National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

National Park Service Geologic Type Section Inventory

Mid-Atlantic Inventory & Monitoring Network

Natural Resource Report NPS/MIDN/NRR—2022/2443

ON THE COVER

View from the summit of Old Rag Mountain, Shenandoah National Park. The Mesoproterozoic-age Old Rag Granite type locality is designated at Old Rag Mountain. NPS photo.

National Park Service Geologic Type Section Inventory

Mid-Atlantic Inventory & Monitoring Network

Natural Resource Report NPS/MIDN/NRR—2022/2443

Tim C. Henderson,[1] Vincent L. Santucci,[1] Tim Connors,[2] and Justin S. Tweet[3]

[1]National Park Service
Geologic Resources Division
1849 "C" Street, NW
Washington, D.C. 20240

[2]National Park Service
Geologic Resources Division
Post Office Box 25287
Denver, Colorado 80225

[3]National Park Service
9149 79th Street S.
Cottage Grove, Minnesota 55016

September 2022

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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 and technically accurate.

This report is available in digital format from the Mid-Atlantic Inventory and Monitoring Network website and the Natural Resource Publications Management website. If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Please cite this publication as:

Henderson, T. C., V. L. Santucci, T. Connors, and J. S. Tweet. 2022. National Park Service geologic type section inventory: Mid-Atlantic Inventory & Monitoring Network. Natural Resource Report NPS/MIDN/NRR—2022/2443. National Park Service, Fort Collins, Colorado. https://doi.org/10.36967/2294240

NPS 956/184079, September 2022

Contents

Page

Figures ... vii

Tables ... ix

Photographs ... ix

Appendices ... ix

Executive Summary ... xi

Acknowledgments ... xiii

Dedication ... xv

Introduction ... 1

- Definitions ... 2

Methods ... 5

- Methodology ... 5
- Geologic Resources Inventory (GRI) Data ... 9
- Additional Considerations ... 9

Geology and Stratigraphy of the MIDN I&M Network Parks ... 11

- Precambrian (4.6 billion to 539 million years ago) ... 13
- Paleozoic (539 to 252 million years ago) ... 13
- Mesozoic (252 to 66 million years ago) ... 13
- Cenozoic (66 million years ago to the present) ... 13

Appomattox Court House National Historical Park (APCO) ... 15

- Park Establishment ... 15
- Geologic Summary ... 15
- Stratotypes ... 15

Booker T. Washington National Monument (BOWA) ... 19

- Park Establishment ... 19
- Geologic Summary ... 19
- Stratotypes ... 19

Contents (continued)

Page

Cedar Creek and Belle Grove National Historical Park (CEBE) 23

Park Establishment 23

Geologic Summary 23

Stratotypes 23

Stickley Run Member, Martinsburg Formation 28

Eisenhower National Historic Site (EISE) 29

Park Establishment 29

Geologic Summary 29

Stratotypes 29

Fredericksburg and Spotsylvania National Military Park (FRSP) 33

Park Establishment 33

Geologic Summary 33

Stratotypes 33

Gettysburg National Military Park (GETT) 37

Park Establishment 37

Geologic Summary 37

Stratotypes 37

Hopewell Furnace National Historic Site (HOFU) 41

Park Establishment 41

Geologic Summary 41

Stratotypes 41

Petersburg National Battlefield (PETE) 45

Park Establishment 45

Geologic Summary 45

Stratotypes 45

Contents (continued)

Page

Richmond National Battlefield Park (RICH) 49

Park Establishment 49

Geologic Summary 49

Stratotypes 49

Shenandoah National Park (SHEN) 53

Park Establishment 53

Geologic Summary 53

Stratotypes 53

Old Rag Granite 58

Swift Run Formation 59

Valley Forge National Historical Park (VAFO) 61

Park Establishment 61

Geologic Summary 61

Stratotypes 61

Recommendations 65

Literature Cited 69

Figures

Page

Figure 1. Screenshot of the GRI-compiled digital geologic map of Richmond National Battlefield Park showing mapped units. 6

Figure 2. GEOLEX search result for Gettysburg Shale unit of the Newark Supergroup/Group........ 7

Figure 3. Stratotype inventory spreadsheet of the MIDN displaying attributes appropriate for geolocation assessment. 8

Figure 4. Map of Mid-Atlantic I&M Network parks. 12

Figure 5. Park map of APCO, Virginia (NPS). 16

Figure 6. Geologic map of APCO, Virginia. 17

Figure 7. Park map of BOWA, Virginia (NPS). 20

Figure 8. Geologic map of BOWA, Virginia. 21

Figure 9. Park map of CEBE, Virginia (NPS). 24

Figure 10. Geologic map of CEBE, Virginia. 25

Figure 11. Modified geologic map of CEBE showing stratotype locations. 27

Figure 12. Type section of the Stickley Run Member of the Martinsburg Formation (Oms) overlying the Edinburg Formation (Oe) along U.S. Highway 11, immediately east of Cedar Creek. 28

Figure 13. Park map of EISE and part of GETT, Pennsylvania (NPS). 30

Figure 14. Geologic map of EISE and GETT. 31

Figure 15. Park map of FRSP, Virginia (NPS). 34

Figure 16. Geologic map of FRSP, Virginia. 35

Figure 17. Park map of GETT and EISE, Pennsylvania (NPS). 38

Figure 18. Geologic map of EISE and GETT. 39

Figure 19. Park map of HOFU, Pennsylvania (NPS). 42

Figure 20. Geologic map of HOFU, Pennsylvania. 43

Figure 21. Park map of PETE, Virginia (NPS). 46

Figure 22. Geologic map of PETE, Virginia. 47

Figures (continued)

Page

Figure 23. Park map of RICH, Virginia (NPS). 50

Figure 24. Geologic map of RICH, Virginia. 51

Figure 25. Park map of SHEN, Virginia (NPS). 54

Figure 26. Geologic map of SHEN, Virginia; see Figure 27 for legend. 55

Figure 27. Geologic map legend of SHEN, Virginia. 56

Figure 28. Modified geologic map of SHEN showing stratotype locations. 57

Figure 29. View looking southeast from Thorofare Mountain Overlook toward Old Rag Mountain, type locality of the Old Rag Granite (NPS). 58

Figure 30. Visitors along the top of the boulders at the summit of Old Rag Mountain, SHEN. 59

Figure 31. Type locality exposure of the Swift Run Formation located east of Swift Run Gap, SHEN. 60

Figure 32. Park map of VAFO, Pennsylvania (NPS). 62

Figure 33. Geologic map of VAFO, Pennsylvania. 63

Tables

Page

Table 1. List of MIDN stratotype units sorted by park unit and geologic age, with associated reference publications and locations....xii

Table 2. List of CEBE stratotype units sorted by age with associated reference publications and locations....26

Table 3. List of SHEN stratotype units sorted by age with associated reference publications and locations....56

Photographs

Page

Jim Comiskey, the Inventory and Monitoring Division Program Manager for Interior Region 1 (North Atlantic–Appalachian)....xv

Appendices

Page

Appendix A: Source Information for GRI Maps of MIDN Parks....73

Appendix B: Geologic Time Scale....77

Appendix C: Stratotypes Located Within 48 km (30 mi) of MIDN Parks....79

Executive Summary

Type sections are one of several kinds of stratotype. A stratotype is the standard (original or subsequently designated), accessible, and specific sequence of rock for a named geologic unit that forms the basis for the definition, recognition, and comparison of that unit elsewhere. Geologists designate stratotypes for rock exposures that are illustrative and representative of the map unit being defined. Stratotypes ideally should remain accessible for examination and study by others. In this sense, geologic stratotypes are similar in concept to biological type specimens; however, they remain in situ as rock exposures rather than curated in a repository. Therefore, managing stratotypes requires inventory and monitoring like other geologic heritage resources in parks. In addition to type sections, stratotypes also include type localities, type areas, reference sections, and lithodemes, all of which are defined in this report.

The goal of this project is to consolidate information pertaining to stratotypes that 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 heritage resources.

This effort identified four stratotypes designated within two park units of the Mid Atlantic Inventory & Monitoring Network (MIDN): Cedar Creek and Belle Grove National Historical Park (CEBE) contains one type section; and Shenandoah National Park (SHEN) contains two type localities and one principal reference section. Table 1 provides information regarding the five stratotypes currently identified within the MIDN. There are currently no designated stratotypes within Appomattox Court House National Historical Park (APCO), Booker T. Washington National Monument (BOWA), Eisenhower National Historic Site (EISE), Fredericksburg and Spotsylvania County Battlefields Memorial National Military Park (FRSP), Gettysburg National Military Park (GETT), Hopewell Furnace National Historic Site (HOFU), Petersburg National Battlefield (PETE), Richmond National Battlefield Park (RICH), and Valley Forge National Historical Park (VAFO).

The inventory of geologic stratotypes across the NPS is an important effort in documenting these locations in order that NPS staff recognize and protect these areas for future studies. The focus adopted for completing the baseline inventories throughout the NPS has centered on the 32 inventory and monitoring (I&M) networks established during the late 1990s. Adopting a network-based approach to inventories worked well when the NPS undertook paleontological resource inventories for the 32 I&M networks and was therefore adopted for the stratotype inventory. The Greater Yellowstone I&M Network (GRYN) was the pilot network for initiating this project (Henderson et al. 2020). Methodologies and reporting strategies adopted for the GRYN have been used in the development of this report for the MIDN.

This report includes 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.

Table 1. List of MIDN stratotype units sorted by park unit and geologic age, with associated reference publications and locations.

Park	Unit Name (GRI map symbol)	Reference	Stratotype Location	Age
CEBE	Stickley Run Member, Martinsburg Formation	Epstein et al. 1995	Type section: roadcut on southeast side of northbound lane of U.S. Highway 11, immediately east of Cedar Creek, about 4 km (2.5 mi) southwest of Middletown, Frederick County, and 4.8 km (3 mi) northeast of Strasburg (latitude 39°00′57″ N., longitude 78°18′52″ W.), in Shenandoah County, Virginia.	Ordovician
SHEN	Swift Run Formation (Zsr)	Jonas and Stose 1939; King 1950; Bailey et al. 2012	Type locality: exposures along US Highway 33, about 1.9 km (1.2 mi) east of Swift Run Gap and on the Skyline Drive just north of the gap, a few miles southeast of the Elkton area in Greene County, Virginia. Principal reference section: an exposure 1.6 km (1 mi) east of the original type locality along a tributary to the north of U.S. Route 33, in Greene County, Virginia.	Neoproterozoic
SHEN	Old Rag Granite (Yo)	Furcron 1934; Lukert 1982; Blackburn et al. 1994	Type locality: exposures on Old Rag Mountain, in Madison County, Virginia.	Mesoproterozoic

Acknowledgments

Many individuals were consulted in the preparation of this report on the geologic type sections for the national parks of the Mid-Atlantic Inventory & 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, Dave, and Nancy manage the National Geologic Map Database and GEOLEX (the U.S. Geologic Names Lexicon, a national compilation of names and descriptions of geologic units), respectively, for the United States, critical sources of geologic map information for science, industry and the American public. We also extend our appreciation to Matthew Heller and Marcie Occhi (Virginia Department of Natural Resources), as well as Christopher Bailey and Rick Berquist, Jr. (College of William & Mary) for their support in reviewing the manuscript and providing professional feedback.

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. We thank Tomoko Korenaga (American Journal of Science) for permission to reprint Figure 34. Additionally, we are grateful to Rory O'Connor-Walston and Alvin Sellmer from the NPS Technical Information Center in Denver for their assistance with locating hard-to-find publications.

Thanks to our NPS colleagues in the Northeast Regional Office and the Mid-Atlantic Inventory and Monitoring Network, including: Jim Comiskey, Carmen Chapin, and Seth Lerman. Jim served as the peer review coordinator for this report.

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 Stephanie Gaswirth, Hal Pranger, Julia Brunner, Jim Wood, Jason Kenworthy, and Rebecca Port. Finally, we want to thank the past and current members of the NPS Geologic Resource Inventory Team for more than 20 years of work to expand our understanding of the geologic features, issues, and processes in our national parks!

Dedication

This Mid-Atlantic Inventory & Monitoring Network (MIDN) Geologic Type Section Inventory is dedicated to Jim Comiskey, the Inventory and Monitoring Division Program Manager for Interior Region 1 (North Atlantic–Appalachian). Jim has been a great supporter of our various geology and paleontology reports associated with MIDN and we are proud to acknowledge his support through our dedication of this report.

Jim Comiskey, the Inventory and Monitoring Division Program Manager for Interior Region 1 (North Atlantic–Appalachian) (Photo courtesy of J. Comiskey).

Introduction

Geologic maps show the distribution and classification of rocks, sedimentary deposits, and geologic features for a given area. The geologic classification of rocks and deposits is hierarchical with several different categories of geologic or stratigraphic units including, from regional scale to local exposure scale: supergroup, group, formation, member, and bed. The mapping of stratigraphic units involves the evaluation of lithologies, bedding properties, thickness, geographic distribution, and other factors. Mappable geologic units 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 2021). 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 or exposure area of the unit is designated as the stratotype (see "Definitions" below). The type section is an important reference exposure for a named geologic unit which presents a relatively complete and representative example for this unit. Geologic stratotypes are important geoheritage resources with historic and scientific significance, and should be available for other researchers to evaluate in the future.

The importance of stratotypes lies in the fact that they represent important comparative sites where past investigations can be built upon or re-examined and can serve as teaching sites for the next generation of geoscientists (Brocx et al. 2019). The geoheritage significance of stratotypes is analogous to libraries and museums in that they are natural repositories of Earth history and record the physical and biologic evolution of our planet. In addition, geologic formations are named after topographic or geologic features and landmarks that are recognizable to park staff and visitors. Therefore, geologic stratotypes are part of our national geologic heritage and are a cornerstone of the scientific value used to define the societal significance of geoheritage sites (refer to https://www.nps.gov/articles/scientific-value.htm for more about geologic heritage).

The goals of this project are to (1) systematically report the assigned stratotypes that occur within national parks of the Mid-Atlantic Inventory and Monitoring (I&M) Network (MIDN), (2) provide detailed descriptions of the stratotype exposures and their locations, and (3) 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. This effort identified four stratotypes within two MIDN parks: Cedar Creek and Belle Grove National Historical Park (CEBE) contains one type section; and Shenandoah National Park (SHEN) contains two type localities and one principal reference section. Table 1 provides information regarding the five stratotypes currently identified within the MIDN. Additionally, numerous stratotypes are located geographically outside of national park boundaries; those within 48 km (30 mi) of park boundaries are mentioned in this report.

The MIDN Geologic Type Section Inventory report is part of a larger effort to document stratotypes in all 32 I&M networks and selected non-I&M parks with significant rock exposures. This report follows the standard practices, methodologies, and organization of information introduced in the Greater Yellowstone I&M Network type section inventory (Henderson et al. 2020), which was the pilot for this effort; refer to the Methods section below for detailed information. As discussed in the Methods section, the NPS Geologic Type Section Inventory Project utilizes NPS Geologic Resources Inventory (GRI) data and information, which is considered the "official" baseline geologic map and report for each park in the Inventory and Monitoring (I&M) program.

Geologic stratotypes within NPS areas have not been previously inventoried, so this report fills a void in basic geologic information compiled by the NPS at most parks. NPS staff may not be aware of the concept of geologic stratotypes nor the significance or occurrence of them in parks. Without proper documentation and awareness, the NPS cannot proactively monitor the stability, condition, or potential impacts to these locations from activities such as ground disturbance or construction. Instances where geologic stratotypes occurred within NPS areas were determined through research of published geologic literature and maps as described in the Methods section. Sometimes the lack of specific locality or other data limited determination of whether a particular stratotype was located within NPS administered boundaries.

Given the importance of geologic stratotypes as geologic references and geologic heritage resources, these MIDN locations should be afforded some level of documentation, preservation, or protection as appropriate. This inventory can inform important conversations on whether geologic stratotypes 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 stratotypes that are established on NPS administered lands.

Through this inventory, the associated report, and close communication with park and I&M Network staff, we hope 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 stratotypes are preserved and available for future study.

Definitions

In order to clarify, standardize, and consistently reference stratigraphic concepts, principles, and definitions, the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature 2021) is recognized and adopted for this inventory. This code describes 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 exposure (original or subsequently designated) for a named geologic unit or boundary, constituting the basis for definition or recognition of that unit or boundary (North American Commission on Stratigraphic Nomenclature 2021). There are several variations of stratotype referred to in the literature and this report, and they are defined as follows:

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 2021). Once a unit stratotype is assigned, it is never changed, but it may be supplemented if it proves inadequate. 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 2021).
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 2021). 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 2021).
4. **Lithodeme**: the term "lithodeme" is defined as a mappable unit of plutonic (igneous rock that solidified at great depth) or highly metamorphosed and pervasively deformed rock that is equivalent in rank to "formation" among stratified rocks (North American Commission on Stratigraphic Nomenclature 2021). 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.

Methods

Methodology

The process of determining whether a specific stratotype occurs within an NPS area involves multiple steps. The process begins with an evaluation of a park-specific Geologic Resources Inventory (GRI) map to prepare a full list of recognized map units (Figure 1). More information about the GRI data can be found later in this section.

Each geologic map unit name is queried in the USGS 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 the geologic 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 2 is taken from a search on the Gettysburg Shale, which is mapped within GETT.

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 not used in the area within the MIDN and therefore are not detailed here. The most accurate GEOLEX descriptions using TRS coordinates can help locate features within 0.1618 km2 (0.0625 mi2). 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.

