the opening and closing of an ancient ocean to form another supercontinent (Pangea), and rifting that formed the Atlantic Ocean (Thornberry-Ehrlich 2020). Rocks along the parkway are broadly divisible into six groups based on age and rock type: (1) Mesoproterozoic basement complex (more than 1 billion years old), (2) Neoproterozoic metasedimentary and metaigneous complexes (more than 539 million years old), (3) Neoproterozoic to Cambrian sedimentary and metamorphic rocks (between 1 billion and 487 million years old), (4) Paleozoic sedimentary and mylonitic rocks, (5) Jurassic igneous rocks (more than 143 million years old), and (6) Cenozoic surficial deposits that are still forming on the landscape today (Figure 8–14; Thornberry-Ehrlich 2020).

BLRI contains one identified stratotype: the Alligator Back Formation type locality (Table 1; Figure 15).

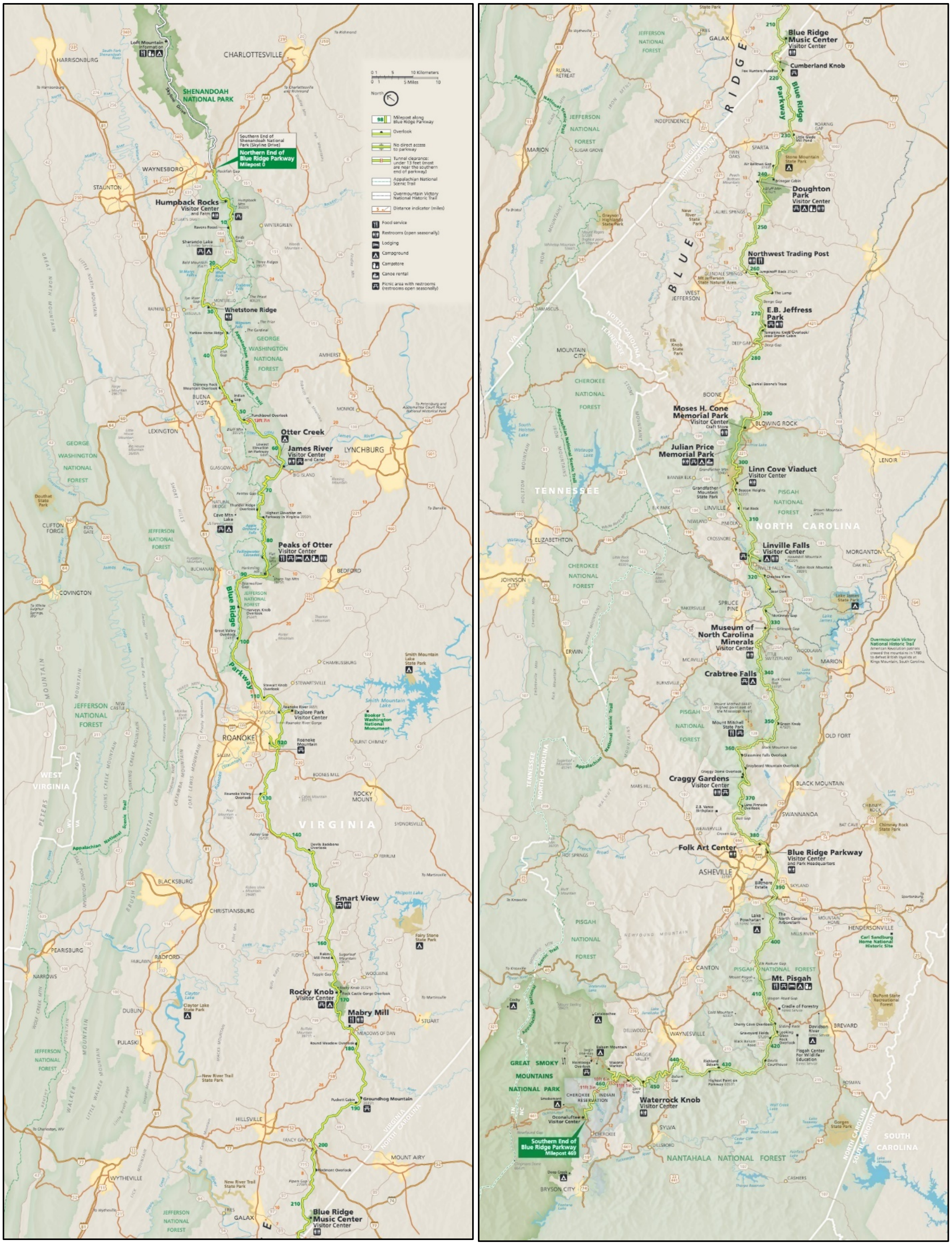


Figure 7. Park map of BLRI, North Carolina–Virginia (NPS).

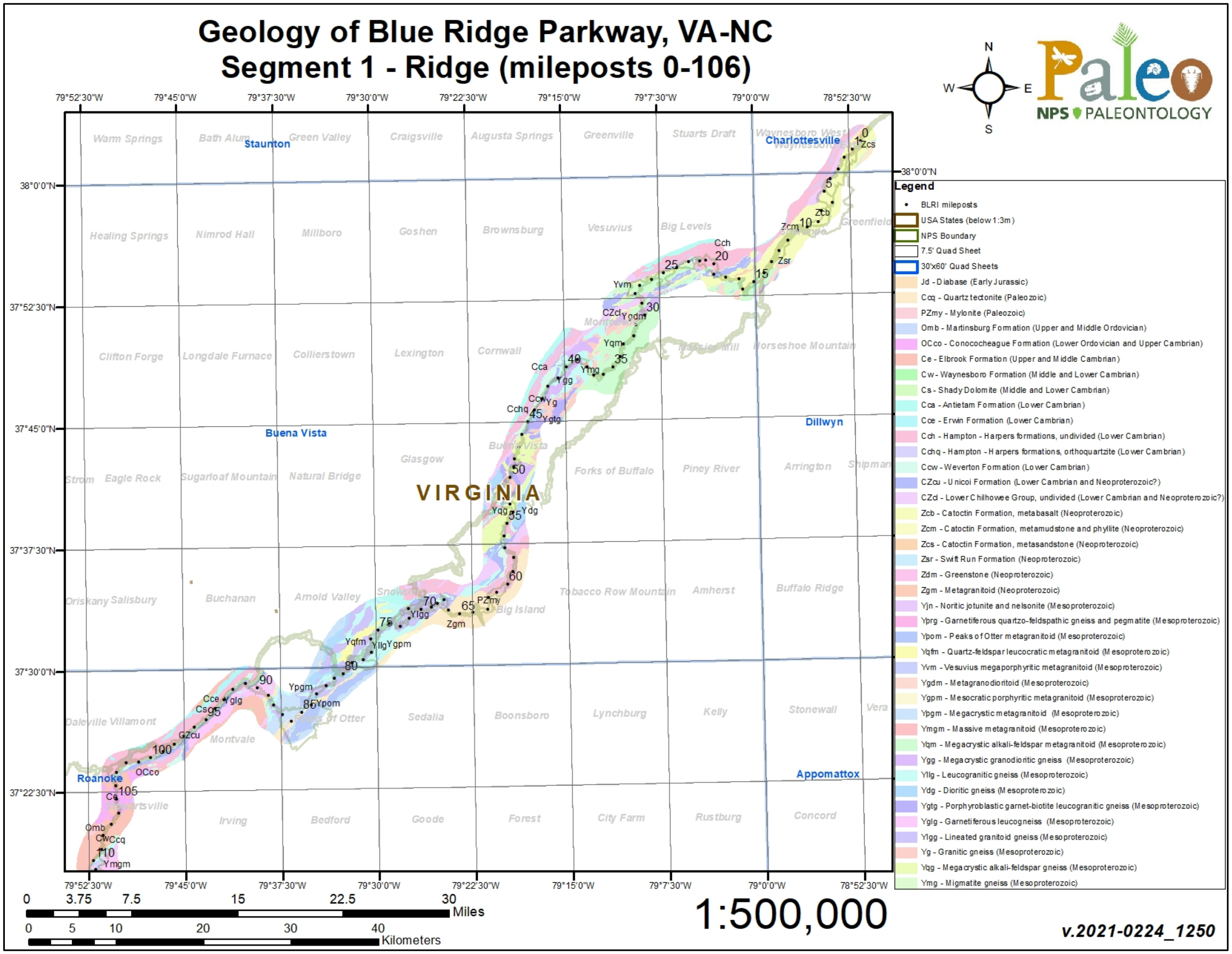


Figure 8. Bedrock geologic map of BLRI along the Ridge segment (mileposts 0–106).

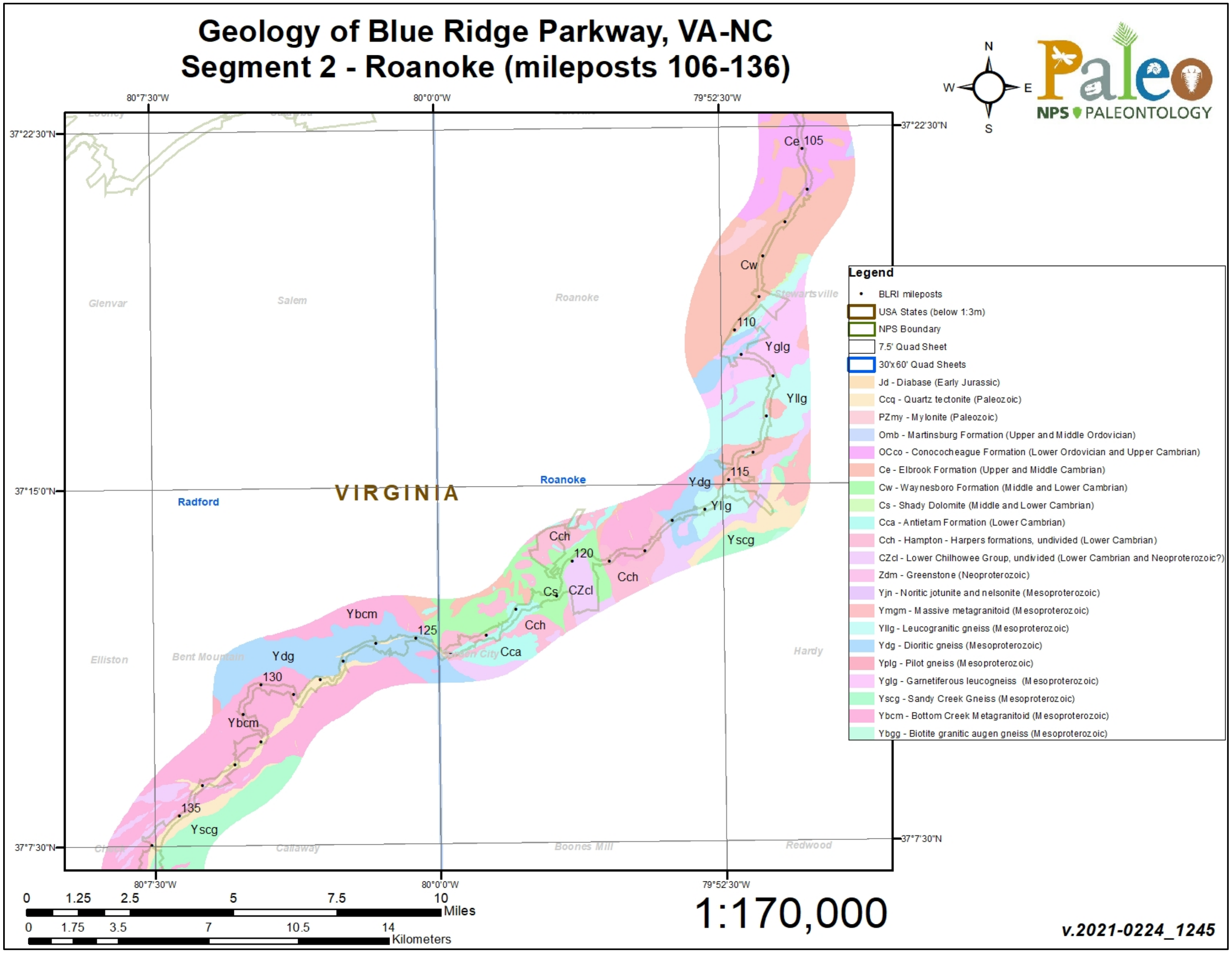


Figure 9. Bedrock geologic map of BLRI along the Roanoke segment (mileposts 106–136).

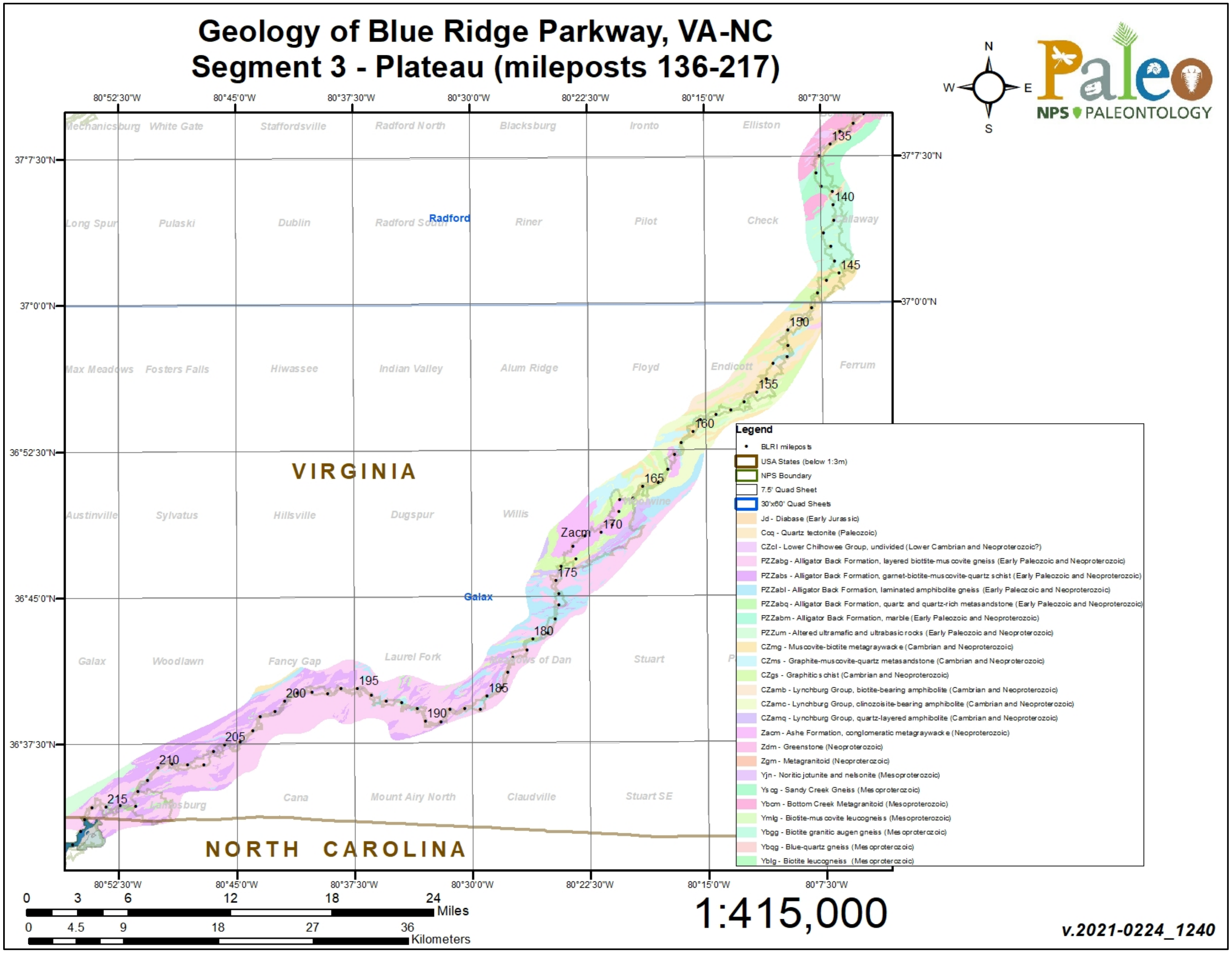


Figure 10. Bedrock geologic map of BLRI along the Plateau segment (mileposts 136–217).

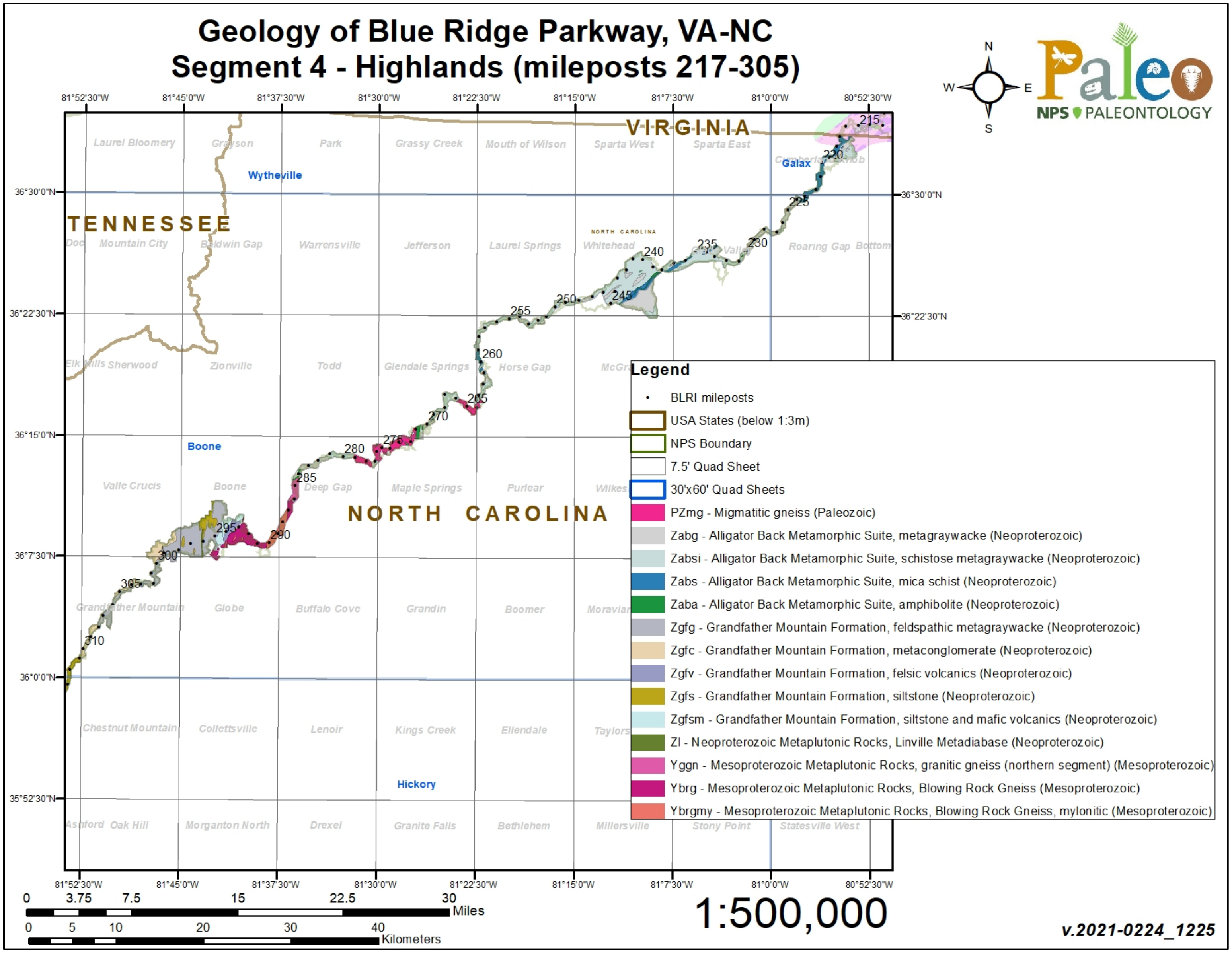


Figure 11. Bedrock geologic map of BLRI along the Highlands segment (mileposts 217–305).