Upon accurately identifying the stratotypes using GEOLEX or peer-reviewed literature, 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) whether a stratotype is officially designated; (2) whether the stratotype is on NPS land; (3) whether the stratotype location has 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) whether the geologic unit was listed in GEOLEX; and (10) a generic notes field (Figure 3).

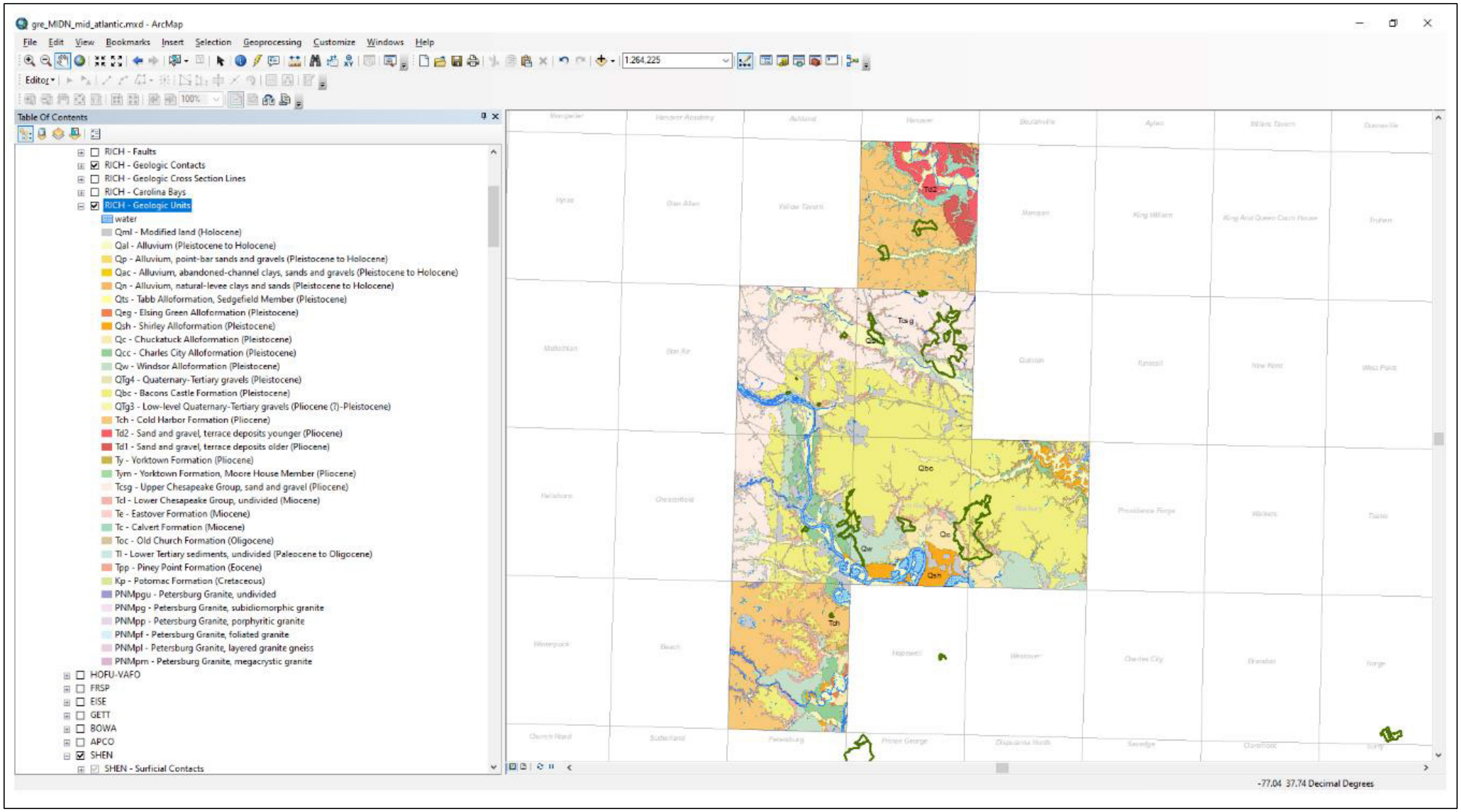
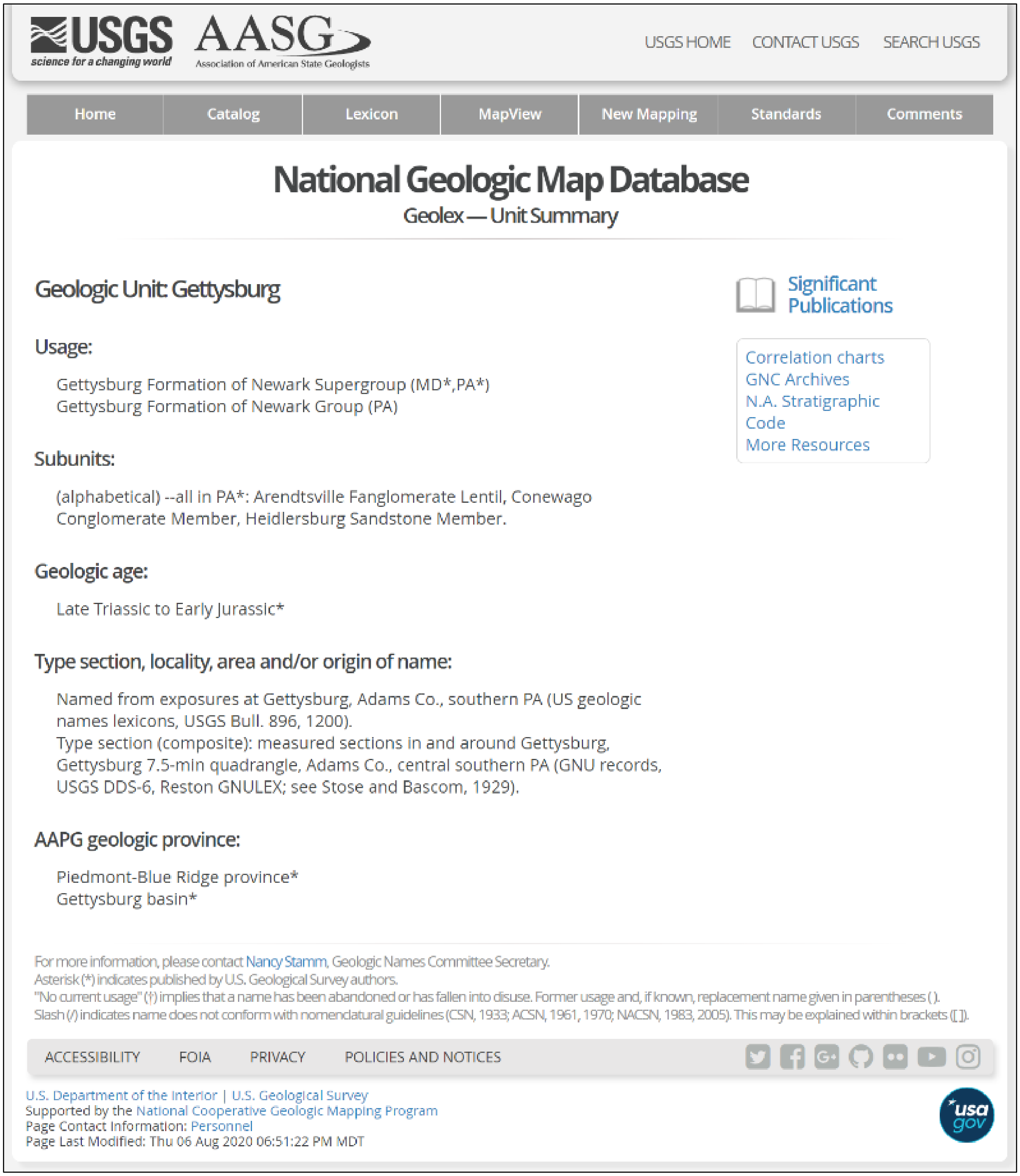


Figure 1. Screenshot of the GRI-compiled digital geologic map of Richmond National Battlefield Park showing mapped units. The NPS boundary layer has been added (green lines). Access the GIS version of the NPS boundary online at https://irma.nps.gov/DataStore/Reference/Profile/2224545?lnv=True and the RICH Digital Geologic Map at https://irma.nps.gov/DataStore/Reference/Profile/2208910.



USGS science for a changing world AASG Association of American State Geologists

USGS HOME CONTACT USGS SEARCH USGS

Home | Catalog | Lexicon | MapView | New Mapping | Standards | Comments

National Geologic Map Database

Geolex — Unit Summary

Geologic Unit: Gettysburg

Significant Publications

Correlation charts
GNC Archives
N.A. Stratigraphic Code
More Resources

Usage:

Gettysburg Formation of Newark Supergroup (MD*,PA*)
Gettysburg Formation of Newark Group (PA)

Subunits:

(alphabetical) --all in PA*: Arendtsville Fanglomerate Lentil, Conewago Conglomerate Member, Heidlersburg Sandstone Member.

Geologic age:

Late Triassic to Early Jurassic*

Type section, locality, area and/or origin of name:

Named from exposures at Gettysburg, Adams Co., southern PA (US geologic names lexicons, USGS Bull. 896, 1200).
Type section (composite): measured sections in and around Gettysburg, Gettysburg 7.5-min quadrangle, Adams Co., central southern PA (GNU records, USGS DDS-6, Reston GNULEX; see Stose and Bascom, 1929).

AAPG geologic province:

Piedmont-Blue Ridge province*
Gettysburg basin*

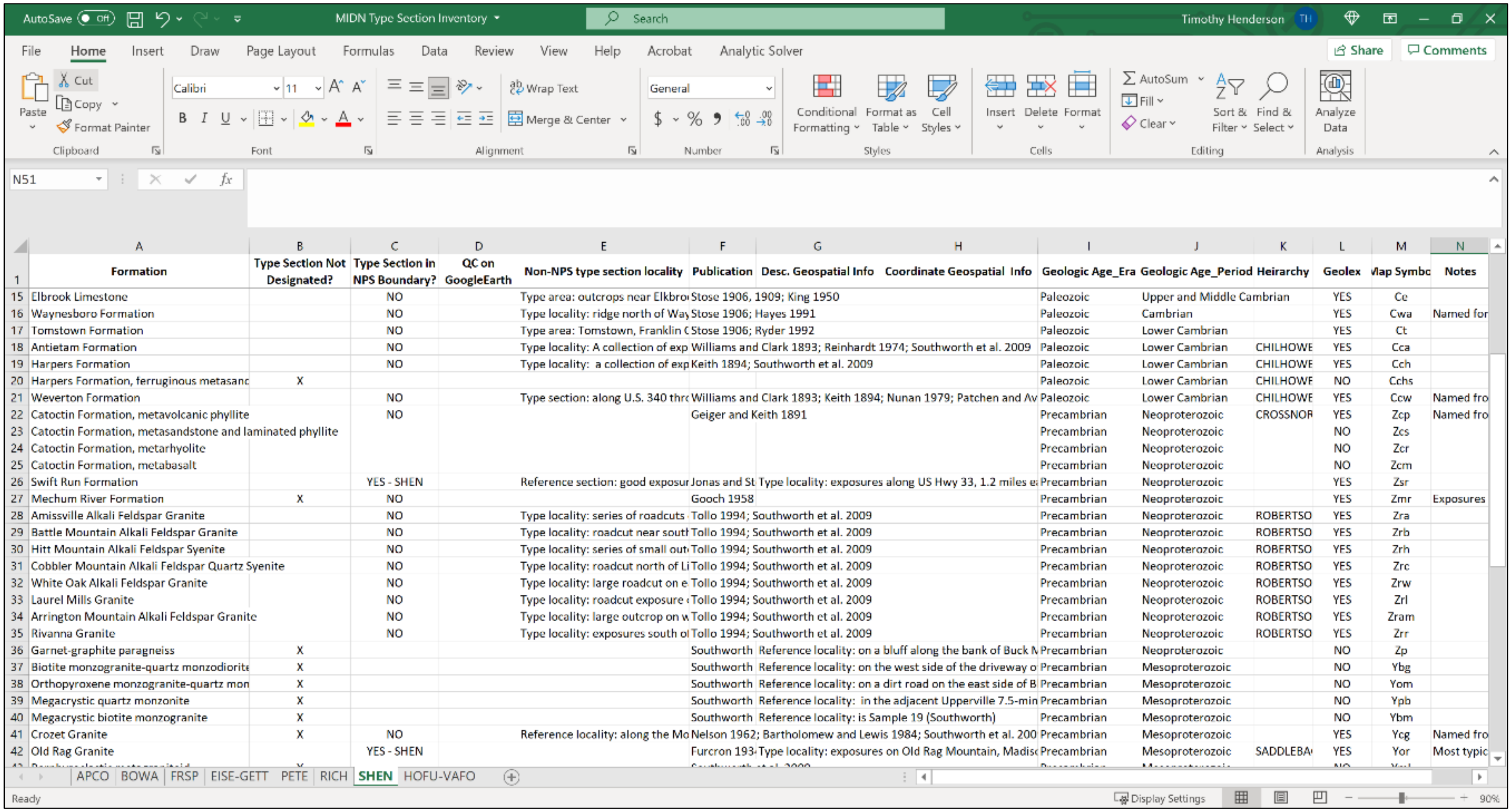
For more information, please contact Nancy Stamm, Geologic Names Committee Secretary.
Asterisk (*) indicates published by U.S. Geological Survey authors.
"No current usage" (†) implies that a name has been abandoned or has fallen into disuse. Former usage and, if known, replacement name given in parentheses ( ).
Slash (/) indicates name does not conform with nomenclatural guidelines (CSN, 1933; ACSN, 1961, 1970; NACSN, 1983, 2005). This may be explained within brackets ([ ]).

ACCESSIBILITY FOIA PRIVACY POLICIES AND NOTICES

U.S. Department of the Interior | U.S. Geological Survey
Supported by the National Cooperative Geologic Mapping Program
Page Contact Information: Personnel
Page Last Modified: Thu 06 Aug 2020 06:51:22 PM MDT

usa gov

Figure 2. GEOLEX search result for Gettysburg Shale unit of the Newark Supergroup/Group.



Row	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 Symbo	Notes
15	Elbrook Limestone		NO		Type area: outcrops near Elkbro	Stose 1906, 1909; King 1950			Paleozoic	Upper and Middle Cambrian		YES	Ce	
16	Waynesboro Formation		NO		Type locality: ridge north of Way	Stose 1906; Hayes 1991			Paleozoic	Cambrian		YES	Cwa	Named for
17	Tomstown Formation		NO		Type area: Tomstown, Franklin (	Stose 1906; Ryder 1992			Paleozoic	Lower Cambrian		YES	Ct	
18	Antietam Formation		NO		Type locality: A collection of exp	Williams and Clark 1893; Reinhardt 1974; Southworth et al. 2009			Paleozoic	Lower Cambrian	CHILHOWE	YES	Cca	
19	Harpers Formation		NO		Type locality: a collection of exp	Keith 1894; Southworth et al. 2009			Paleozoic	Lower Cambrian	CHILHOWE	YES	Cch	
20	Harpers Formation, ferruginous metasanc	X							Paleozoic	Lower Cambrian	CHILHOWE	NO	Cchs	
21	Weverton Formation		NO		Type section: along U.S. 340 thr	Williams and Clark 1893; Keith 1894; Nunan 1979; Patchen and Av			Paleozoic	Lower Cambrian	CHILHOWE	YES	Ccw	Named fro
22	Catoctin Formation, metavolcanic phyllite		NO			Geiger and Keith 1891			Precambrian	Neoproterozoic	CROSSNOR	YES	Zcp	Named fro
23	Catoctin Formation, metasandstone and laminated phyllite								Precambrian	Neoproterozoic		NO	Zcs	
24	Catoctin Formation, metarhyolite								Precambrian	Neoproterozoic		NO	Zcr	
25	Catoctin Formation, metabasalt								Precambrian	Neoproterozoic		NO	Zcm	
26	Swift Run Formation		YES - SHEN		Reference section: good exposur	Jonas and St	Type locality: exposures along US Hwy 33, 1.2 miles e		Precambrian	Neoproterozoic		YES	Zsr	
27	Mechum River Formation	X	NO			Gooch 1958			Precambrian	Neoproterozoic		YES	Zmr	Exposures
28	Amissville Alkali Feldspar Granite		NO		Type locality: series of roadcuts	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zra	
29	Battle Mountain Alkali Feldspar Granite		NO		Type locality: roadcut near soutl	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zrb	
30	Hitt Mountain Alkali Feldspar Syenite		NO		Type locality: series of small out	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zrh	
31	Cobbler Mountain Alkali Feldspar Quartz Syenite		NO		Type locality: roadcut north of Li	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zrc	
32	White Oak Alkali Feldspar Granite		NO		Type locality: large roadcut on e	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zrw	
33	Laurel Mills Granite		NO		Type locality: roadcut exposure	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zrl	
34	Arrington Mountain Alkali Feldspar Granite		NO		Type locality: large outcrop on w	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zram	
35	Rivanna Granite		NO		Type locality: exposures south o	Tollo 1994; Southworth et al. 2009			Precambrian	Neoproterozoic	ROBERTSO	YES	Zrr	
36	Garnet-graphite paragneiss	X				Southworth	Reference locality: on a bluff along the bank of Buck N		Precambrian	Neoproterozoic		NO	Zp	
37	Biotite monzogranite-quartz monzodiorite	X				Southworth	Reference locality: on the west side of the driveway o		Precambrian	Mesoproterozoic		NO	Ybg	
38	Orthopyroxene monzogranite-quartz mon	X				Southworth	Reference locality: on a dirt road on the east side of B		Precambrian	Mesoproterozoic		NO	Yom	
39	Megacrystic quartz monzonite	X				Southworth	Reference locality: in the adjacent Upperville 7.5-min		Precambrian	Mesoproterozoic		NO	Ypb	
40	Megacrystic biotite monzogranite	X				Southworth	Reference locality: is Sample 19 (Southworth)		Precambrian	Mesoproterozoic		NO	Ybm	
41	Crozet Granite	X	NO		Reference locality: along the Mo	Nelson 1962; Bartholomew and Lewis 1984; Southworth et al. 200			Precambrian	Mesoproterozoic		YES	Ycg	Named fro
42	Old Rag Granite		YES - SHEN			Furcron 193	Type locality: exposures on Old Rag Mountain, Madis		Precambrian	Mesoproterozoic	SADDLEBA	YES	Yor	Most typic

Figure 3. Stratotype inventory spreadsheet of the MIDN displaying attributes appropriate for geolocation assessment.