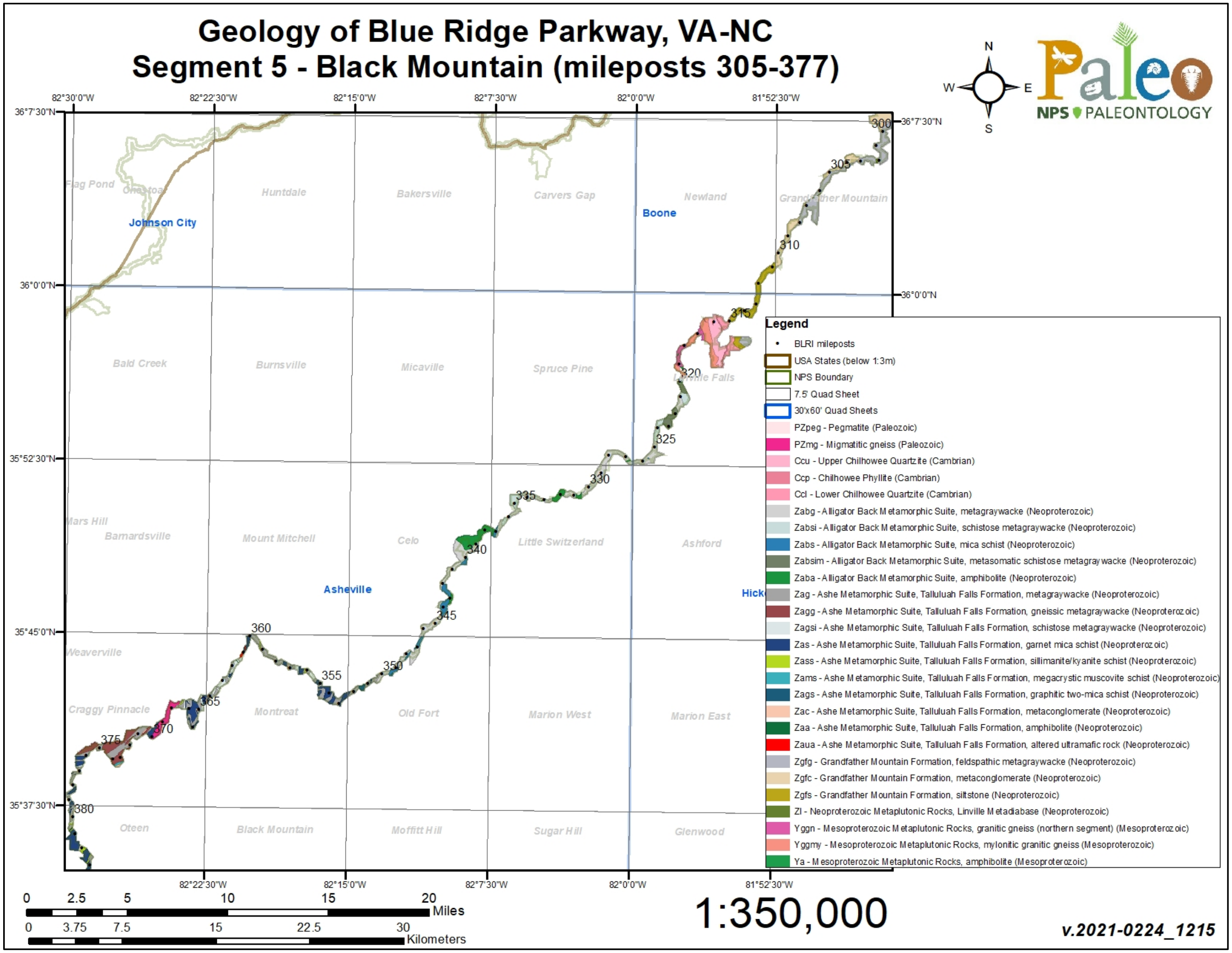


Figure 12. Bedrock geologic map of BLRI along the Black Mountain segment (mileposts 305–377).

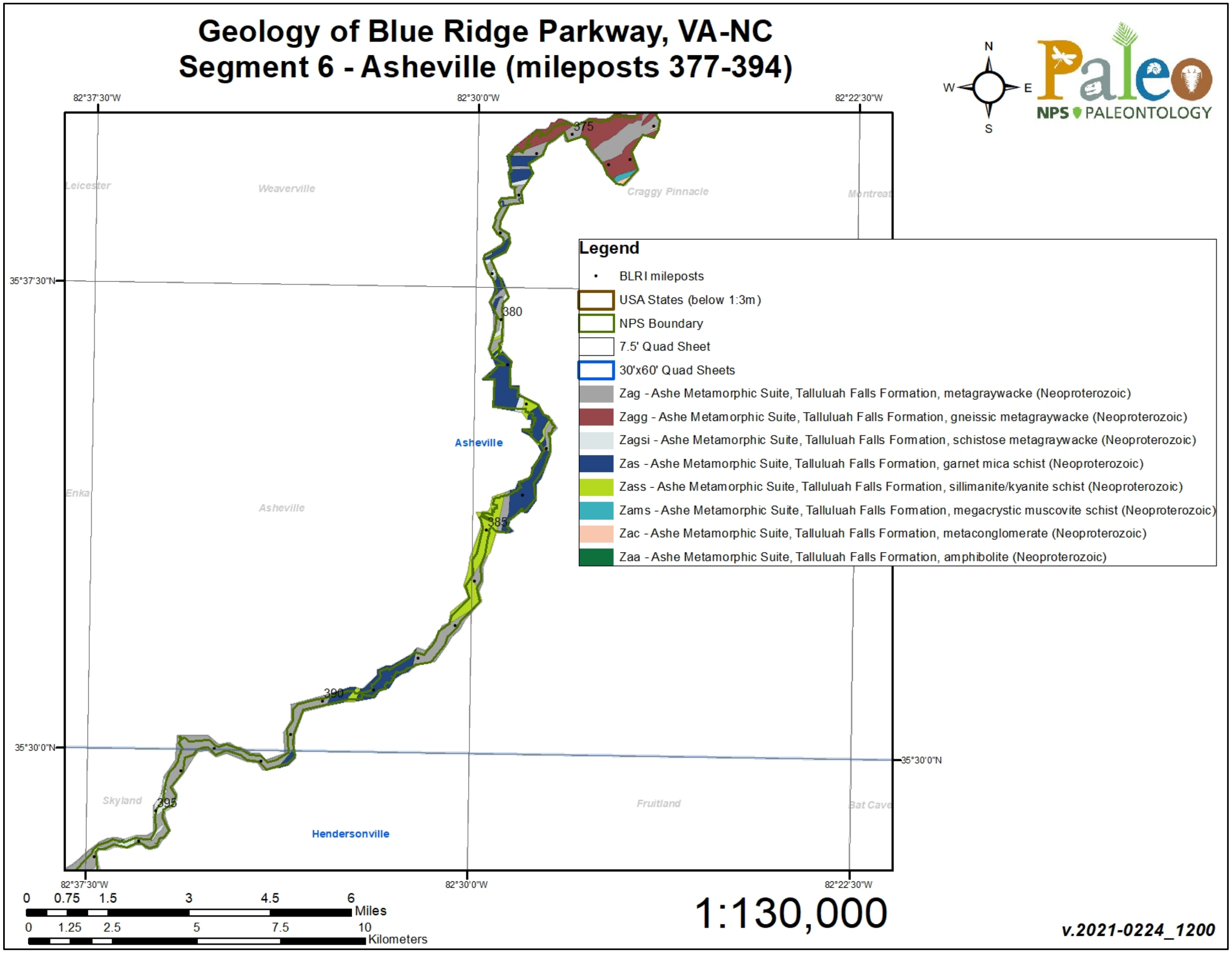


Figure 13. Bedrock geologic map of BLRI along the Asheville segment (mileposts 377–394).

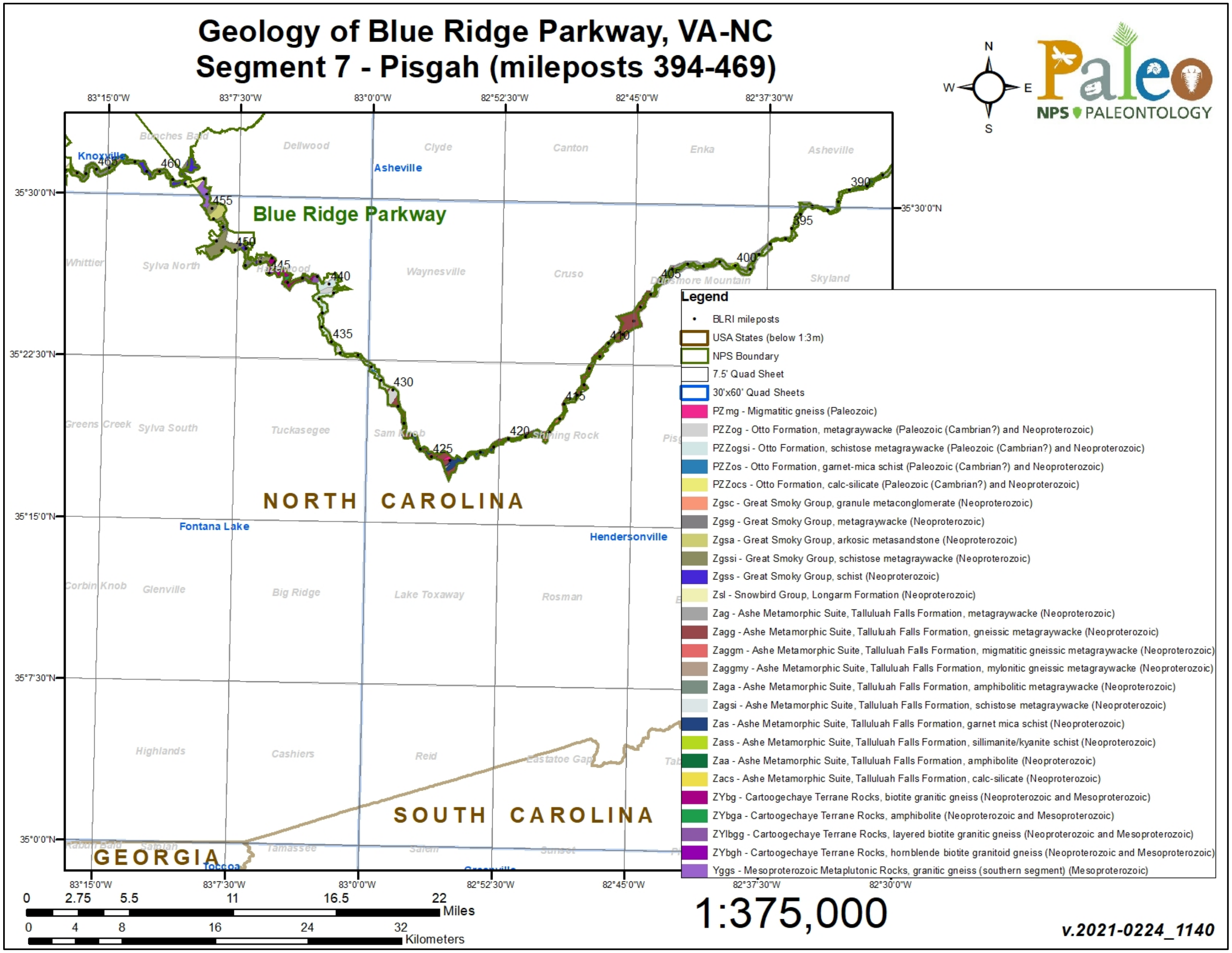


Figure 14. Bedrock geologic map of BLRI along the Pisgah segment (mileposts 394–469).

Table 1. List of BLRI stratotype units sorted by age with associated reference publications and locations.

Unit Name (map symbol)	Reference	Stratotype Location	Age
Alligator Back Formation (Zabg)	Rankin et al. 1973	Type locality: in a long roadcut at milepost 242 of the BLRI around Bluff Mountain and on the Park Service Alligator Back Trail	late Proterozoic–early Paleozoic

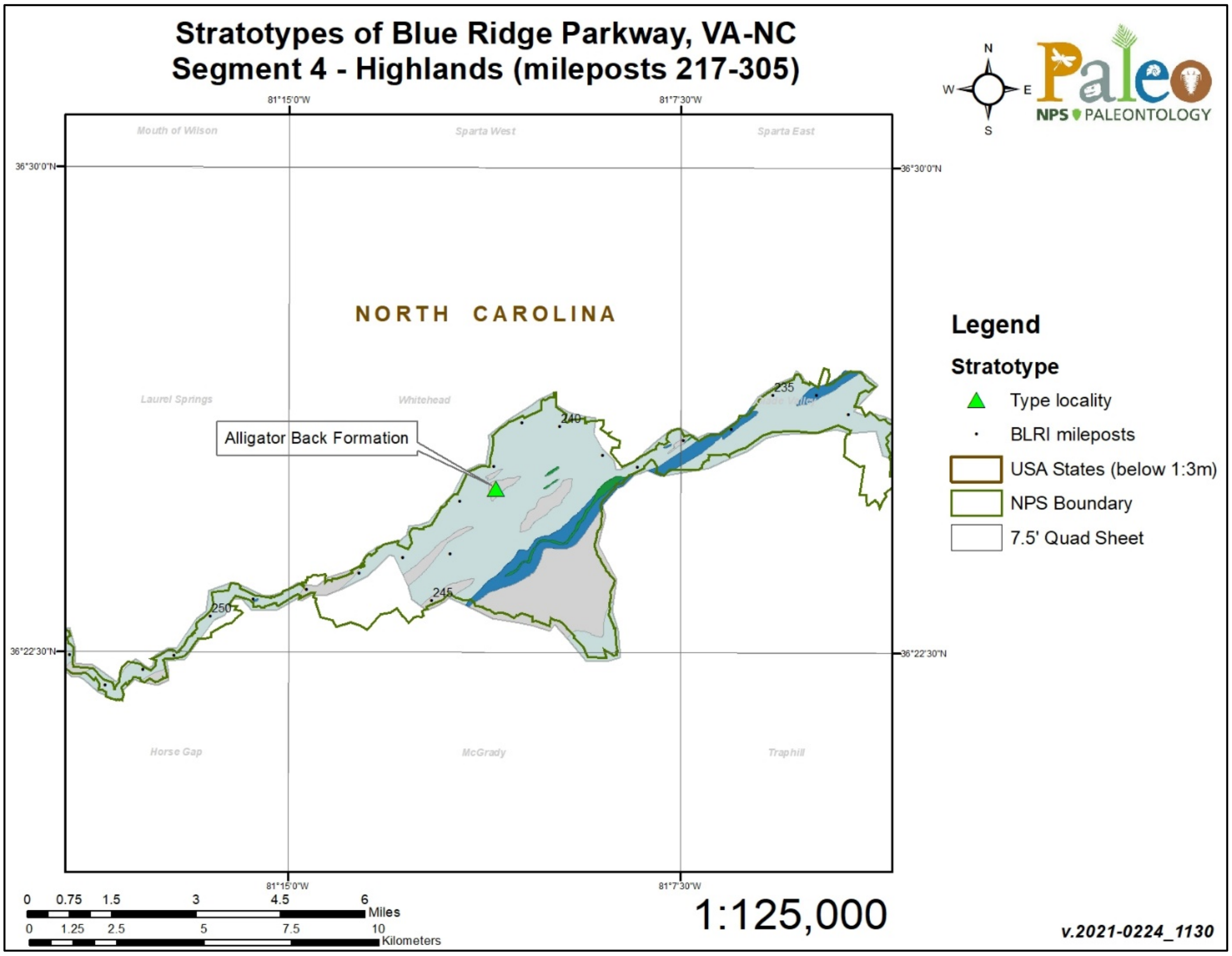


Figure 15. Modified geologic map of BLRI showing stratotype location along the Highland segment. The transparency of the geologic units layer has been increased.

The late Proterozoic–early Paleozoic Alligator Back Formation was designated by Rankin et al. (1973) after its type locality on Bluff Mountain (Alligator Back) in Alleghany County, northwestern North Carolina (Table 1; Figure 15). Excellent exposures of the formation occur at the type locality in a long roadcut of the BLRI around Bluff Mountain and on the Park Service Alligator Back Trail. The formation consists of laminated gneiss with interlayered schist and amphibolite with minor amounts of quartzite and marble (Rankin et al. 1973). The bedding of the Alligator Back Formation is generally severely deformed into isoclinal folds (with parallel limbs) and has enhanced pinstriping (thin laminations) that is a characteristic feature throughout the formation (Rankin et al. 1973).

Stratigraphically, the unit occurs conformably above the Ashe Formation and has a gradational contact over many tens of meters (Rankin et al. 1973). More recent work by Carter and Merschat (2014, 2016) show this underlying contact to be faulted.

Great Smoky Mountains National Park

Great Smoky Mountains National Park (GRSM) is situated in the southern Appalachian Mountains of Tennessee (Blount, Cocke, and Sevier Counties) and North Carolina (Haywood and Swain Counties) (Figure 16). The crest of the Great Smoky Mountains forms the North Carolina–Tennessee boundary and bisects the park from northeast to southwest in an unbroken mountain chain that rises more than 1,500 m (5,000 ft) for more than 58 km (36 mi) (Thornberry-Ehrlich 2008). Established on May 22, 1926, GRSM encompasses 211,419 hectares (522,427 acres) and preserves an exquisite collection of plants, animals, and geologic structures (Anderson 2017). The park was designated a Biosphere Reserve in 1976 and a World Heritage Site in 1983.

The geology of GRSM consists predominantly of sedimentary rocks that span a wide range of geologic time from the Neoproterozoic Era (1,000–539 million years ago) to the Mississippian (359–323 million years ago) (Figures 17 and 18). Some of the oldest rocks of the park are metamorphic and igneous units that are more than one billion years old and date to the Mesoproterozoic Era. Rocks of GRSM preserve ancient depositional environments and were subsequently uplifted and modified by multiple tectonic episodes that include the Grenville, Taconic, Acadian, and Appalachian orogenies. The Great Smoky Mountains formed approximately 300–200 million years ago and contain geologic units that represent a transitional deformation style associated with different provinces of the Appalachian Mountains. The Great Smoky Mountains contain mostly rocks of the Blue Ridge Province (as part of the Blue Ridge–Piedmont crystalline thrust sheet; Hatcher 1987), in addition to some sedimentary rocks of the Valley and Ridge Province (Thornberry-Ehrlich 2008).

GRSM contains nine identified stratotypes that are subdivided into one type section, five type localities, and three type areas (Table 2; Figure 19).