Geologic Resources Inventory (GRI) Data

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 to the 270 parks in the I&M program. The GRI team provides three products to each park that can be useful in the determination of stratotypes: (1) a summary document from an initial scoping meeting, (2) digital geologic map data in a geographic information system (GIS) format, and (3) a GRI report.

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 meeting summaries serve as an interim report until the final report is delivered.

Following the scoping meeting, the GRI map team converts the geologic source maps identified in the mapping plan to GIS data in accordance with the GRI data model (https://www.nps.gov/articles/gri-geodatabase-model.htm). The GRI uses a unique "GMAP ID" value for each geologic source map, and all sources used to produce the GRI GIS data sets for the MIDN parks can be found in Appendix A. The GRI map data is the basis for this stratotype inventory as it is considered the "official" geologic dataset for the park. The list of units present in the GRI GIS data was used to search GEOLEX.

After the digital geologic map is completed, the GRI report team uses the map data, as well as the scoping summary and additional research, to prepare the GRI report. The GRI reports were utilized for additional information about geologic resources in a given park and connections to park landscape, history, or other resources. Posters that display the GRI GIS data over imagery of the park are also created as part of the report process. They are available with the reports or separately from the GRI publications page (https://www.nps.gov/subjects/geology/geologic-resources-inventory-products.htm).

Additional Considerations

There are several additional considerations for this inventory. The most up-to-date information available is necessary, and is either found online or in published articles and maps. Occasionally, there is a lack of specific information which limits the information contained within the final report. This 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 that cross state boundaries. Geologic formations and other geologic units that cross state boundaries may have different names or ranks in each of the states the units are mapped. An example is the Paleocene Fort Union Formation (as used by the Montana Bureau of Mines and

Geology and the U.S. Geological Survey), which is equivalent to the Fort Union Group of the North Dakota Geological Survey.

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.

This inventory report is intended for a wide audience, including NPS staff who may not have a background in geology. Therefore, this document is developed as a reference document that supports science, resource management, and a historic framework for geologic information associated with MIDN parks.

All network-specific reports are peer-reviewed and submitted to the Natural Resources Stewardship and Science Publications Office for finalization.

Geology and Stratigraphy of the MIDN I&M Network Parks

The Mid-Atlantic Inventory & Monitoring Network (MIDN) consists of ten national park units in Pennsylvania and Virginia (Figure 4). The parks include: Appomattox Court House National Historical Park (APCO), Booker T. Washington National Monument (BOWA), Eisenhower National Historic Site (EISE), Fredericksburg and Spotsylvania National Military Park (FRSP), Gettysburg National Military Park (GETT), Hopewell Furnace National Historic Site (HOFU), Petersburg National Battlefield (PETE), Richmond National Battlefield Park (RICH), Shenandoah National Park (SHEN), and Valley Forge National Historical Park (VAFO). In addition, although Cedar Creek & Belle Grove National Historical Park (CEBE) is a non-network park, it is geographically associated with the MIDN and mentioned in this report. The parks of MIDN are primarily recognized for significant cultural and historic resources, including numerous American Civil War battlefield parks.

The MIDN include parks in southern Pennsylvania and south-central Virginia. The parks occur within the Atlantic Coastal Plain, Piedmont, and Blue Ridge physiographic provinces. Shenandoah National Park is the largest park in the MIDN and is primarily recognized for natural resources and scenery from atop an iconic portion of the Blue Ridge Mountains known as the Skyline Drive. SHEN towers over the valleys to the east and west of the north–south trending mountains. The highest point in the park is Hawksbill Mountain which summits at 4,051 ft (1,235 m).

The geologic history of the MIDN parks can be described in four phases: (1) the development of the basement rock starting in the Precambrian; (2) uplift and deformation associated with the Alleghanian Orogeny during the late Paleozoic; (3) complex events during the early Mesozoic resulting in the development of the Piedmont Province; and (4) the deposition of Atlantic Coastal Plain marine sediments on the eastern portion of the network (see Appendix B for a geologic time scale).

The rocks of SHEN extend back into the Neoproterozoic and include Grenville granitic basement rocks, representing some of the oldest rocks in Virginia and for all the MIDN parks. The Blue Ridge Mountains were formed during the late Paleozoic Alleghanian Orogeny which resulted in uplift, folding, faulting, and some metamorphism of the older rocks.

Most of the MIDN parks are located in the Piedmont Province, a plateau region situated between the Atlantic Coastal Plain to the east and the Appalachian Mountains to the west. The Piedmont has a complex geologic history influenced by multiple orogenic events during the Paleozoic involving the formation and breakup of Pangaea. A series of Mesozoic basins existed along the eastern margin of the Appalachians during the Triassic and extended from Virginia into Pennsylvania. During the Triassic the basins were depositional centers where lacustrine sedimentation preserved footprints of early dinosaurs and other vertebrates (GETT and MANA).

Igneous activity during the Jurassic is represented by dikes and sills preserved at several network parks. Coastal plain sedimentation with changing sea level is preserved in several of the network parks in Virginia. The arrival of Europeans in the New World has reshaped portions of the landscape over the past few centuries, leaving historic footprints within many of the MIDN parks.

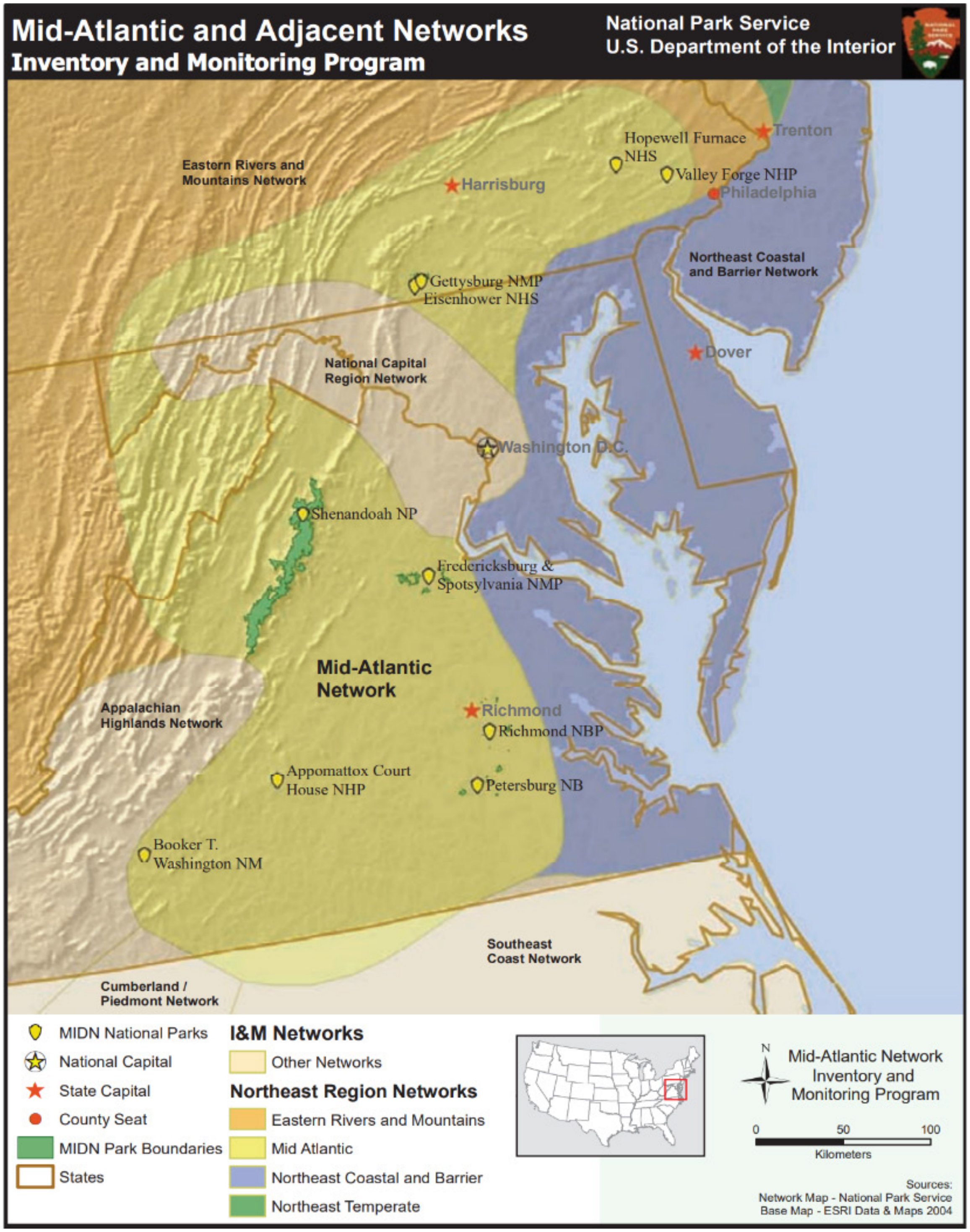


Figure 4. Map of Mid-Atlantic I&M Network parks including: Appomattox Court House National Historical Park (APCO), Booker T. Washington National Monument (BOWA), Eisenhower National Historic Site (EISE), Fredericksburg and Spotsylvania County Battlefields Memorial National Military Park (FRSP), Gettysburg National Military Park (GETT), Hopewell Furnace National Historic Site (HOFU), Petersburg National Battlefield (PETE), Richmond National Battlefield Park (RICH), Shenandoah National Park (SHEN), and Valley Forge National Historical Park (VAFO). Although Cedar Creek & Belle Grove National Historical Park (CEBE) is a non-network park, it is mentioned in this report (NPS).

Precambrian (4.6 billion to 539 million years ago)

Some of the oldest rocks in the MIDN include Mesoproterozoic banded mafic (silicate minerals containing iron and magnesium, typically dark) and graphitic felsic (feldspar- and/or quartz-rich) gneiss exposed at HOFU. Various igneous and metamorphosed igneous rocks of Mesoproterozoic to Neoproterozoic age are documented at SHEN, including the Neoproterozoic Swift Run Formation and Catoctin Formation. At BOWA, the Neoproterozoic is represented by the Ashe Formation, a metagraywacke, and amphibolite. Rocks of the Po River Metamorphic Suite span from the Neoproterozoic into the Paleozoic at FRSP, as does the Fork Mountain Formation at APCO.

Paleozoic (539 to 252 million years ago)

Cambrian strata are widespread throughout the MIDN parks. The early Cambrian Chickies Formation is mapped at HOFU and VAFO in Pennsylvania. At SHEN a thick sequence of early Cambrian rocks includes the Weverton, Harpers Ferry, Antietam, Tomstown, and Waynesboro Formations. The Antietam Formation is also present in VAFO, overlain by the middle Cambrian Ledger and Elbrook Formations. The Elbrook Formation is also mapped at SHEN where it is overlain by the Beekmantown Group. The Cambrian is represented at APCO by the Fork Mountain Formation and sequences of greenstone, gneiss, metavolcanics, and other high grade metamorphic rocks.

The Ordovician Period is well-represented at CEBE and includes rocks of the Rockdale Run Formation, Pinesburg Station Dolomite, New Market Limestone, Lincolnshire Limestone, Edinburg Formation, Martinsburg Formation, and Oswego Sandstone. Additional Ordovician strata underlie FRSP and consist of the Ta River Metamorphic Suite, Chopawamsic Formation, Quantico Formation, Plagiogranite of Richland Run pluton, and Mine Run Complex (mélange). At FRSP the Ordovician metasedimentary rocks and the Quantico Formation are overlain by the Silurian Falls Run Granite. The Petersburg Granite is a Pennsylvanian–Permian unit at PETE.

Mesozoic (252 to 66 million years ago)

Late Triassic rocks are mapped within three park units of the MIDN in portions of GETT, HOFU, and SHEN. The Gettysburg Shale and York Haven Diabase are the predominant bedrock at GETT. Rocks of the Late Triassic Stockton Formation and Hammer Creek Conglomerate underlie HOFU. The Stockton Formation also occurs at VAFO. Late Triassic–Early Jurassic diabase dikes are documented at SHEN. Strata of the Cretaceous Potomac Group/Formation are present at three of the Virginia MIDN parks: FRSP, PETE, and RICH. The Cretaceous Patapsco Formation is present at VAFO.

Cenozoic (66 million years ago to the present)

Paleogene rocks are exposed in three of the Civil War battlefield parks in Virginia: FRSP, PETE, and RICH. The late Paleocene Aquia Formation is mapped in all three of these parks. At RICH the Pamunkey Group includes a sequence of late Paleocene–middle Eocene units including the Aquia Formation, Marlboro Clay, Nanjemoy Formation, and Piney Point Formation.

The Neogene is well-represented at FRSP, PETE, and RICH by formations associated with the Chesapeake Group. The oldest strata of the Chesapeake Group occur in RICH and consists of the

Oligocene–Miocene Old Church Formation. The early–middle Miocene Calvert Formation is mapped in portions of FRSP and RICH, and the late Miocene Eastover Formation is distributed across PETE and RICH. Other Miocene units that underlie RICH include the Choptank Formation and St. Mary's Formation. At VAFO the Miocene Bryn Mawr Formation and late Miocene–Pliocene Pensauken Formation are mapped. Unnamed sand and gravel deposits of the Miocene and Pliocene are distributed across the Chancellorsville, Fredericksburg, and Spotsylvania Courthouse battlefield sites in FRSP. The Pliocene is also exposed in three of the Civil War battlefield parks in Virginia including FRSP, PETE, and RICH. This includes the early–late Pliocene Yorktown Formation mapped in all three of these parks, along with the late Pliocene Bacon Castle Formation. The late Pliocene Moorings Unit also occurs at FRSP.

Several Pleistocene units occur within the park units of the MIDN. The early Pleistocene Windsor Formation and Charles City Alloformation are mapped in both FRSP and RICH. The Chuckatuck Formation is a middle Pleistocene unit present at FRSP, PETE, and RICH where it is overlain by the Shirley Alloformation. At FRSP the late Pleistocene is represented by the Tabb Formation.

Appomattox Court House National Historical Park (APCO)

Park Establishment

Appomattox Court House National Historical Park (APCO) is located about 16 km (10 mi) east of Lynchburg and 24 km (15 mi) west of Farmville in Appomattox County, Virginia (Figure 5). Originally established as Appomattox Battlefield Site on June 18, 1930, the park unit was redesignated a historical park on April 15, 1954. The historical park encompasses approximately 718 hectares (1,774 acres) and preserves the village of Appomattox Court House and the surrounding farm, forest, and meadow lands (National Park Service 2016). The purpose of APCO is to commemorate General Robert E. Lee's surrender of the Confederate Army of Northern Virginia to Lieutenant General Ulysses S. Grant on April 9, 1865, leading to the end of the American Civil War. Various cultural resources are preserved within APCO, including the surrender site at McLean House; the historic village of Appomattox; and the site of the Battle of Appomattox Court House, the failed final war effort by the Confederate army that led directly to the surrender.

Geologic Summary

Regionally, APCO lies within the western Piedmont physiographic province of the Appalachian Mountains, characterized by hard crystalline igneous and metamorphic rocks such as slates, phyllites, schists, gneisses, and gabbros. The bedrock geology of APCO consists of Proterozoic–Cambrian-age metamorphic rocks including mica schist, biotite gneiss, amphibolite, greenstone and amphibole gneiss, with an interlayered belt of silica-rich metamorphosed tuff, mica schist, and gneiss (Figure 6; Thornberry-Ehrlich 2009a). Some of the oldest rocks in the park are exposed along the deeply eroded reaches of the Appomattox River and consist of porphyroblastic (large mineral crystals in a fine-grained matrix) aluminosilicate mica schist, garnetiferous biotite gneiss, and amphibolite of the Fork Mountain Formation. Some of the youngest rock units in APCO (not indicated on the digital geologic map) include thick alluvium deposits of sand, gravel, silt, and clays; marsh and swamp deposits; terrace deposits; and artificial fill from construction of roads, dams, bridges, landfills, and highways (Thornberry-Ehrlich 2009a).

Stratotypes

There are no designated stratotypes identified within the boundaries of APCO. There are six identified stratotypes located within 48 km (30 mi) of APCO boundaries that are provided in Appendix C for reference in case of future historical park boundary expansion.