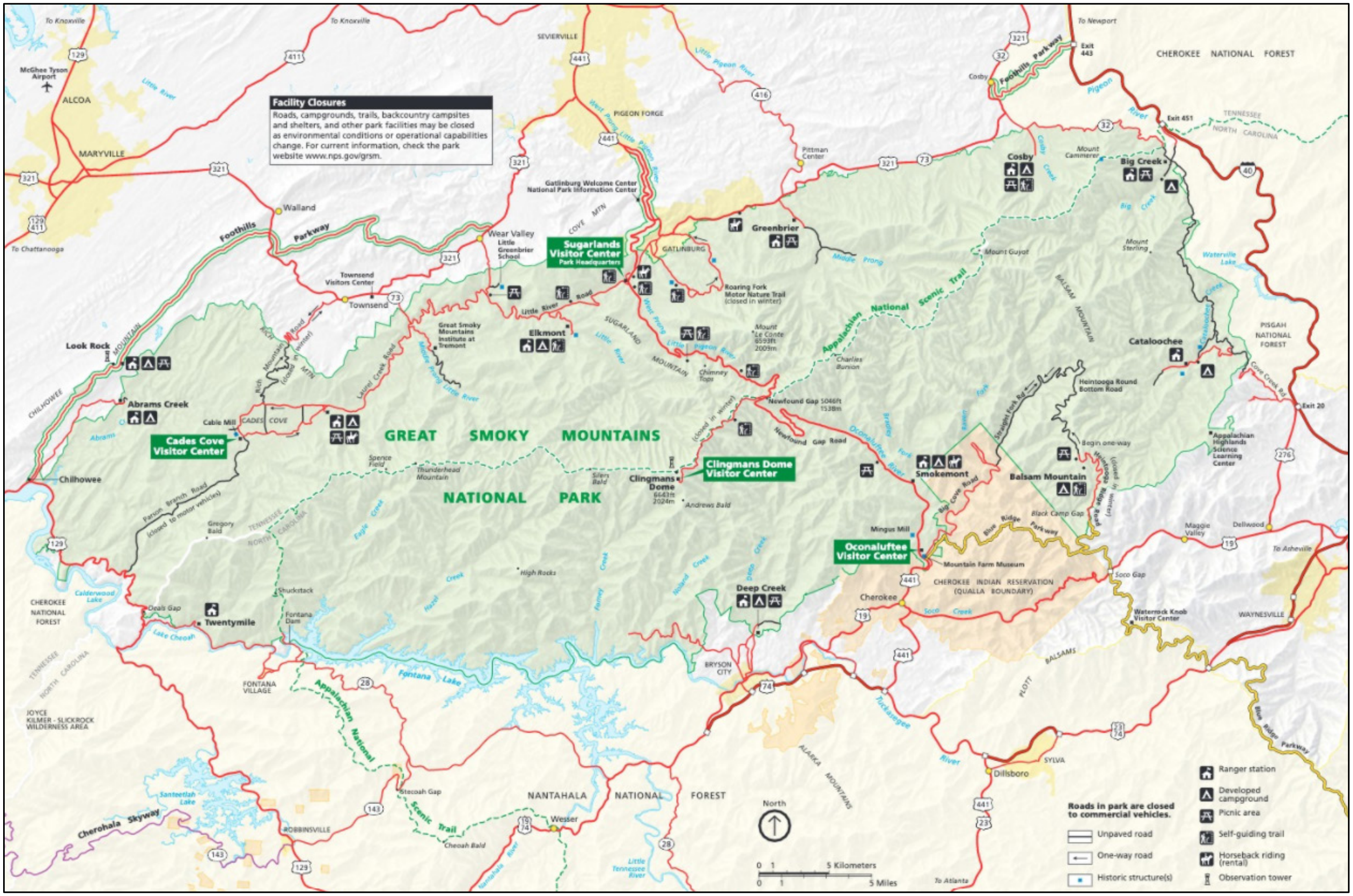


Figure 16. Park map of GRSM, Tennessee–North Carolina (NPS).

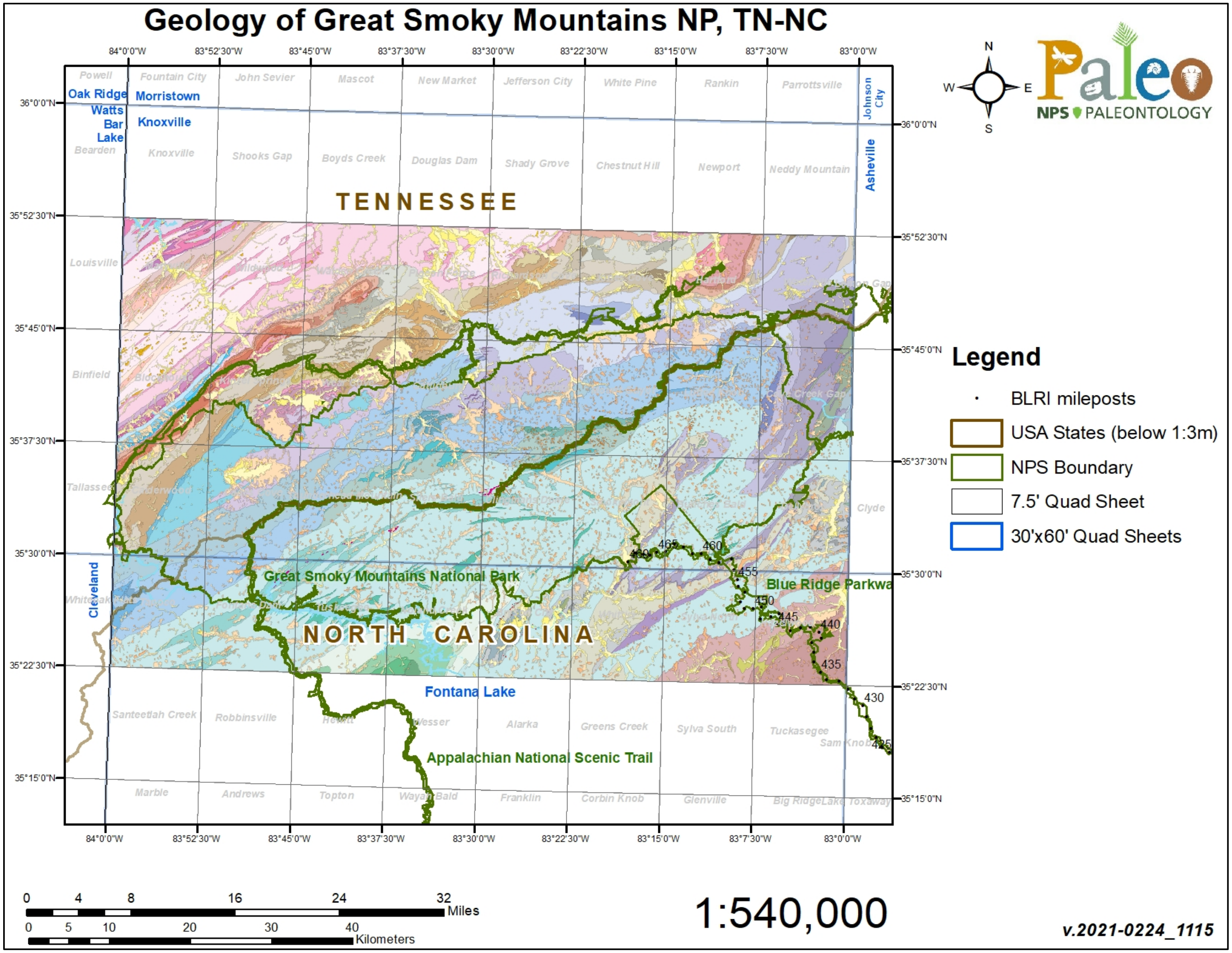


Figure 17. Geologic map of GRSM, Tennessee–North Carolina.

Figure 18. Bedrock geologic map legend of GRSM, Tennessee–North Carolina.

Table 2. List of GRSM stratotype units sorted by age with associated reference publications and locations.

Unit Name (map symbol)	Reference	Stratotype Location	Age
Anakeesta Formation (Za)	King et al. 1958	Type locality: located along US Highway 441 from the base of Anakeesta Ridge up to Newfound Gap	Neoproterozoic
Cades Sandstone (Zc)	King et al. 1958; King 1964	Type locality: exposed beds in the foothill area in the vicinity of Cades Cove	Neoproterozoic
Thunderhead Sandstone (Zt)	King 1964	Type area: Thunderhead Mountain	Neoproterozoic
Elkmont Sandstone (Ze)	King et al. 1958; King 1964	Type locality: along the lower slopes and spur ends of the Great Smoky Mountains along the Little River from Tennessee Highway 73 southeastward past Elkmont to the base of Thunderhead Mountain Type area: near Elkmont	Neoproterozoic
Rich Butt Sandstone (Zr)	King et al. 1958; King 1964	Type section: southeast of Mount Cammerer on Big Creek, above the community of Mount Sterling, North Carolina Type area: Rich Butt Mountain	Neoproterozoic
Metcalf Phyllite (Zm)	King et al. 1958; King 1964	Type locality: at Metcalf Bottoms on the Little River south of Wear Cove	Neoproterozoic
Roaring Fork Sandstone (Zrf)	King et al. 1958	Type locality: along the upper course of Roaring Fork stream	Neoproterozoic

The Neoproterozoic Roaring Fork Sandstone of the Snowbird Group (Ocoee Supergroup) was named by King et al. (1958) after its type locality exposures along the upper course of Roaring Fork, a stream located 2–5 km (1–3 mi) southeast of Gatlinburg in Sevier County, Tennessee. Type locality exposures are approximately 2,400 m (8,000 ft) thick and consist of massive, fine- to medium-grained, greenish-gray sandstone beds 3–30 m (10–100 ft) thick that are interbedded with thick- to thin-bedded, dull green sandstone, siltstone, and argillaceous rocks (King et al. 1958; King 1964). The Roaring Fork Sandstone conformably underlies the Pigeon Siltstone at the type locality.

The Neoproterozoic Metcalf Phyllite of the Snowbird Group (Ocoee Supergroup) was designated by King et al. (1958) for exposures located at Metcalf Bottoms on the Little River in Sevier County, eastern Tennessee. The type locality of the formation is located at Metcalf Bottoms on the Little River south of Wear Cove (King et al. 1958). The type locality is represented in exposures at a belt of foothills that have been dissected by the Little River, where exposures occur in roadcuts and bold natural ledges along the various prongs of the river (King 1964). Lithologically, the formation consists of thoroughly foliated, fissile, lustrous or silky, grayish-green or gray phyllite and siltstone that are interbedded with layers of fine-grained sandstone (King et al. 1958; King 1964). In most places, the Metcalf Formation is faulted against other rocks, making age relationships uncertain and total thickness estimates indeterminate.

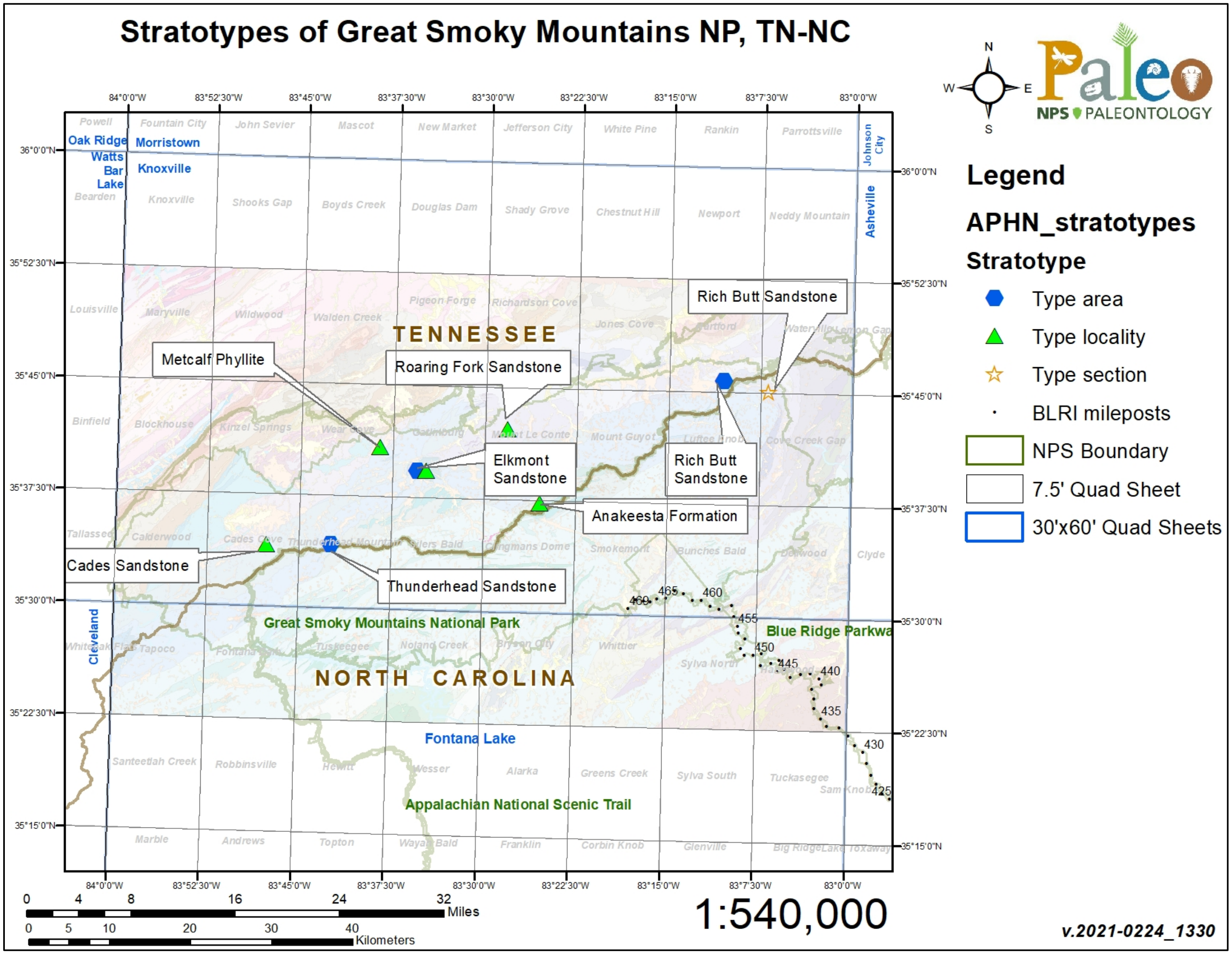


Figure 19. Modified geologic map of GRSM showing stratotype locations. The transparency of the geologic units layer has been increased.

The Neoproterozoic Rich Butt Sandstone of the Snowbird Group (Ocoee Supergroup) was designated by King et al. (1958) for its type area exposures near Rich Butt Mountain at the northeast end of the Great Smoky Mountains (Table 2; Figure 19). The type section of the formation is located southeast of Mount Cammerer on Big Creek, above the community of Mount Sterling, North Carolina (King et al. 1958). The type section measures approximately 910 m (3,000 ft) and consists of light, feldspathic, medium- to thick-bedded, medium- to fine-grained sandstone that contains sharply contrasting pelitic layers (Figure 20; King et al. 1958). Type area exposures at Rich Butt Mountain measure approximately 550 m (1,800 ft) thick and consist of thicker beds of coarse-grained sandstone and arkosic conglomerate (King et al. 1958; King 1964).

Figure 20. Exposure of the Rich Butt Sandstone located near the type section on the east bank of Big Creek 0.8 km (0.5 mi) above the bridge at Mount Sterling, GRSM. Lenticular bedding of fine-grained sandstone and darker argillaceous sandstone is visible. Scale bar is approximately 16 cm (6 in) (USGS; a modified version of this or a very similar photo was used as Figure 20A in Hadley and Goldsmith [1963]).

The Neoproterozoic Elkmont Sandstone of the Great Smoky Group (Ocoee Supergroup) was named by King et al. (1958) after the town of Elkmont in Sevier County, eastern Tennessee. Type locality exposures of the formation are situated along the lower slopes and spur ends of the Great Smoky Mountains along the Little River from Tennessee Highway 73 southeastward past Elkmont to the base of Thunderhead Mountain (Table 2; Figure 19; King et al. 1958; King 1964). Exposures in the type area near Elkmont are heavily faulted by the Gatlinburg, Oconaluftee, Mids Gap, and Huskey Gap faults that partly repeat stratigraphic sequence (King 1964). Type area exposures measure approximately 1,830 m (6,000 ft) and consist of feldspathic sandstone interbedded with numerous siltstone and argillaceous layers that display graded bedding in places (King et al. 1958). The upper part of the formation is generally coarser-grained than the lower part. Stratigraphically, the Elkmont Sandstone intertongues laterally with the overlying Thunderhead Sandstone and its basal contact is cut off by the Greenbrier fault.

The Neoproterozoic Thunderhead Sandstone of the Great Smoky Group (Ocoee Supergroup) was designated by Keith (1895) for well-developed exposures on Thunderhead Mountain in the western Great Smoky Mountains along the Tennessee–North Carolina divide. King (1964) would later designate the exposures on Thunderhead Mountain as the type area for the formation (Table 2; Figures 19 and 21). Type area exposures measure approximately 1,920 m (6,300 ft) and consist of gray to dark gray, ledge-forming, coarse-grained sandstone separated by partings of slate (King 1964). The Thunderhead Sandstone is conformably overlain by the Anakeesta Formation and intertongues laterally with the underlying Elkmont Sandstone.

Figure 21. Thunderhead Mountain of the Great Smoky Mountains rises above Cades Cove in Blount County, Tennessee. Thunderhead Mountain is the type area for the Thunderhead Sandstone. Cropped from photograph by user "Notneb82" available via Wikimedia Commons https://commons.wikimedia.org/wiki/File:Thunderhead_Mountain_with_an_October_Snow.JPG (Creative Commons Attribution-Share Alike 3.0 Unported [CC BY-SA 3.0]; https://creativecommons.org/licenses/by-sa/3.0/deed.en).

The Neoproterozoic Cades Sandstone of the Great Smoky Group (Ocoee Supergroup) was originally named the Cades Conglomerate by Keith (1895) for exposures near Cade Cove in Blount County, eastern Tennessee. King et al. (1958) and King (1964) revised the formation and designated the type locality from exposed beds in the foothill area in the vicinity of Cades Cove, GRSM (Table 2; Figures 19 and 22). The Cades Sandstone consists predominantly of coarse-grained, gray to dark gray feldspathic sandstone with thin interbedded layers of dark gray, silty, argillaceous rocks, and conglomerate (King et al. 1958; King 1964). Around its periphery, the formation has been thrust over adjacent rocks and its strata are inverted over wide areas (King et al. 1958). The only non-faulted, continuous section of the formation occurs along the Middle Prong of the Little River and measures approximately 460 m (1,500 ft) thick (King 1964).

Figure 22. Cades Cove in Great Smoky National Park. Exposures located in the foothills near Cades Cove are the type locality of the Cades Sandstone (NPS/KEVIN NOON).

The Neoproterozoic Anakeesta Formation of the Great Smoky Group (Ocoee Supergroup) was designated by King et al. (1958) after Anakeesta Ridge, a high spur between Mount Le Conte and Newfound Gap in Sevier County, Tennessee. The type locality of the formation is located along US Highway 441 from the base of Anakeesta Ridge up to Newfound Gap (Table 2; Figure 19; King et al. 1958). The Anakeesta Formation consists of dark gray or black, silty and argillaceous rocks that are interbedded with beds of dark gray, fine-grained sandstone (Figure 23; King et al. 1958; King 1964). The thickest unbroken sequence of the formation occurs along the state line divide west of Thunderhead Mountain and measures approximately 1,370 m (4,500 ft) thick (King 1964).

Figure 23. Sheared sandstone and green phyllite of the Anakeesta Formation in the type locality near Newfound Gap, GRSM. Yellow arrow indicates hammer for scale (USGS).

In addition to the designated stratotypes located within GRSM, a list of stratotypes located within 48 km (30 mi) of park boundaries is included here for reference. These nearby stratotypes include the Mesoproterozoic Spring Creek Granitoid Gneiss (type locality), Doggett Gap Protomylonitic Granitoid Gneiss (type locality), Sandymush Felsic Gneiss (type locality), and Earlies Gap Biotite Gneiss (type locality); Neoproterozoic Snowbird Group (type section), Nantahala Formation (type locality), Ammons Formation (type section), Sandsuck Formation (type locality), Shields Formation (type area), Pigeon Siltstone (type section), Licklog Formation (type locality), Wilhite Formation (type locality), Yellow Breeches Member of the Wilhite Formation (type locality), Dixon Mountain Member of the Wilhite Formation (type locality), Wading Branch Formation (type locality), and Longarm Quartzite (type locality); Cambrian Maryville Limestone (type locality), Nebo Quartzite (type locality), Hesse Quartzite (type locality), Nichols Shale (type locality), Murray Shale (type locality), and Cochran Formation (type locality); Ordovician Lenoir Limestone (type locality), Chapman Ridge Formation (type locality), Chota Formation (type section), Tellico Formation (type section), and Blockhouse Formation (type section); and the Mississippian Greasy Cove Formation (type section).