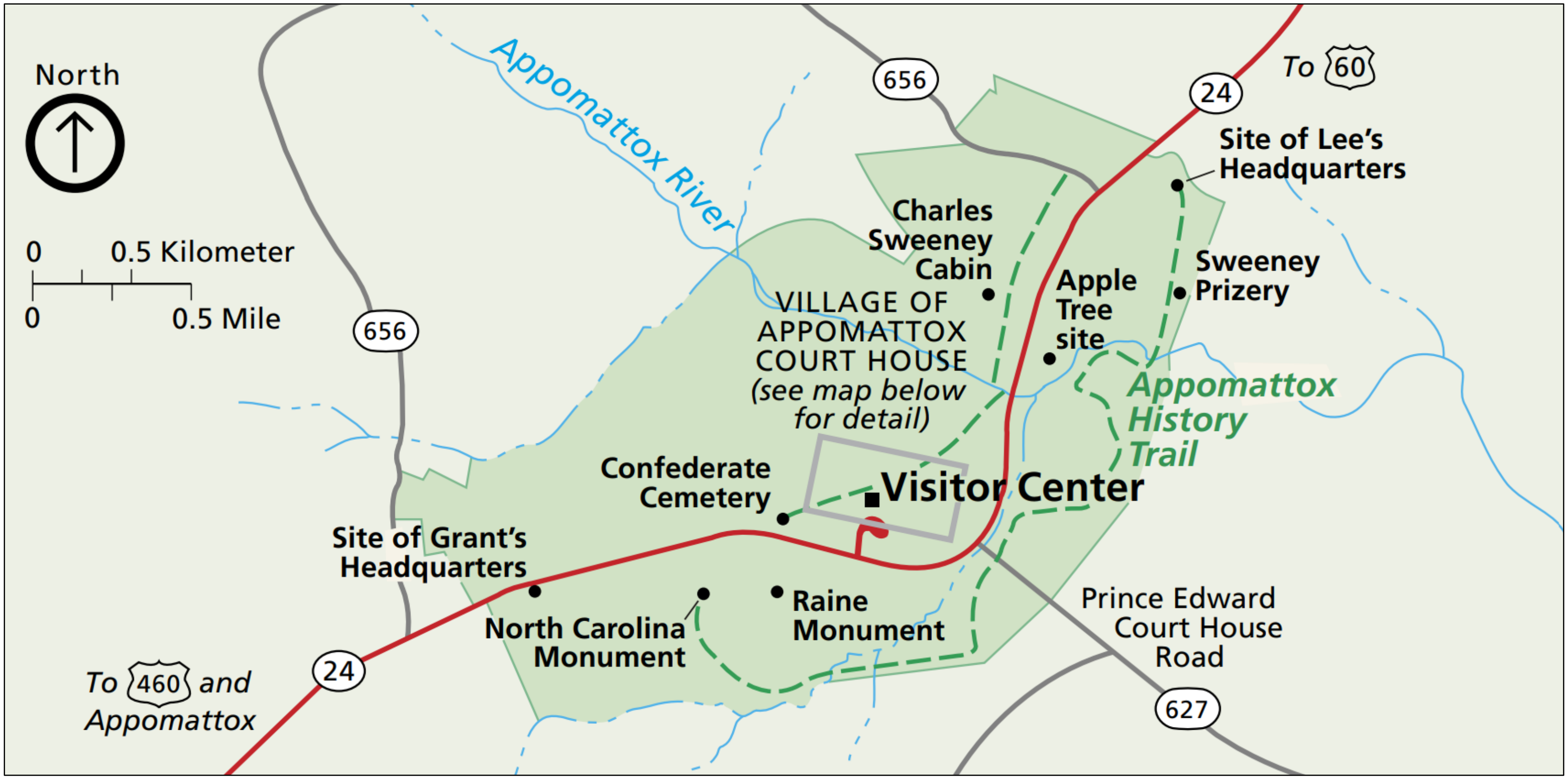


Figure 5. Park map of APCO, Virginia (NPS).

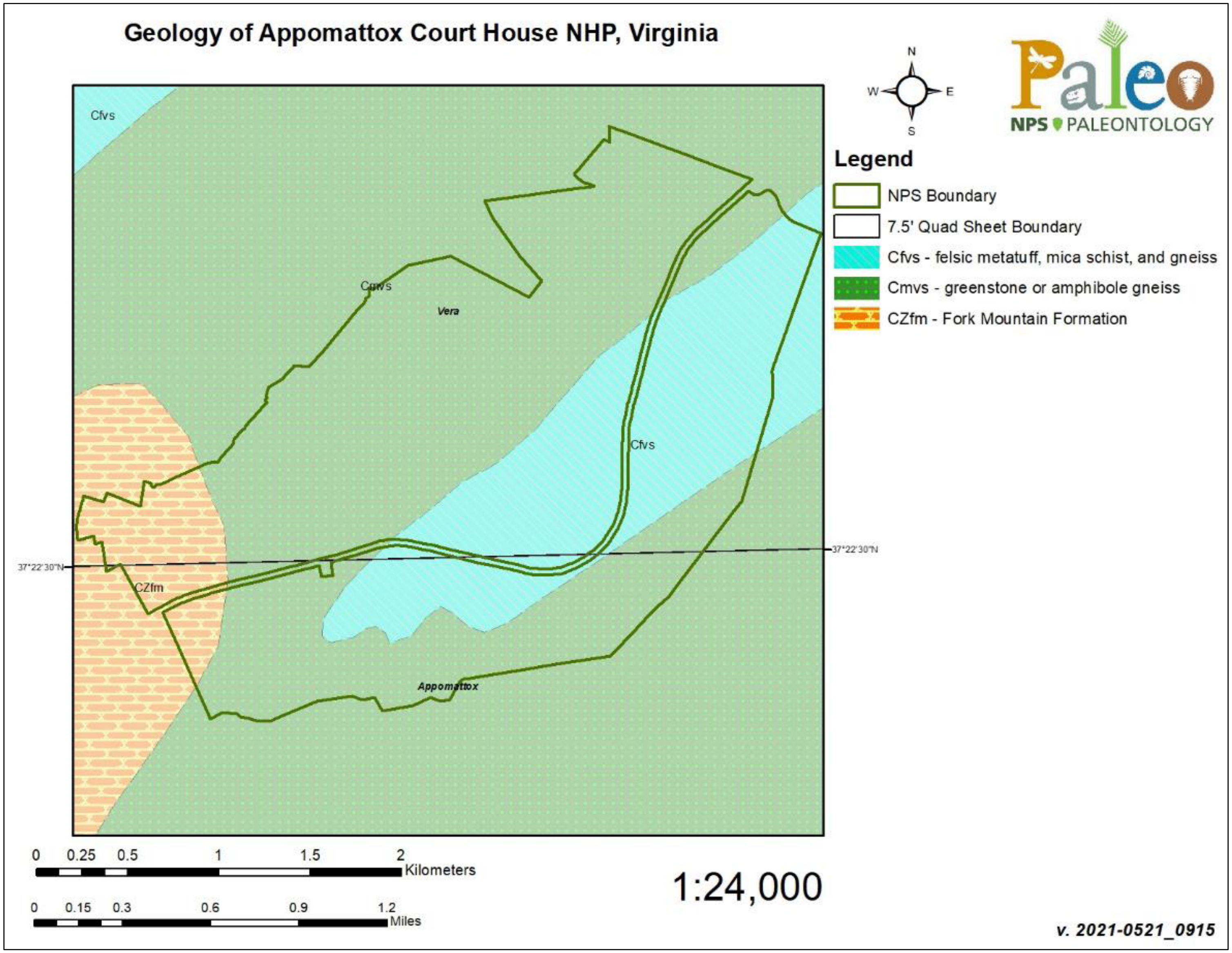


Figure 6. Geologic map of APCO, Virginia. Data modified from APCO GRI Digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1044678.

Booker T. Washington National Monument (BOWA)

Park Establishment

Booker T. Washington National Monument (BOWA) is located about 35 km (22 mi) south of the major town of Roanoke just east of the Blue Ridge Parkway in Franklin County, Virginia (Figure 7). Authorized on April 2, 1956, BOWA encompasses about 97 hectares (239 acres) and preserves the tobacco plantation setting of the birthplace of Booker T. Washington (National Park Service 2016). Born into slavery in 1856, Booker T. Washington was freed at the age of nine and became one of the most influential African Americans of the late 19th and early 20th centuries. The monument commemorates the achievements and legacy of Washington, who rose from slavery and poverty to serve as an educator, orator, and presidential advisor. Many cultural resources are preserved at BOWA, including replica slave quarters, plantation outbuildings (smoke house, blacksmith shop, privy, hog pen, duck lot, chicken house), a 20th century segregated schoolhouse, and three small cemeteries (Thornberry-Ehrlich 2010a).

Geologic Summary

Located in the Piedmont physiographic province near the Piedmont–Blue Ridge transitional zone, the geology of BOWA consists of elongate parallel belts of crystalline rock that reflect multiple orogenic events related to the formation of the Appalachian Mountains. The bedrock within BOWA consists of late Proterozoic–Cambrian-age metamorphic rocks (Figure 8). Most of the ancient metamorphic units in the BOWA area are deeply weathered and overlain by a thick blanket of regolith. The oldest exposures in the monument include gneiss, schist, and amphibolite of the Ashe Formation. Younger units within BOWA include Cambrian-age amphibolite and laminated mica gneiss. Cutting through these rocks are small-scale faults, fractures, joints, mylonite zones, and minor folds that formed due to tectonic collisional processes (Thornberry-Ehrlich 2010a).

Stratotypes

There are no designated stratotypes identified within the boundaries of BOWA. There are four identified stratotypes located within 48 km (30 mi) of BOWA boundaries that are provided in Appendix C for reference in case of future monument boundary expansion.

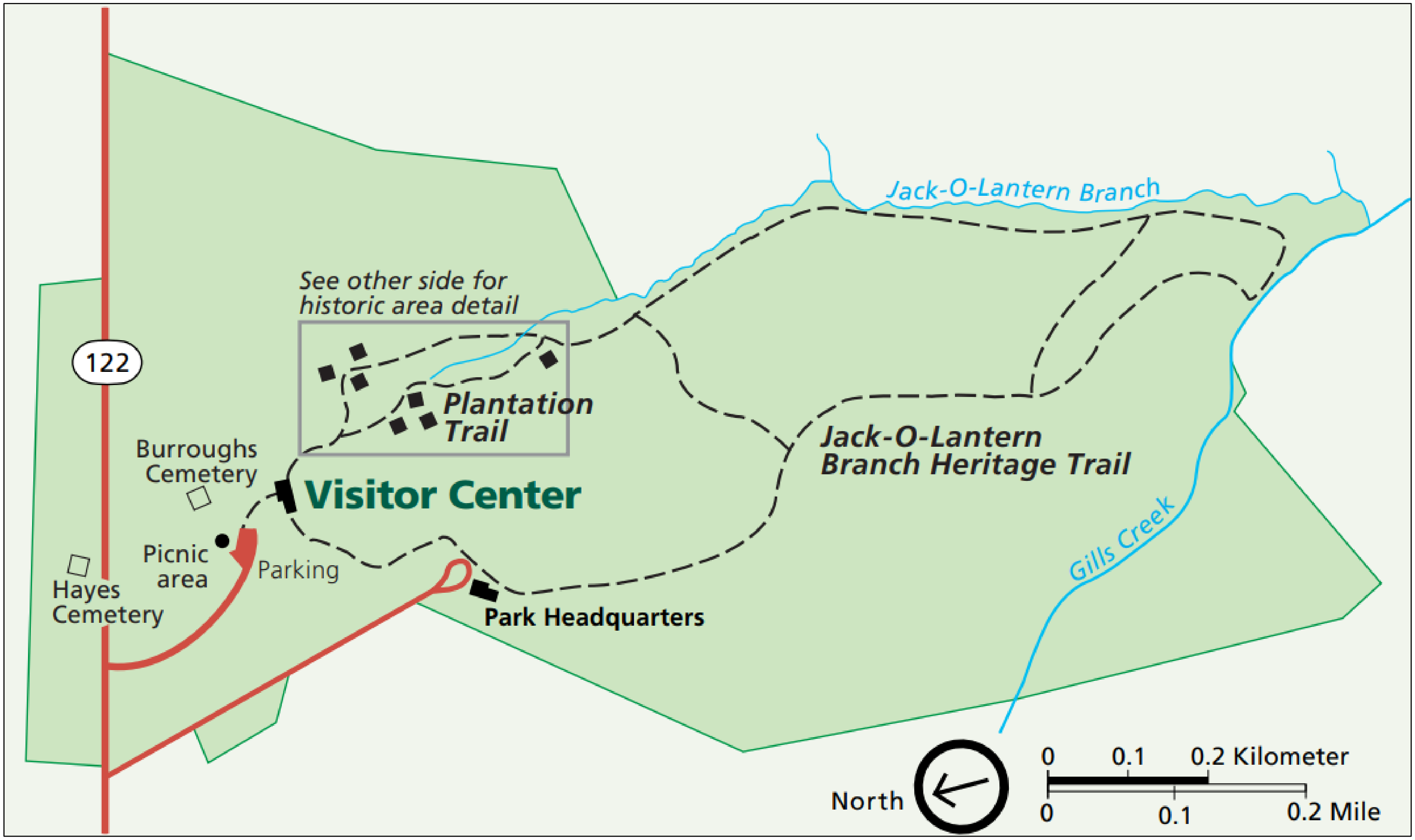


Figure 7. Park map of BOWA, Virginia (NPS).

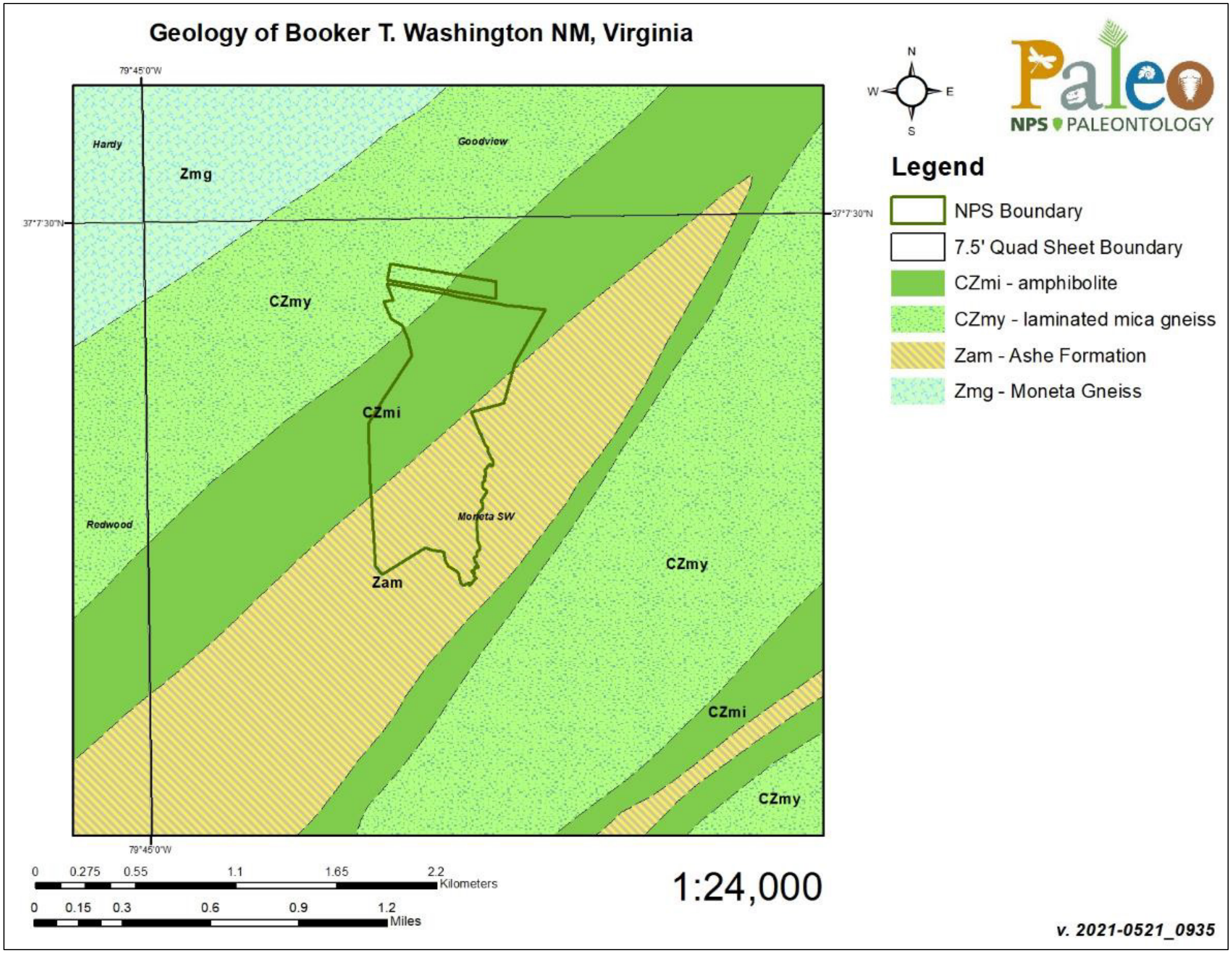


Figure 8. Geologic map of BOWA, Virginia. Data modified from BOWA GRI Digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1043799.