Obed Wild and Scenic River

The Obed Wild and Scenic River (OBED) is situated on the Cumberland Plateau in Cumberland and Morgan Counties, Tennessee. Encompassing approximately 2,053 hectares (5,073 acres), OBRI preserves and protects 72 km (45 mi) of free-flowing streams, rich wildlife and plant resources, and the rugged character of this area on the Cumberland Plateau (Anderson 2017; Figure 24). OBED was authorized a park unit on October 12, 1976 and was designated for outstandingly remarkable aesthetics, wildlife, fish, and recreational, cultural, ecological, geological, and aquatic values (Anderson 2017). The history of OBED can be traced back many centuries, but the scenery still looks much the same as when Americans Indians and early pioneers walked along its banks.

The regional geology of OBED consists predominantly of Pennsylvanian-age (323–300 million years ago) sedimentary rocks that are relatively flat-lying but have been dissected by the Obed River. The rocks of OBED are predominantly sandstone and shale, and include siltstone, conglomerate, and coal that have been slowly weathered and sculpted to produce an array of geologic formations that include arches, mesas, chimneys, cracks, and rock shelters. Geologic units commonly exposed along the river in OBED are the Rockcastle Conglomerate, Dorton Shale, and Crossville Sandstone (Figure 25). The landscape of OBED is characterized by a dendritic river drainage pattern and narrow, V-shaped gorges with river valleys dotted by huge boulders which have broken from the cliff faces. Rivers and streams at OBED consist of stretches of rugged whitewater rapids and quiet pools nestled below towering cliffs and forested talus slopes.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of OBED. There are ten identified stratotypes located within 48 km (30 mi) of OBED boundaries, for the Ordovician Lenoir Limestone (type locality), and the Pennsylvanian Crooked Fork Group (type section and type locality), Dorton Shale (type locality), Crossville Sandstone (type locality), Newton Sandstone (type area), Coalfield Sandstone (type locality), Slatestone Formation (type section), Glenmary Shale (type locality), and Rockcastle Sandstone Member of the Bee Rock Formation (type locality).

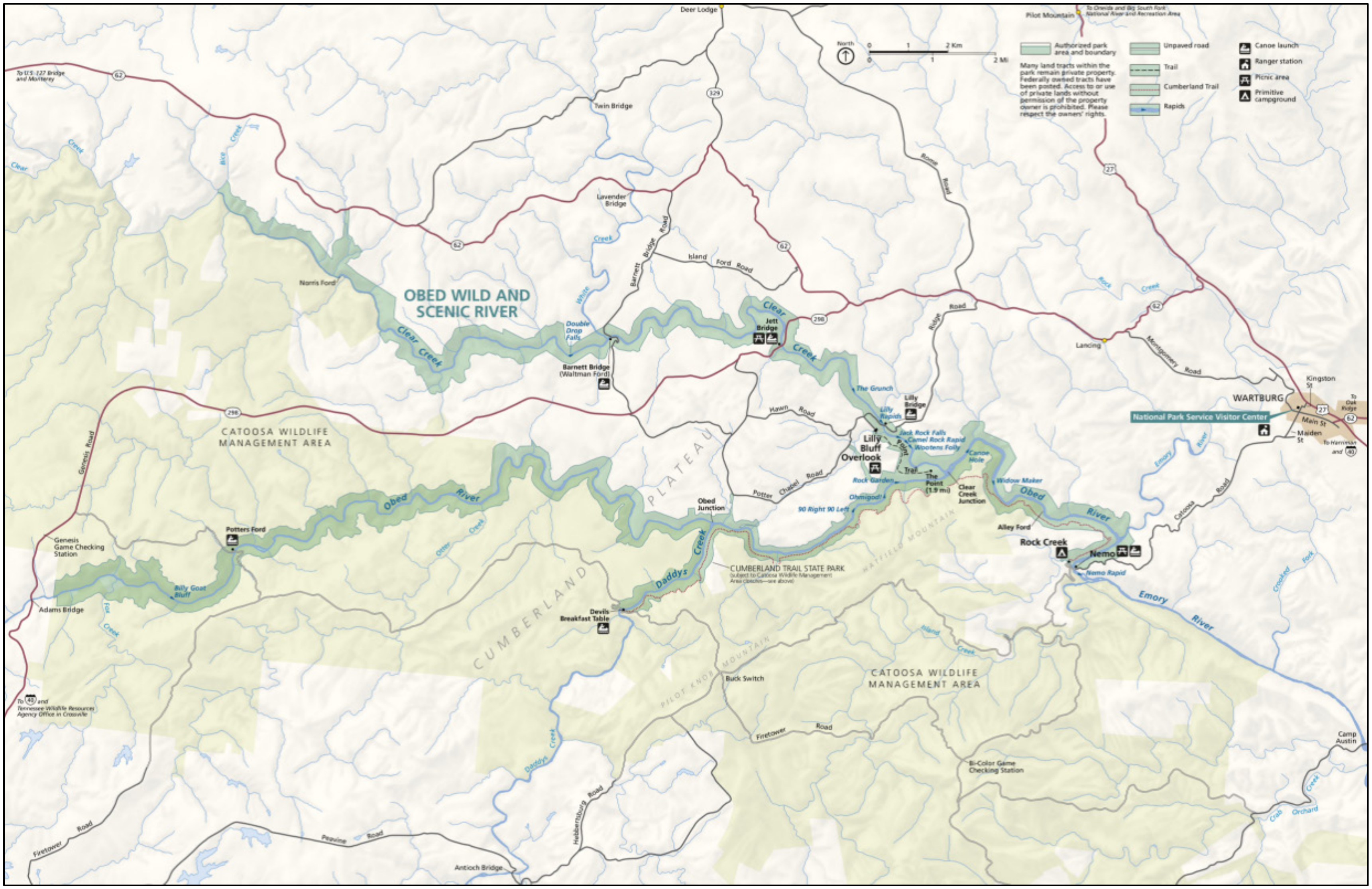


Figure 24. Park map of OBED (NPS).

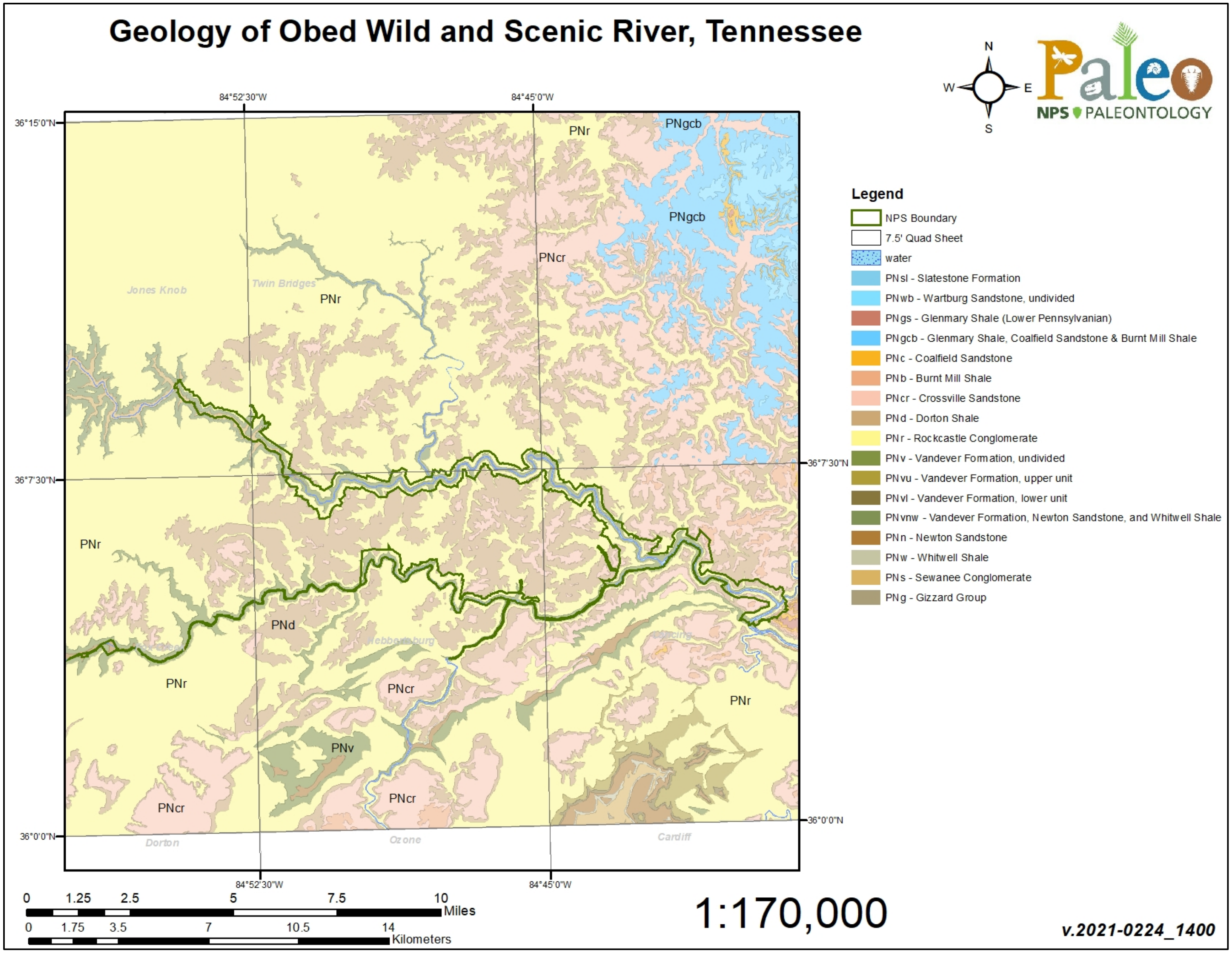


Figure 25. Bedrock geologic map of OBED, Tennessee.