Cedar Creek and Belle Grove National Historical Park (CEBE)

Park Establishment

Cedar Creek and Belle Grove National Historical Park (CEBE) is located adjacent to the historic towns of Middletown and Strasburg in the Shenandoah Valley of Frederick, Shenandoah, and Warren Counties, Virginia (Figure 9). Authorized on December 19, 2002, CEBE encompasses approximately 1,500 hectares (3,706 acres) and preserves the American Civil War landscape site of the Battle of Cedar Creek as well as the Belle Grove Plantation (National Park Service 2016). The Battle of Cedar Creek was fought on October 19, 1864 and resulted in a decisive Union victory that essentially eliminated the Confederate military presence in the Shenandoah Valley and contributed to the re-election of President Abraham Lincoln (National Park Service 2018). The historical park contains significant antebellum agricultural landscapes that once defined the Shenandoah Valley, and CEBE offers scenic panoramic views of Massanutten Mountain and the surrounding Blue Ridge and Allegheny ranges.

Geologic Summary

CEBE is located adjacent to SHEN within the Valley and Ridge physiographic province, a region defined by a series of northeast–southwest trending synclines and anticlines composed of Paleozoic sedimentary rocks. Geologic units mapped within CEBE are predominantly Ordovician in age and include the Rockdale Run Formation, Pinesburg Station Dolomite, New Market Limestone, Lincolnshire Limestone, Edinburg Formation, Martinsburg Formation, and Oswego Sandstone. The predominant structural feature of CEBE is the Belle Grove anticline that traverses the northern part of the historical park (Orndorff et al. 1999). Younger surficial deposits that occur within CEBE include Quaternary terrace deposits and alluvium that are mapped along Cedar Creek and the Shenandoah River (Figure 10).

Stratotypes

There is one designated stratotype identified within the boundaries of CEBE, for the Ordovician Stickley Run Member of the Martinsburg Formation (Table 2; Figure 11). There are 11 identified stratotypes located within 48 km (30 mi) of CEBE boundaries that are provided in Appendix C for reference in case of future historical park boundary expansion.

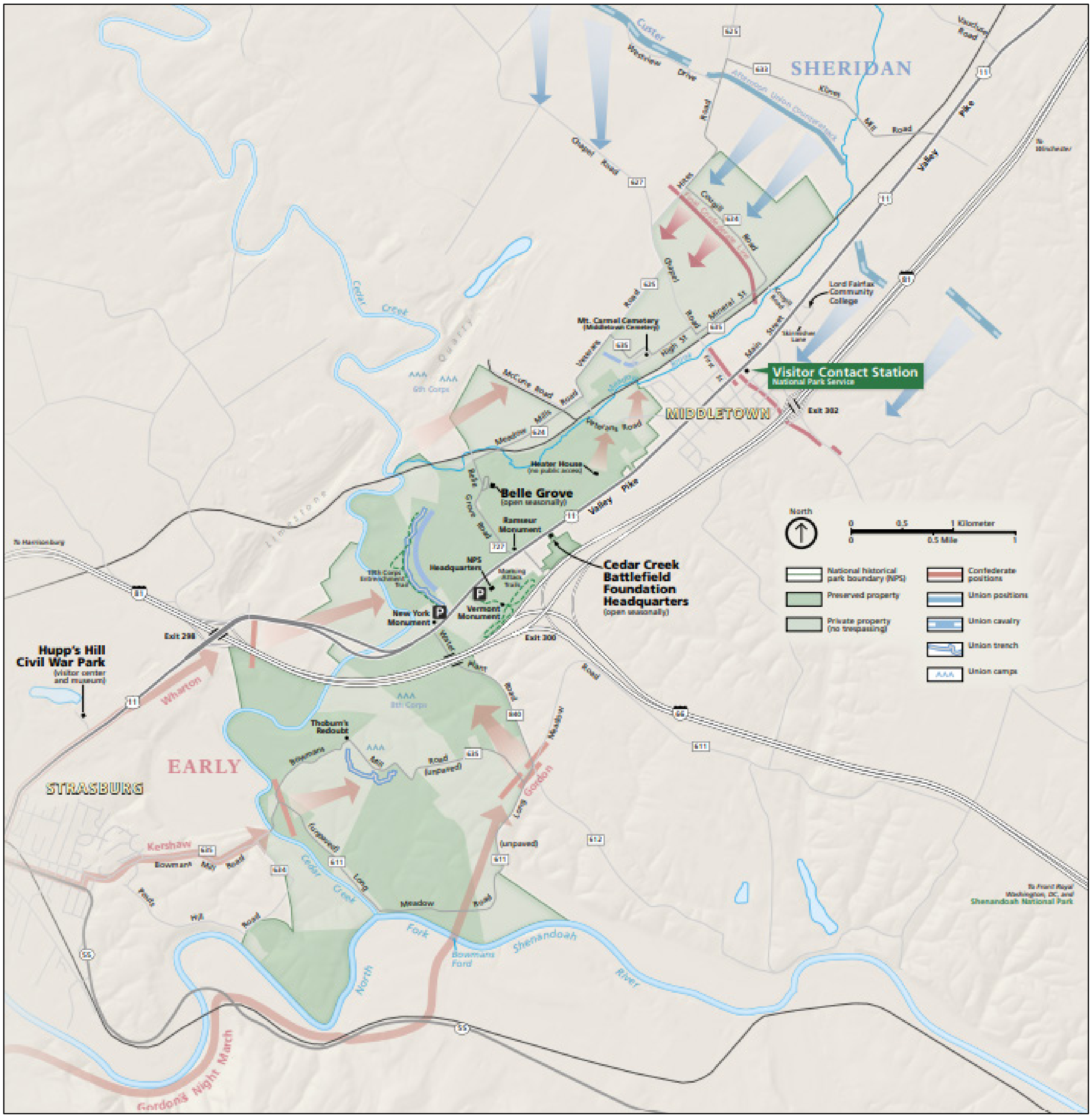


Figure 9. Park map of CEBE, Virginia (NPS).

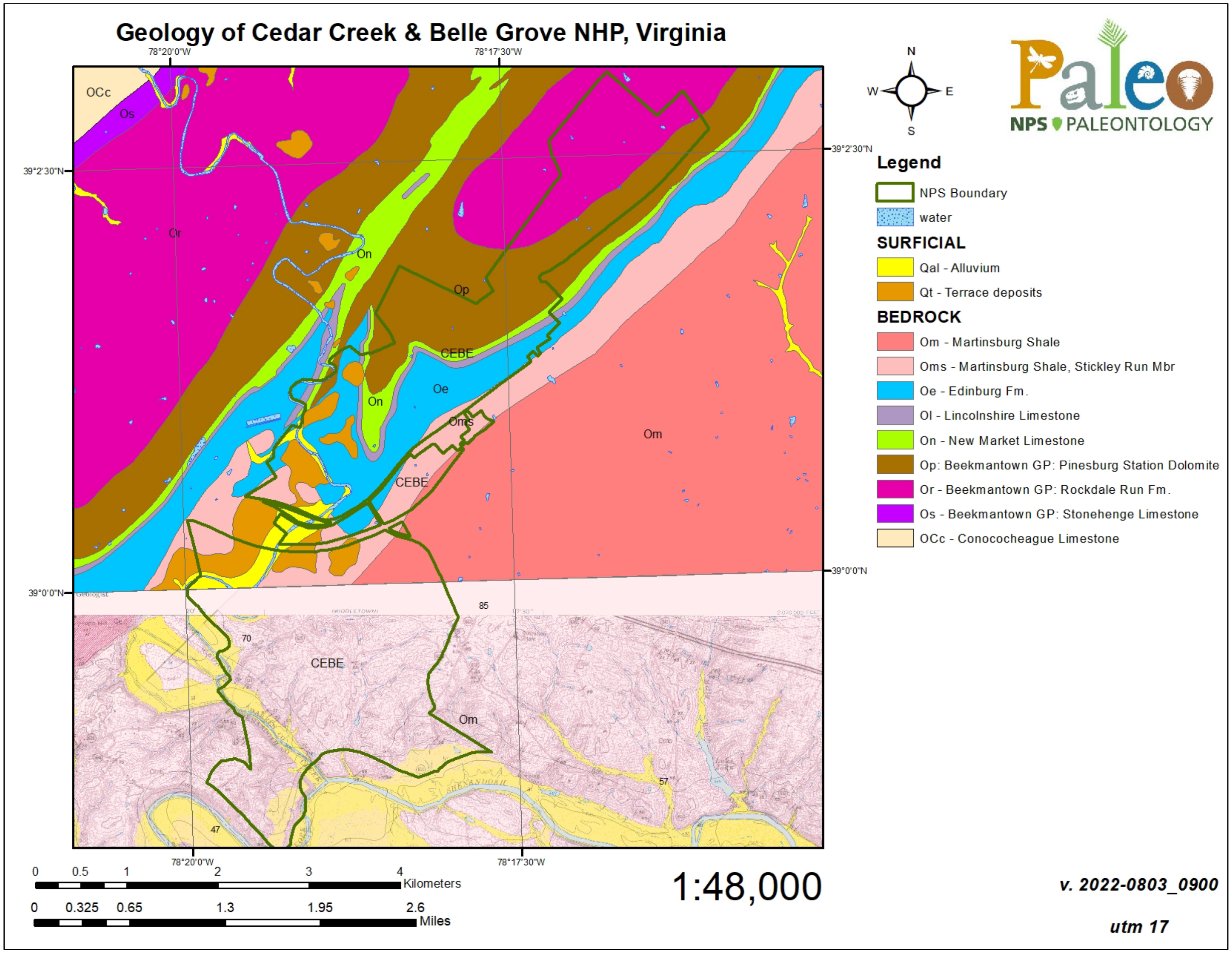


Figure 10. Geologic map of CEBE, Virginia. Modified from data at https://pubs.usgs.gov/gq/gq-1803/ and https://ngmdb.usgs.gov/Prodesc/proddesc_38899.htm. Note the northern 7.5′ Quadrangle (Middletown) has GIS data and the southern 7.5′ Quadrangle (Strasburg) is merely an image file; to date NPS GRI has not digitized these maps.

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

Unit Name (GRI map symbol)	Reference	Stratotype Location	Age
Stickley Run Member, Martinsburg Formation	Epstein et al. 1995	Type section: roadcut on southeast side of northbound lane of U.S. Highway 11, immediately east of Cedar Creek, about 4 km (2.5 mi) southwest of Middletown, Frederick County, and 4.8 km (3 mi) northeast of Strasburg (latitude 39°00′57″ N., longitude 78°18′52″ W.), in Shenandoah County, Virginia.	Ordovician

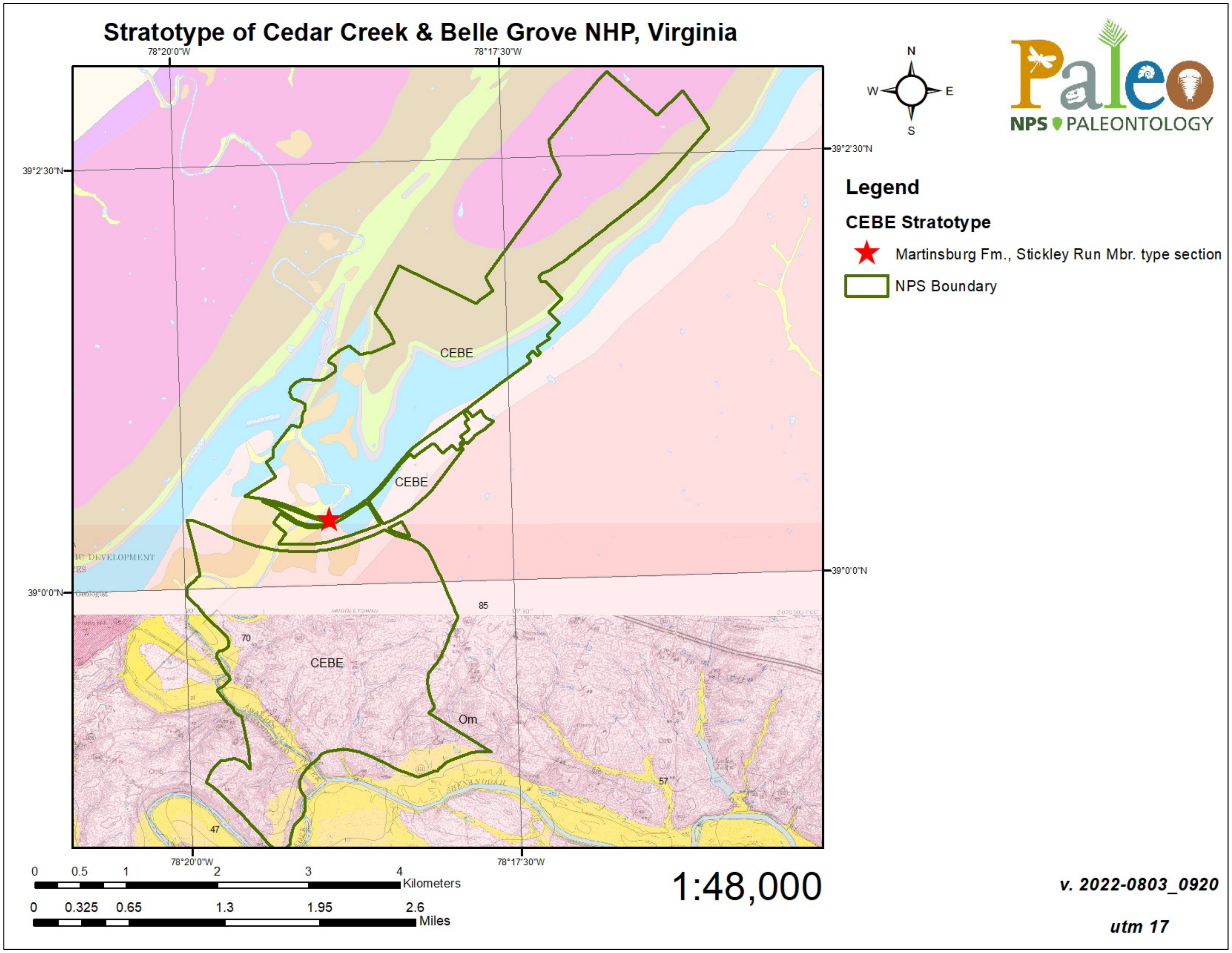


Figure 11. Modified geologic map of CEBE showing stratotype locations. The transparency of the geologic units layer has been increased.

Stickley Run Member, Martinsburg Formation

The Ordovician Stickley Run Member of the Martinsburg Formation was proposed by Epstein et al. (1999) and named after exposures along Stickley Run, a tributary of Cedar Creek in CEBE. The type section of the member is designated in a roadcut exposure on the southeast side of the northbound lane of U.S. Highway 11, immediately east of Cedar Creek, about 4 km (2.5 mi) southwest of Middletown, Frederick County, and 4.8 km (3 mi) northeast of Strasburg, in Shenandoah County, Virginia (Table 2; Figures 11 and 12; Epstein et al. 1995). The type section measures about 43 m (140 ft) thick and consists of dark gray, laminated to thin-bedded shaly limestone and calcareous shale and siltstone (Epstein et al. 1995). The type section accounts for only the lower portion of the member, and the upper part of the Stickley Run Member is poorly exposed and described from scattered outcrops (Epstein et al. 1995). The Stickley Run Member overlies limestone of the Edinburg Formation and underlies interbedded shale (mudstone), siltstone, and graywacke of the Martinsburg Formation.

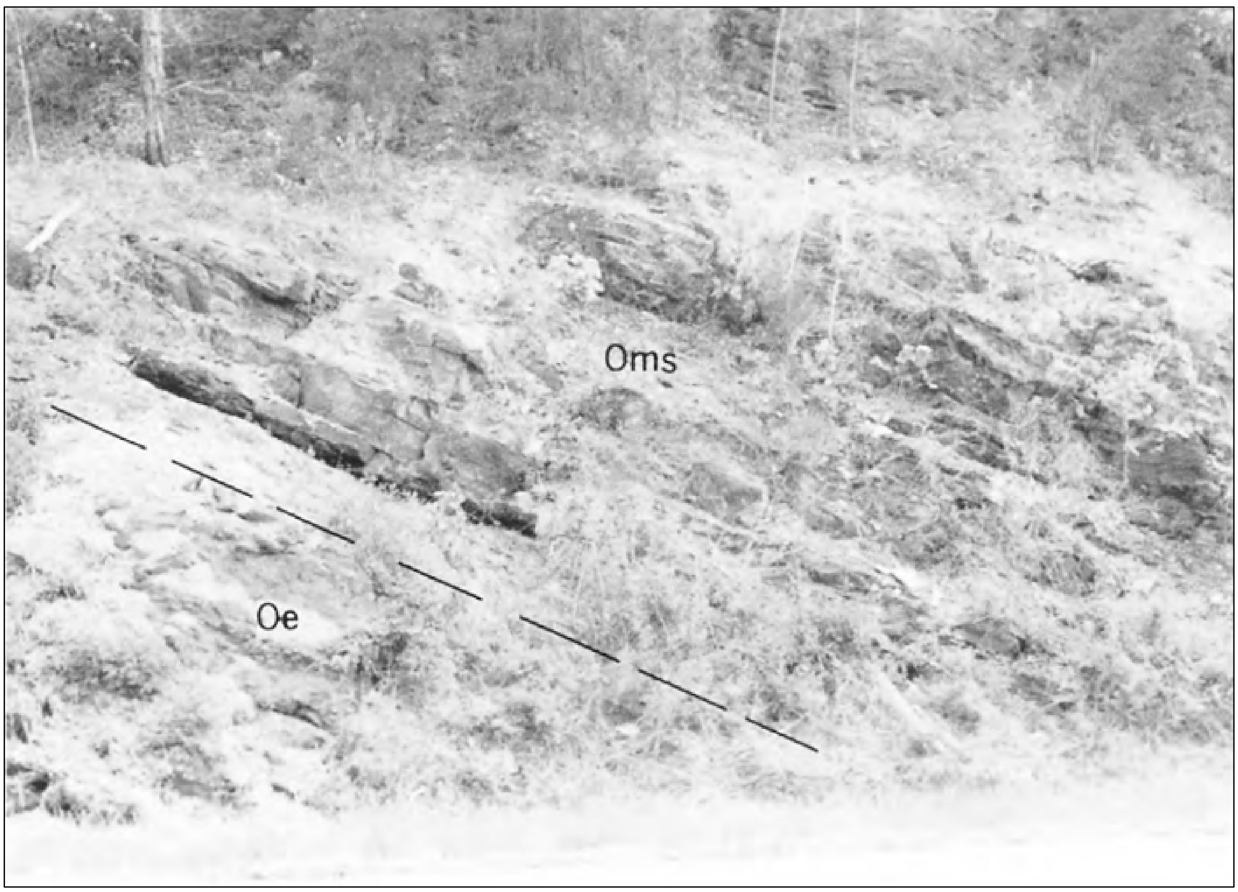


Figure 12. Type section of the Stickley Run Member of the Martinsburg Formation (Oms) overlying the Edinburg Formation (Oe) along U.S. Highway 11, immediately east of Cedar Creek. Figure 4 from Epstein et al. (1995).

Eisenhower National Historic Site (EISE)

Park Establishment

Eisenhower National Historic Site (EISE) is located about 64 km (40 mi) southwest of Harrisburg on the southwest side of Gettysburg National Military Park in Adams County, Pennsylvania (Figure 13). Authorized as a national park unit on November 27, 1967, EISE encompasses approximately 279 hectares (690 acres) including the 34th president and World War II commander Dwight D. Eisenhower's home and farm. The family farmhouse at EISE is the only home ever owned by Eisenhower and his wife, Mamie (National Park Service 2016), and was dedicated to the National Park Service two years before his death. The farmhouse served as a weekend retreat as well as a stage for international diplomacy during the Eisenhower administration. The purpose statement identifies that EISE was established to preserve and interpret the home and farms of the Eisenhower family as a fitting and enduring memorial to the life, work, and times of Eisenhower. Today the historic site is maintained as it was during the Eisenhower years, with the family home retaining many of its original furnishings.

Geologic Summary

EISE is located within the Gettysburg basin between the Piedmont Plateau and Blue Ridge physiographic provinces of the Appalachian Mountains. The Gettysburg basin is a northeast–southwest-trending extensional rift basin that typically contains sedimentary sandstones, siltstones, and shales intruded by igneous sills, dikes, and irregular igneous bodies (Figure 14; Thornberry-Ehrlich 2009b). Bedrock in EISE originated within this rift basin and are associated with the formation of the present-day Atlantic Ocean and the Appalachian Mountains (Thornberry-Ehrlich 2009b). Thick accumulations of sediment 6,100 m (20,000 ft) thick filled the Gettysburg basin during the Late Triassic, immediately followed in the earliest Jurassic by rising magma that intruded laterally as sills and vertically as dikes (Cuffey et al. 2006). The bedrock geology within EISE consists of the Triassic Gettysburg Shale, Triassic-age York Haven Diabase that intrudes the Gettysburg Shale, and younger Quaternary alluvium of clay, sand, and gravel.

Stratotypes

There are no designated stratotypes identified within the boundaries of EISE. There are 20 identified stratotypes located within 48 km (30 mi) of EISE boundaries that are provided in Appendix C for reference in case of future historic site boundary expansion.

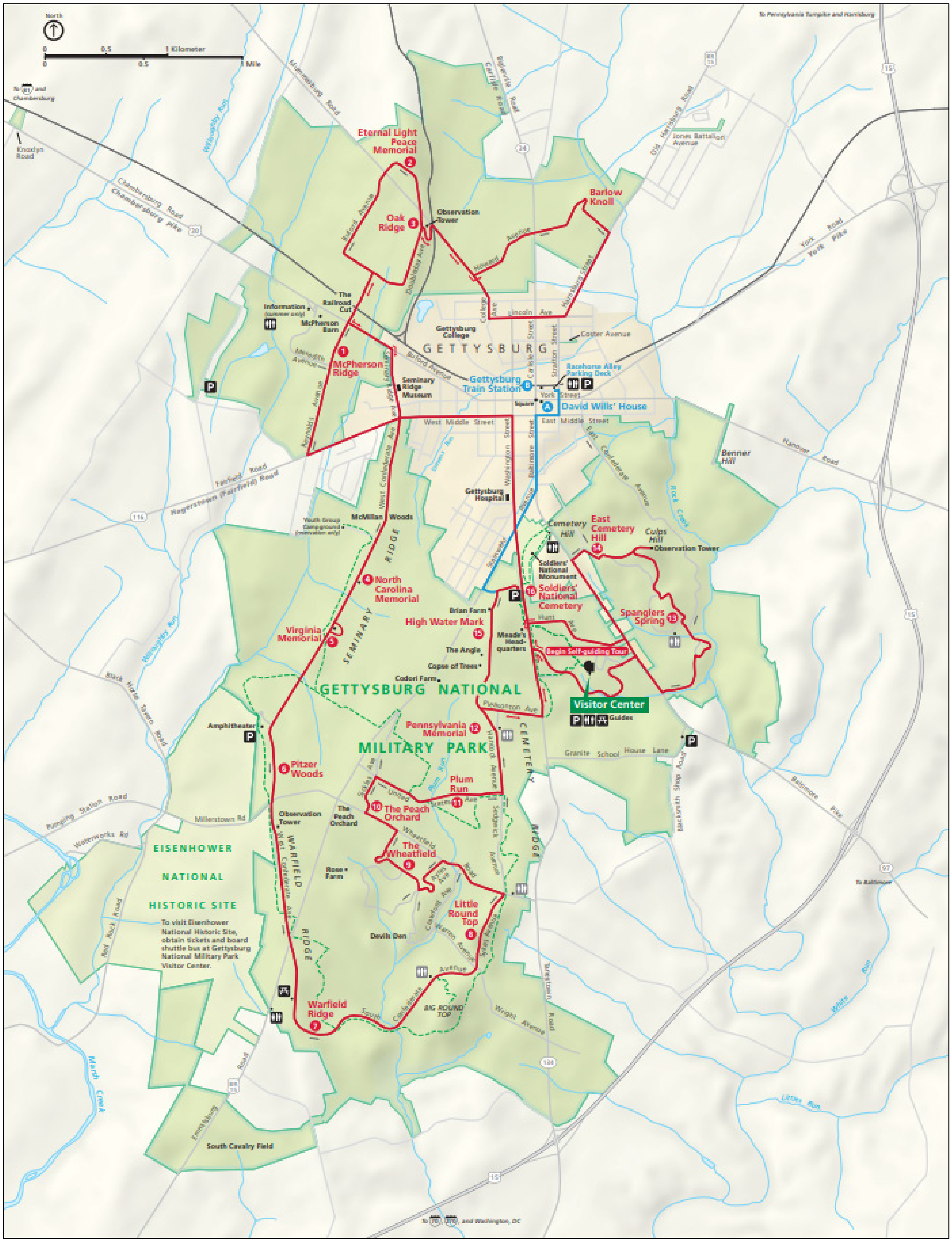


Figure 13. Park map of EISE and part of GETT, Pennsylvania (NPS).

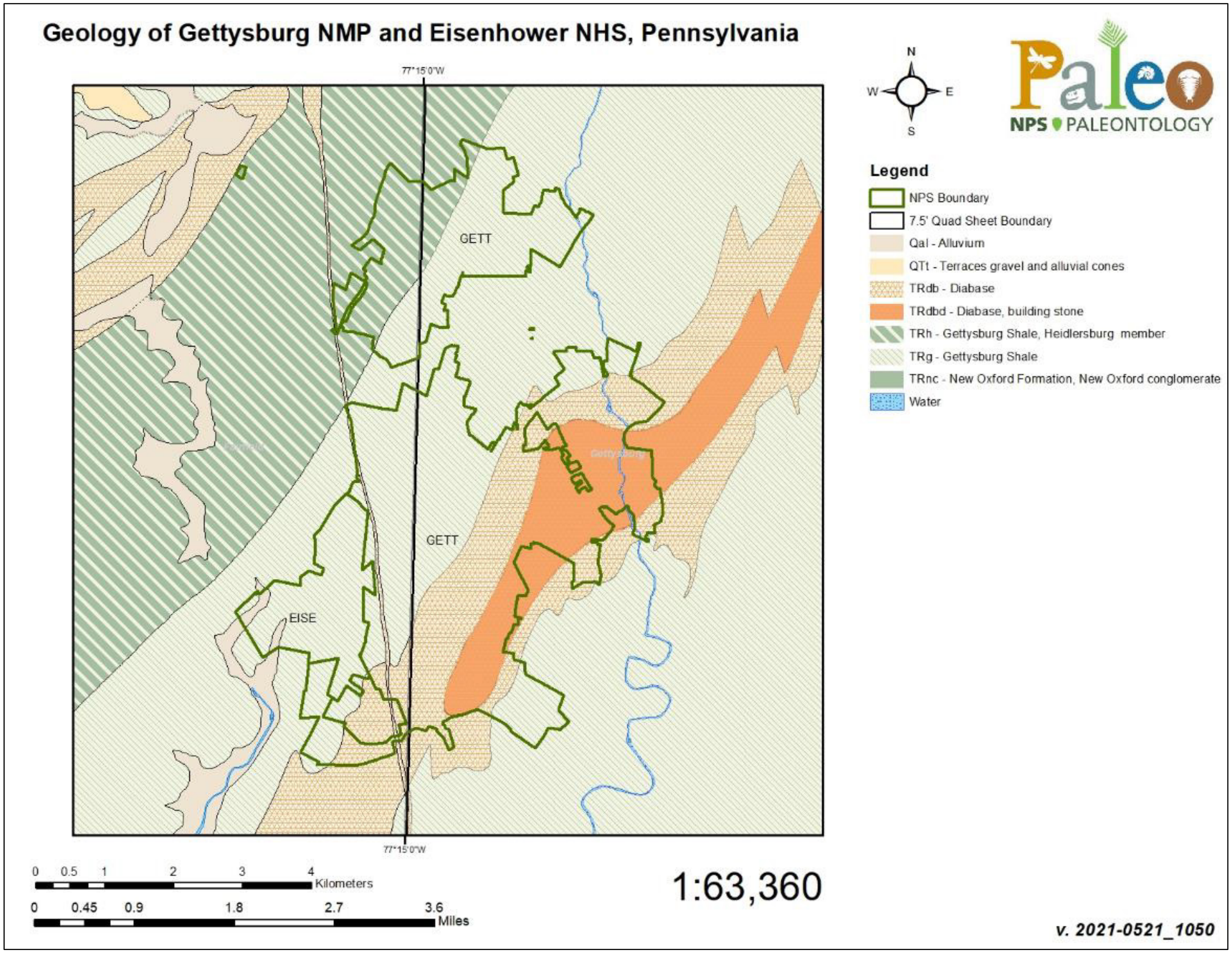


Figure 14. Geologic map of EISE (data modified from EISE GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1041799) and GETT (data modified from GETT GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1041800).

Fredericksburg and Spotsylvania National Military Park (FRSP)

Park Establishment

Fredericksburg and Spotsylvania County Battlefields Memorial National Military Park (FRSP), often known by the shorter name Fredericksburg and Spotsylvania National Military Park, is located between Washington D.C. and Richmond in Fredericksburg City and Spotsylvania County, Virginia (Figure 15). Established on February 14, 1927, FRSP encompasses about 1,550 hectares (8,380 acres) and is one of the largest military parks in the eastern United States. The military park commemorates the more than 15,000 soldiers that died during the fighting that took place near the town of Fredericksburg. Preserved at FRSP are four major Civil War battlefield sites, including Fredericksburg, Chancellorsville, Wilderness, and Spotsylvania Court House. The park contains four historic buildings associated with the battlefield sites—Chatham, Salem Church, Ellwood, and the house where Stonewall Jackson died—in addition to historic homesites of local families and numerous monuments to Civil War soldiers (Thornberry-Ehrlich 2010b; National Park Service 2016).

Geologic Summary

FRSP contains a diverse assemblage of metamorphic, igneous, and sedimentary rocks spanning from the late Proterozoic–Ordovician to the Pliocene (Figure 16). Some of the oldest bedrock in the park are metamorphic rocks of the Po River Metamorphic Suite and include biotite gneiss, garnet-muscovite gneiss, and schist. Geologic features of the FRSP landscape were used during the Civil War to the Confederate army's advantage in the 1862 Battle of Fredericksburg. The Confederate army utilized the floodplains, river terraces, and north-south trending ridges around the Rappahannock River to impede the Union advance on the Confederate capital of Richmond for several years (Thornberry-Ehrlich 2010b).

Stratotypes

There are no designated stratotypes identified within the boundaries of FRSP. There are 29 identified stratotypes located within 48 km (30 mi) of FRSP boundaries that are provided in Appendix C for reference in case of future park boundary expansion.

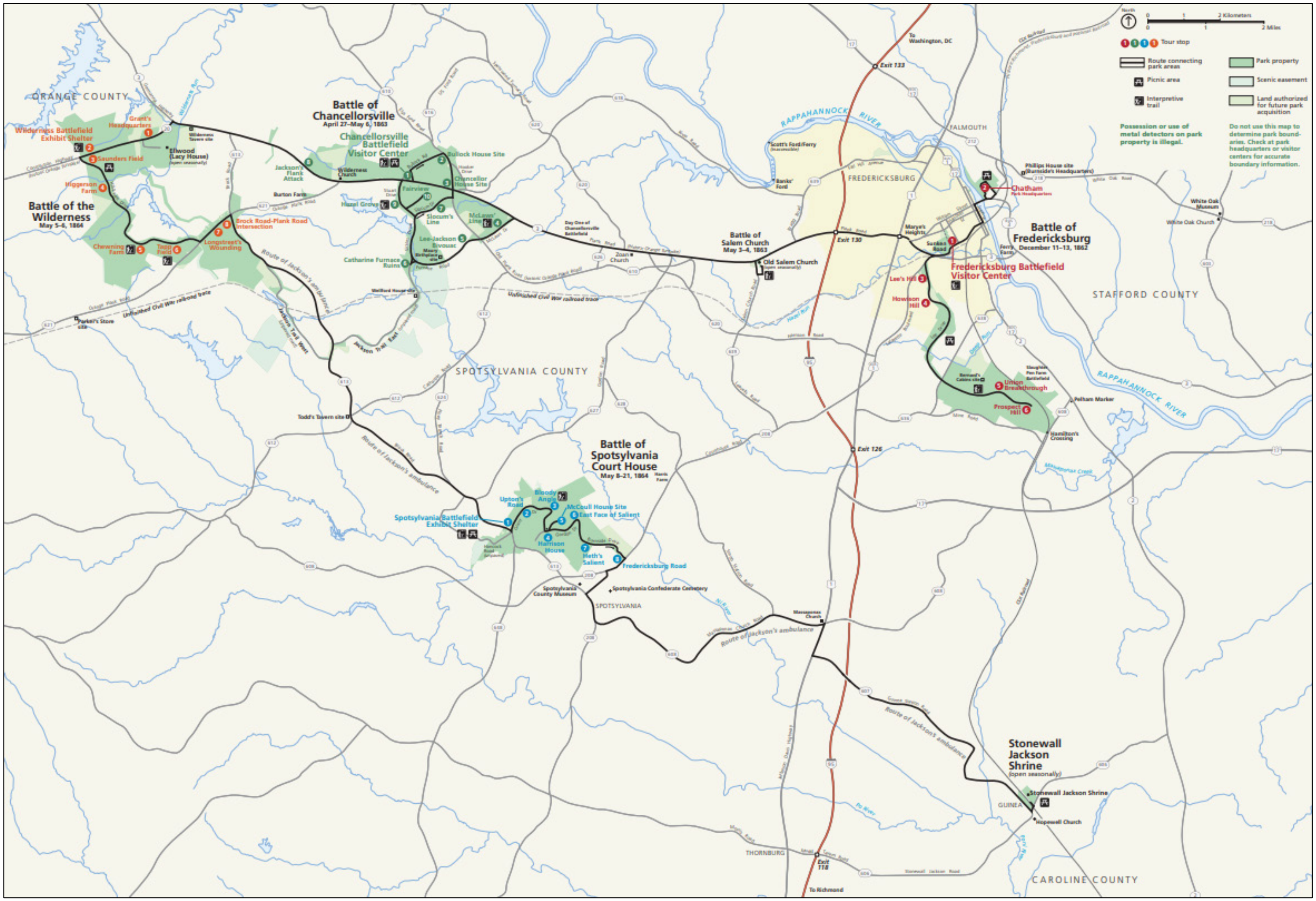


Figure 15. Park map of FRSP, Virginia (NPS).