Recommendations

1. The NPS Geologic Resources Division should work with park and network staff to increase their awareness and understanding about the scientific, historic and geologic heritage significance of geologic stratotypes (type sections/localities/areas, reference sections, lithodemes).
2. Once the APHN Geologic Type Section Inventory report is finalized, the NPS Geologic Resources Division should schedule a briefing for the staff of the APHN and respective network parks.
3. The Pennsylvanian Burnt Mill Shale was named by Wilson et al. (1956) from exposures near Burnt Mill Bridge in Robbins and Oneida South Quadrangles, Scott County, eastern Tennessee within or near the park boundaries of BISO. However, no formal stratotype for the Burnt Mill Shale has been identified. Therefore, we recommend a formal type section be designated in order to A) provide a standard reference for scientific research; B) educate park staff and visitors about the geoheritage significance of the unit; and C) help safeguard the exposure.
4. The NPS Geologic Resources Division should work with park and network staff to ensure they are aware of the location of stratotypes in park areas. This information would be important to ensure that proposed park activities or development would not adversely impact the stability and condition of these geologic exposures. Preservation of stratotypes should not limit availability for future scientific research but help safeguard these exposures from infrastructural development.
5. The NPS Geologic Resources Division should work with park and network staff, the U.S. Geological Survey, state geological surveys, academic geologists, and other partners to formally assess potential new stratotypes as to their significance (international, national, or statewide), based on lithology, stratigraphy, fossils or notable features using procedural code outlined by the North American Commission on Stratigraphic Nomenclature.
6. From the assessment in (4), NPS staff should focus on registering new stratotypes at State and Local government levels where current legislation allows, followed by a focus on registering at Federal and State levels where current legislation allows.
7. The NPS Geologic Resources Division should work with park and network staff to compile and update a central inventory of all designated stratotypes and potential future nominations.
8. The NPS Geologic Resources Division should ensure the park-specific Geologic Type Section Inventory Reports are widely distributed and available online.
9. The NPS Geologic Resources Division should work with park and network staff to regularly monitor geologic type sections to identify any threats or impacts to these geologic heritage features in parks.
10. The NPS Geologic Resources Division should work with park and network staff to obtain good photographs of each geologic type section within the parks. In some cases, where there may be active geologic processes (rock falls, landslides, coastal erosion, etc.), the use of photogrammetry may be considered for monitoring of geologic type sections. GPS locations should also be recorded and kept in a database when the photographs are taken.

11. The NPS Geologic Resources Division should work with park and network staff to utilize selected robust internationally and nationally significant type sections as formal teaching/education sites and for geotourism so that the importance of the national- and international-level assets are more widely (and publicly) known, using information boards and walkways.
12. The NPS Geologic Resources Division should work with park and network staff in developing conservation protocols of significant type sections, either by appropriate fencing, walkways, and information boards or other means (e.g., phone apps).

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Appendix A: Source Information for GRI Maps of APHN Parks

BISO

- GMAP 1517: Smith, J. H. 1978. Geologic map of the Bell Farm Quadrangle and part of the Barthell SW Quadrangle, McCreary and Wayne Counties, Kentucky. U.S. Geological Survey, Washington, D.C. Geologic Quadrangle Map 1496. Scale 1:24,000. Available at: http://ngmdb.usgs.gov/Prodesc/proddesc_1046.htm (accessed February 25, 2021).
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- GMAP 1523: Pomerene, J. B. 1964. Geology of the Barthell Quadrangle and part of the Oneida North Quadrangle, Kentucky. U.S. Geological Survey, Washington, D.C. Geologic Quadrangle Map 314. Scale 1:24,000. Available at: http://ngmdb.usgs.gov/Prodesc/proddesc_775.htm (accessed February 25, 2021).
- GMAP 67749: Jewell, J. W. 1972. Geologic map and mineral resources summary of the Burrville Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Quadrangle Map 115-SE. Scale 1:24,000
- GMAP 74714: Sparks, T. N., W. H. Anderson, and X. Yang. 2011. Geologic map of the Corbin 30 x 60 Minute Quadrangle, south-central Kentucky. Kentucky Geological Survey, Lexington, Kentucky. Geologic Map 27. Scale 1:100,000.
- GMAP 75619: Clendening, R. J., and A. B. Horton. 2012. Geologic map of the Oneida South Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Quadrangle Map 128A-NE. Scale 1:24,000.
- GMAP 75620: Clendening, R. J., A. B. Horton, and J. W. Jewell. 2009. Geologic map of the Stockton Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Quadrangle Map 115-NE. Scale 1:24,000.
- GMAP 75621: Clendening, R. J., and A. B. Horton. 2010. Geologic map and mineral resources summary of the Honey Creek Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Map 128A-NW. Scale 1;24,000.
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- GMAP 75744: Zhang, Q., and M. Stidham. 2006. Spatial database of the Barthell Quadrangle and part of the Oneida North Quadrangle, Kentucky. Kentucky Geological Survey, Lexington, Kentucky. Digitally Vectorized Geological Quadrangle 314. Scale 1:24,000.
- GMAP 75782: Horton, A. B., R. J. Clendening, and M. L. Hoyal. 2013. Geologic map of the Oneida North Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Quadrangle Map 336-SE. Scale 1:24,000.
- GMAP 75960: Horton, A., and M. Hoyal. 2016. Geologic map of the Barthell SW Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Map 336-SW. Scale 1;24,000.
- GMAP 76048: Hoyal, M., and A. Horton. 2015. Geologic map of the Sharp Place Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Quadrangle Map 335-SE. Scale 1:24,000.
- GMAP 76061: Zhang, Q., and M. Stidham. 2006. Spatial Database of the Nevelsville Quadrangle, south-central Kentucky. Kentucky Geological Survey, Lexington, Kentucky. Digitally Vectorized Geological Quadrangle 1326. Scale 1:24,000.
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BLRI

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GRSM

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OBED

- GMAP 67760: Coker, A. E. 1965. Geologic map and mineral resources summary of the Jones Knob Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Map 116-NW. Scale 1:24,000.
- GMAP 68526: Coker, A. E. 1965. Geologic map and mineral resources summary of the Twin Bridges Quadrangle, Tennessee. Tennessee Geological Survey, Nashville, Tennessee. Geologic Map 116-NE. Scale 1:24,000.
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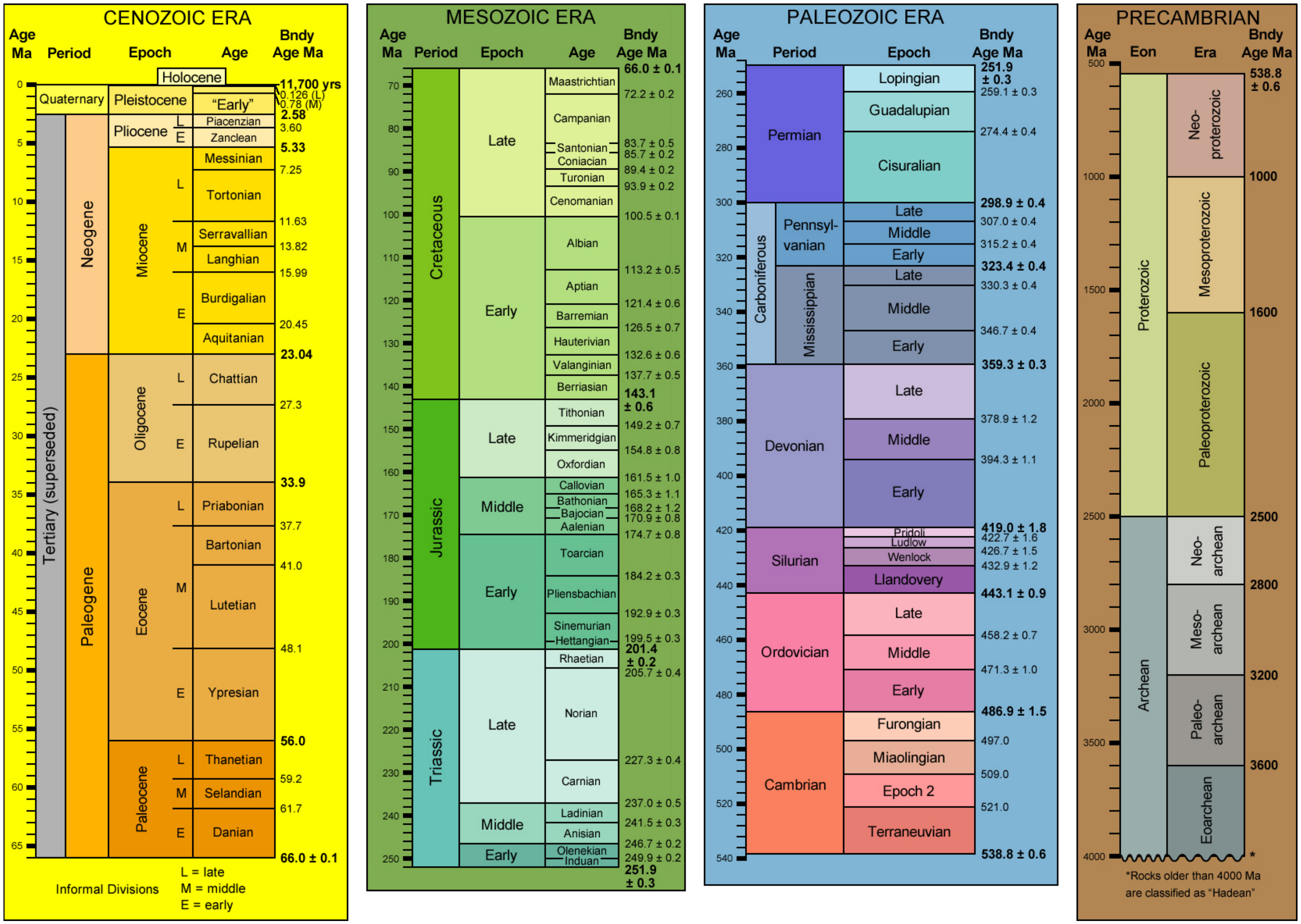
- GMAP 76047: Scruggs, P. L., B. Rascoe, R. G. Stearns, B. R. Hansen, A. L. Wunderlich, and R. D. Hatcher, Jr. 2015. Geologic map of the Fox Creek 7.5-Minute Quadrangle, Tennessee. University of Tennessee, Knoxville, Tennessee. 7.5-Minute Series Map. Scale 1:24,000.

Appendix B: Geologic Time Scale



Ma=Millions of years old. **Bndy Age**=Boundary Age. Layout after 1999 Geological Society of America Time Scale (https://www.geosociety.org/documents/gsa/timescale/timescl-1999.pdf). Dates after Gradstein et al. (2020).

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