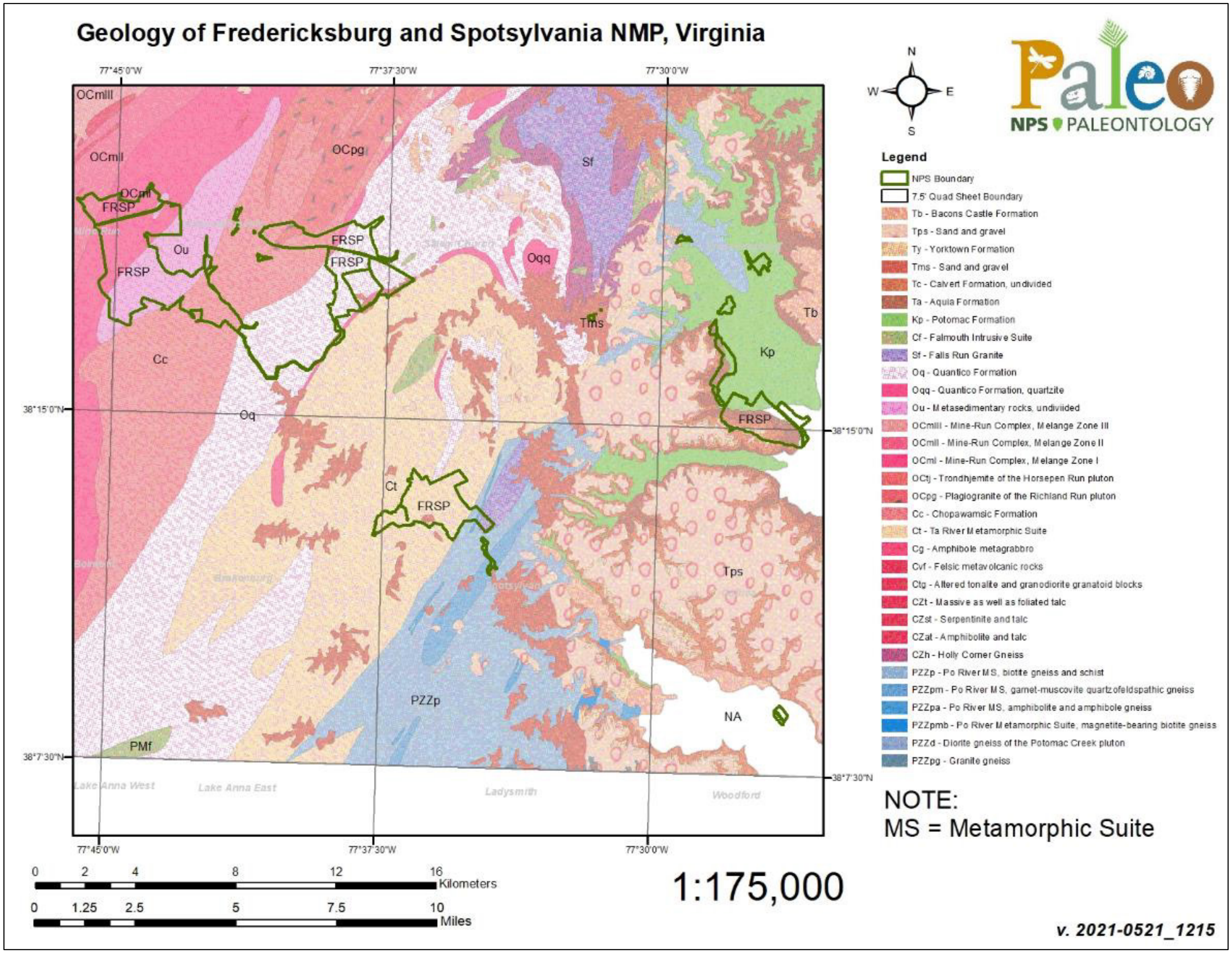


Figure 16. Geologic map of FRSP, Virginia. Data modified from FRSP GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/2164871. Some units identified as Cambrian are now known to be younger.

Gettysburg National Military Park (GETT)

Park Establishment

Gettysburg National Military Park (GETT) is located approximately 56 km (35 mi) southwest of Harrisburg and 105 km (65 mi) northeast of Washington D.C. in Adams County, Pennsylvania (Figure 17). The military park was established on February 11, 1895 and transferred to the National Park Service from the War Department on August 10, 1933 (National Park Service 2016). Encompassing about 2,441 hectares (6,033 acres), GETT commemorates the historic Battle of Gettysburg that is widely considered the turning point of the American Civil War. Gettysburg was the bloodiest battle of the war, causing 51,000 casualties and inspiring President Abraham Lincoln's famous Gettysburg Address (National Park Service 2016). The military park preserves battleground sites, Soldiers' National Cemetery, more than 1,300 monuments, 400 cannons, 147 historic buildings, and surrounding farms, forests, hillsides, and riparian areas.

Geologic Summary

GETT is situated within the Triassic-age Gettysburg basin between the Piedmont Plateau and Blue Ridge physiographic provinces of the Appalachian Mountains. The Gettysburg basin is a northeast–southwest-trending extensional rift basin that typically contains sedimentary sandstones, siltstones, and shales (mudstones) intruded by igneous sills, dikes, and irregular igneous bodies (Thornberry-Ehrlich 2009b; Cuffey et al. 2006). Geologic units within GETT include reddish-brown to gray siltstone, shale, and sandstone of the Triassic Gettysburg Shale and associated Heidlersburg Member, and the Triassic-age York Haven Diabase that intrudes the Gettysburg Shale (Figure 18). Many of the landscape features within the military park reflect the underlying geology and had a significant impact on the Battle of Gettysburg. Topographic high points such as Little Round Top, Big Round Top, Cemetery Ridge, and Culps Hill along southeastern GETT consist of the more resistant York Haven Diabase and provided the high-ground advantage to the Union Army.

Stratotypes

There are no designated stratotypes identified within the boundaries of GETT. A type section for the Gettysburg Shale is vaguely described by Glaeser (1963) as a composite of measured sections in and around Gettysburg, but there is not enough information to locate any of the included sections within GETT, and the formation should have a more clearly defined stratotype (see "Recommendations"). There are 21 identified stratotypes located within 48 km (30 mi) of GETT boundaries that are provided in Appendix C for reference in case of future park boundary expansion.

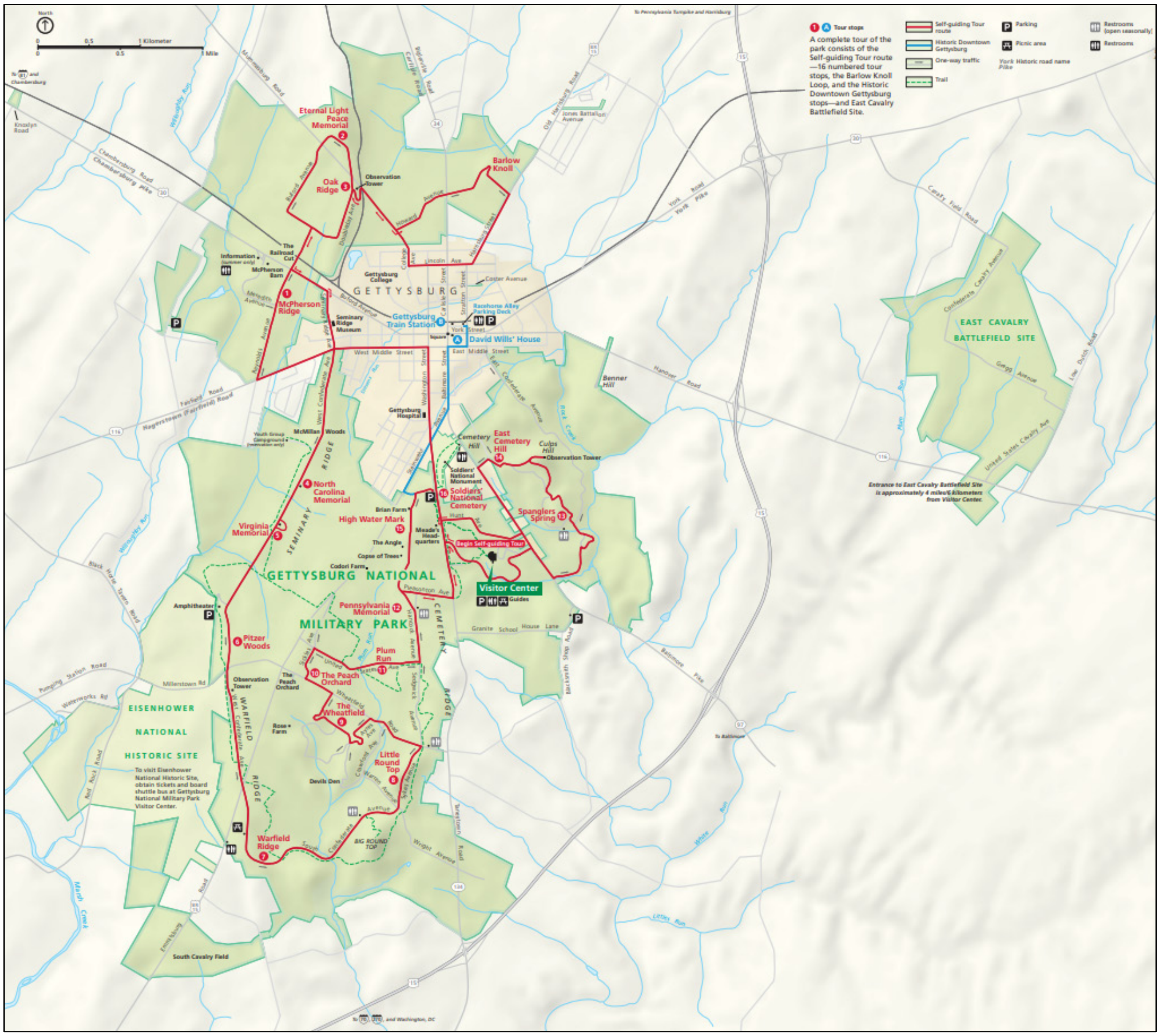


Figure 17. Park map of GETT and EISE, Pennsylvania (NPS).

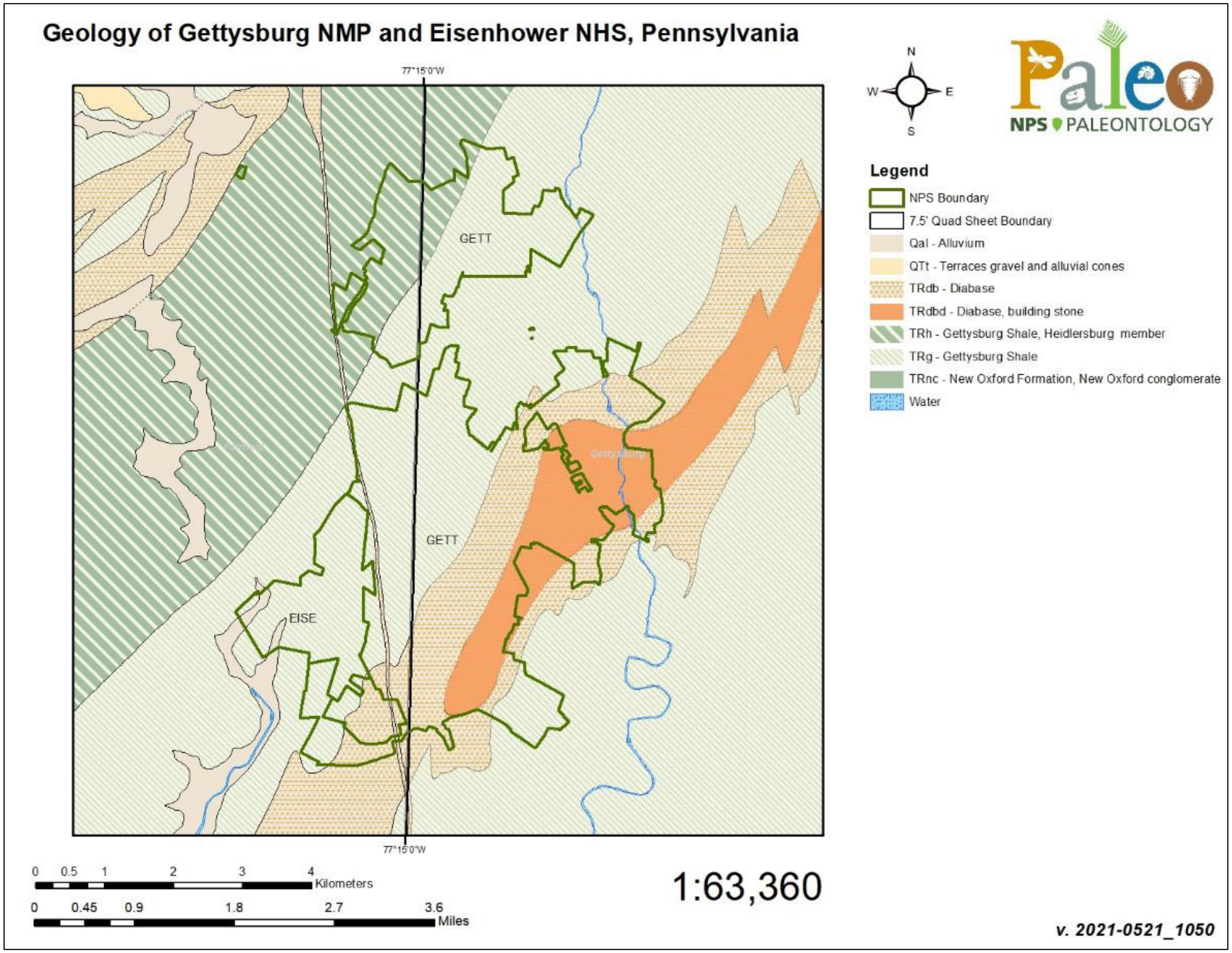


Figure 18. Geologic map of EISE (data modified from EISE GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1041799) and GETT (data modified from GETT GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1041800).

Hopewell Furnace National Historic Site (HOFU)

Park Establishment

Hopewell Furnace National Historic Site (HOFU) straddles the border of Berks and Chester Counties in southeastern Pennsylvania and is surrounded by French Creek State Park (Figure 19). Originally designated Hopewell Village National Historic Site on August 3, 1938, the park unit was renamed on September 19, 1985 (National Park Service 2016). Encompassing about 343 hectares (848 acres), HOFU is one of the finest examples of a rural American iron plantation of the 1800s. The historic site contains buildings that include a blast furnace, the ironmaster's mansion, and auxiliary structures. Mark Bird founded Hopewell Furnace in 1771 and during its period of operation until 1883 the iron-making complex produced pig iron and cast-iron products such as stove plates, kettles, plowshares, shot, weights, and other necessities for living in 19th century America. HOFU commemorates the essential role of the industrial age in the growth of the early United States and educates the public about this pivotal time in American history.

Geologic Summary

The geology of HOFU is characterized by Precambrian crystalline rocks, Paleozoic metamorphic and sedimentary rocks, and Triassic sedimentary rocks (Figure 20). Older, more resistant Precambrian and Cambrian-age metamorphic rocks including silica-rich graphitic gneiss, banded mafic gneiss, and quartzite underlie the steepest topography in the southern area of the historic site. The northern part of the historic site consists of quartz conglomerate and sandstone of the Triassic Hammer Creek Formation that is more resistant to erosion than the sandstone, siltstone, and mudstone of the Triassic Stockton Formation found throughout the center of HOFU (Thornberry-Ehrlich 2010c). The unconformable contact between the younger Triassic and older Precambrian strata represents a 300-million-year gap in the historic site's rock record.

Stratotypes

There are no designated stratotypes identified within the boundaries of HOFU. There are 11 identified stratotypes located within 48 km (30 mi) of HOFU boundaries that are provided in Appendix C for reference in case of future historic site boundary expansion.

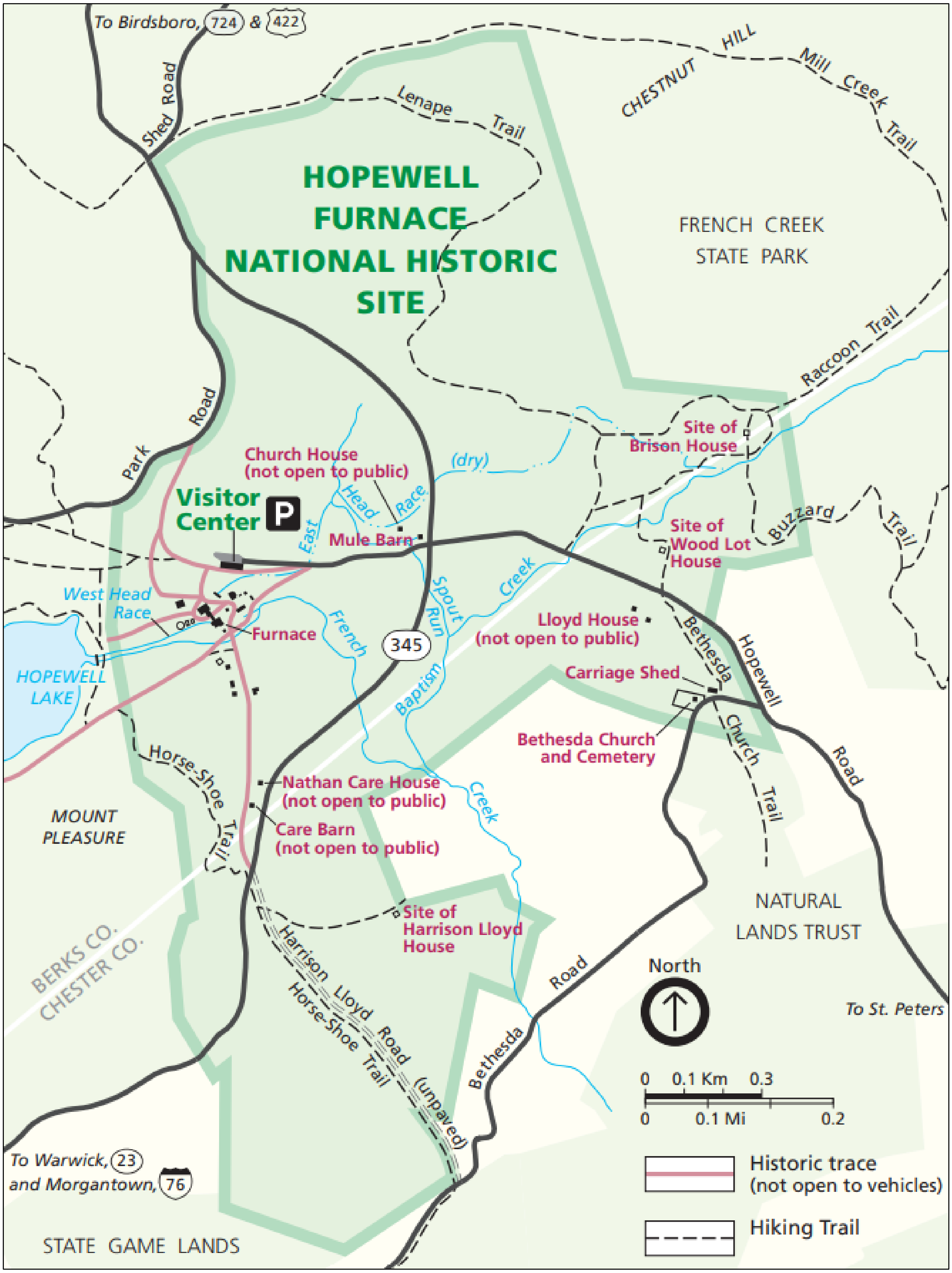


Figure 19. Park map of HOFU, Pennsylvania (NPS).

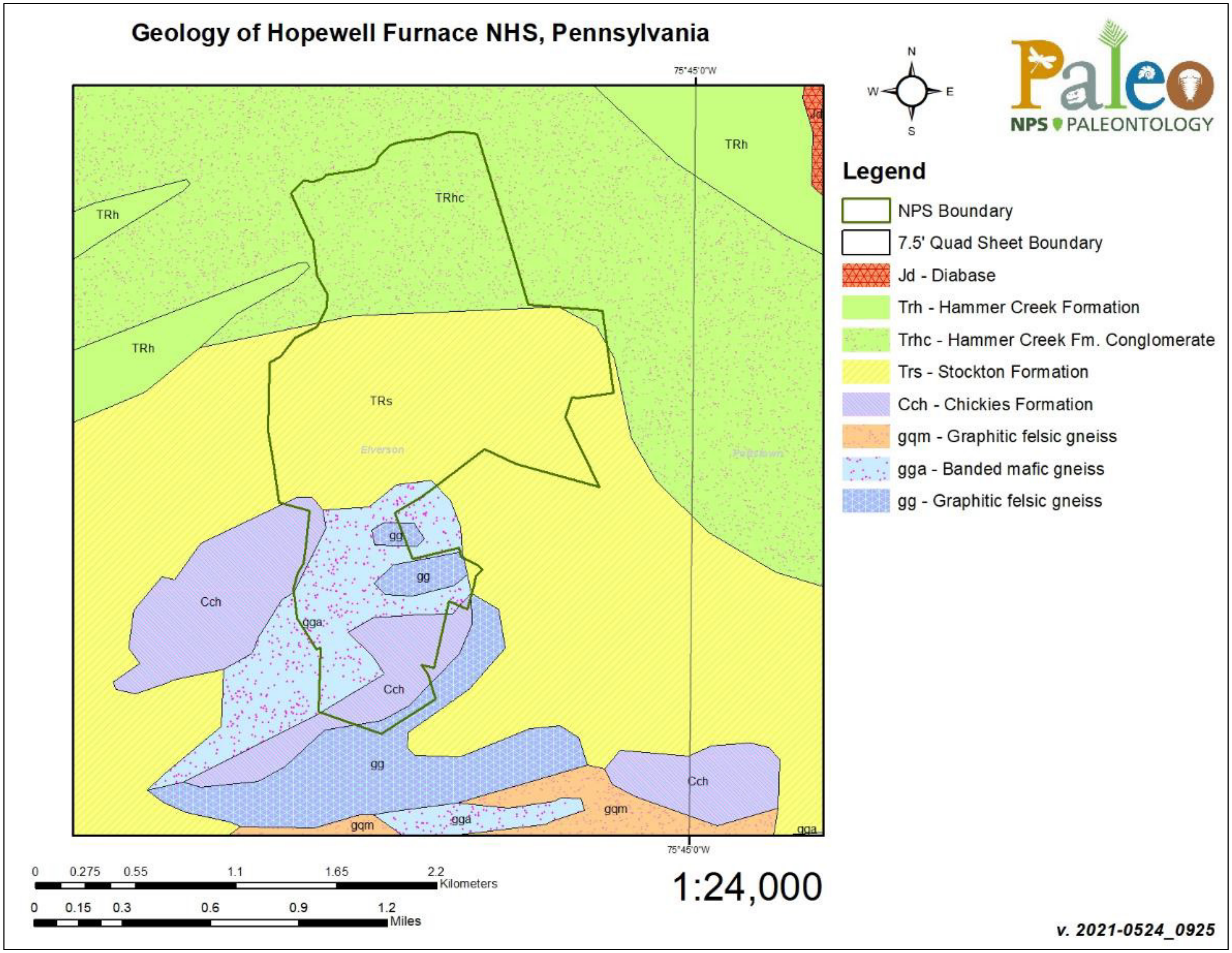


Figure 20. Geologic map of HOFU, Pennsylvania. Data modified from HOFU GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1045747.

Petersburg National Battlefield (PETE)

Park Establishment

Petersburg National Battlefield (PETE) is located approximately 32 km (20 mi) south of Richmond in Peterburg City, Hopewell City, Dinwiddie County, and Prince George County, Virginia (Figure 21). Originally established as a national military park on July 3, 1926, the park unit was redesignated a national battlefield on August 24, 1962 (National Park Service 2016). Encompassing about 1,109 hectares (2,740 acres), PETE preserves the historic sites, structures, and landscapes of the Civil War campaign, siege, and defense of Petersburg, and fosters an understanding of these events, their causes, and impacts on the country. The Union Army waged a 10-month campaign from 1864 into 1865 to seize Petersburg, and it is here that General Ulysses S. Grant cut off Peterburg's supply lines, ensuring the fall of Richmond in April 1865. The national battlefield includes General Grant's Headquarters located along the James River in Hopewell, Virginia, as well as the Five Forks Battlefield in Dinwiddie County where the Confederate Army collapse led to the fall of the city and ultimately of Richmond (National Park Service 2016).

Geologic Summary

The regional geology of the PETE area predominantly consists of ancient crystalline metasedimentary and metaigneous rocks of Neoproterozoic age, Paleozoic metamorphic and igneous rocks, and younger Cretaceous and Quaternary sedimentary strata (Figure 22). Some of the oldest bedrock in PETE underlies the Five Forks Battlefield and consists of the Pennsylvanian–Permian Petersburg Granite. The Petersburg Granite was first named by Jonas (1928) to describe a widely mappable granite body that occurs outside the park boundary in the area of Petersburg, Virginia. The Cretaceous Potomac Formation occurs near Soldiers Pond along Harrison Creek and near the Eastern Front Visitor Center. Younger Cenozoic-age geologic units within the national battlefield include Miocene-age gravel terraces and sedimentary rocks of the lower Chesapeake Group, Pliocene Yorktown Formation, Cold Harbor Formation, and Pleistocene Bacons Castle Formation.

Stratotypes

There are no designated stratotypes identified within the boundaries of PETE. There are 11 identified stratotypes located within 48 km (30 mi) of PETE boundaries that are provided in Appendix C for reference in case of future park boundary expansion.

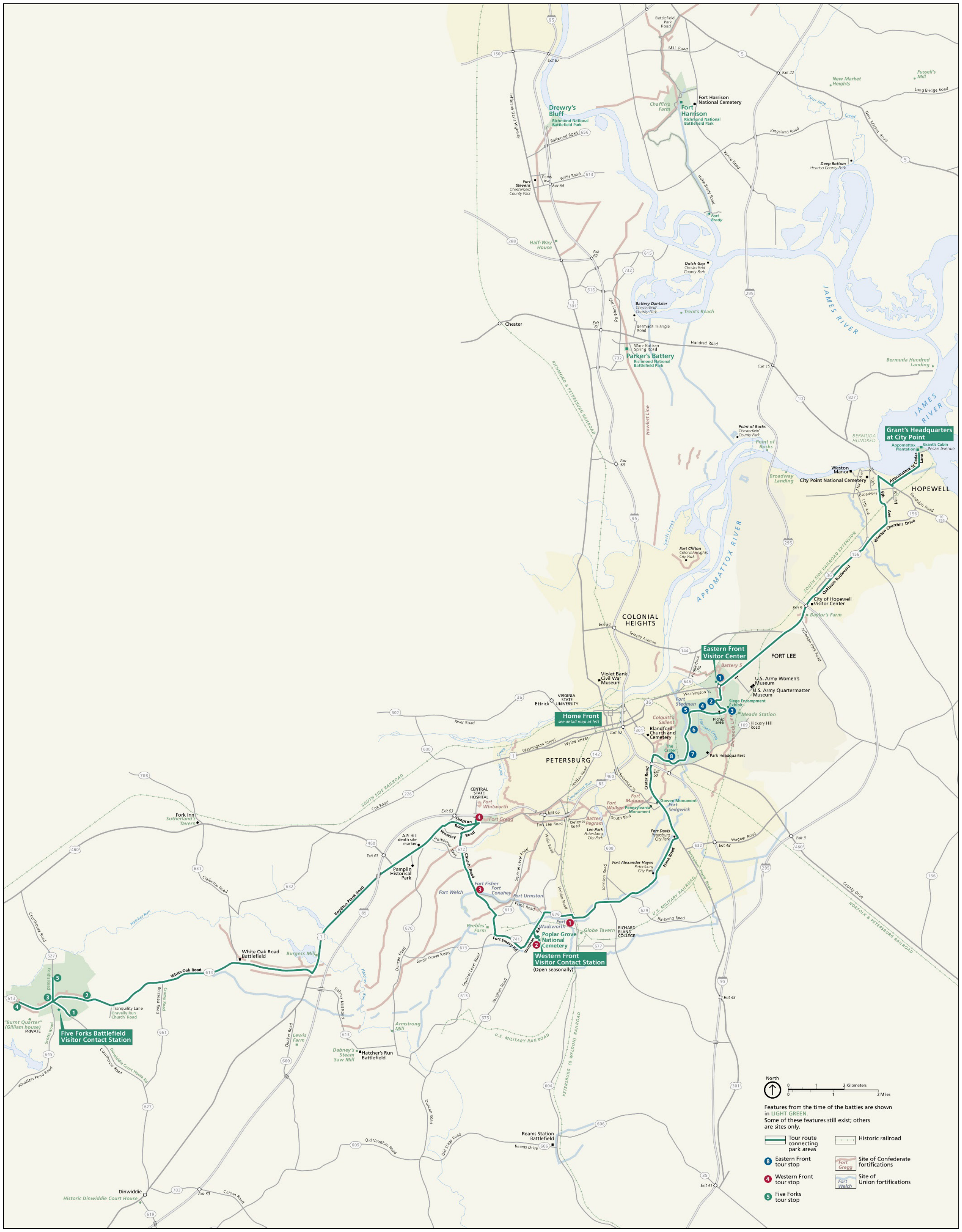


Figure 21. Park map of PETE, Virginia (NPS).

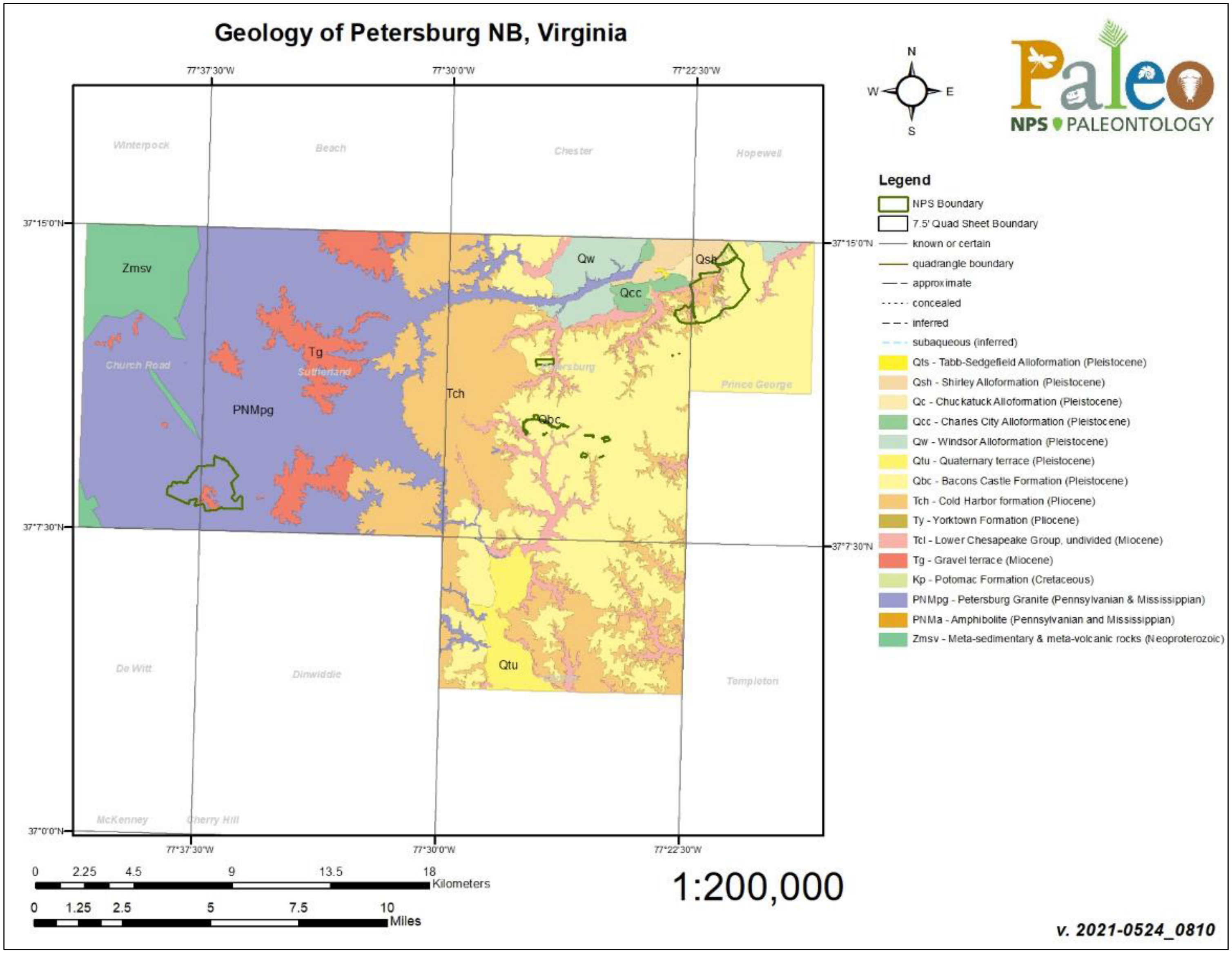


Figure 22. Geologic map of PETE, Virginia. Data modified from PETE GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/2263653.

Richmond National Battlefield Park (RICH)

Park Establishment

Richmond National Battlefield Park (RICH) is a collection of battleground sites located along the upper reaches of the James River in Richmond City and Chesterfield, Hanover, and Henrico Counties, Virginia (Figure 23). Established as a national park unit on March 2, 1936, RICH encompasses about 3,239 hectares (8,004 acres) and preserves, interprets, and commemorates major Civil War battlefield landscapes around Richmond. Battleground sites include Beaver Dam Creek, Cold Harbor, Gaines' Mill, Frayser's Farm (Glendale), Malvern Hill, Fort Harrison, Drewry's Bluff, Totopotomoy Creek, and New Market Heights (National Park Service 2016). RICH also protects historic resources and monuments while providing visitor services at sites associated with Civil War-era military medical, and industrial operations in, and around Richmond.

Geologic Summary

The regional geology of the RICH area consists of Paleozoic igneous rocks, Mesozoic sedimentary rocks, and a plethora of Cenozoic sedimentary strata that span the entire era (Figure 24). Park units of RICH located in and south of Richmond have bedrock consisting of the Cretaceous Potomac Formation, Miocene-age rocks of the lower Chesapeake Group, Pliocene Yorktown Formation, and Pleistocene-age units of the Bacons Castle Formation, Windsor Alloformation, Charles City Alloformation, and the Chuckatuck Alloformation. Park sites located north of Richmond are underlain by the Miocene Calvert Formation, Miocene–Pliocene-age rocks of the Chesapeake Group, Pliocene Cold Harbor formation, and Pleistocene Windsor Alloformation. A veneer of Pleistocene to Holocene alluvium consisting of unconsolidated gravel, sand, and clay occupies the river valleys and creek drainages of the park.

Stratotypes

There are currently no designated stratotypes identified within the boundaries of RICH. However, the Pliocene Cold Harbor Formation is named from two borings within the Cold Harbor Battlefield of RICH. A reference boring outside the park in the Quinton 7.5′ Quadrangle should also be included when the process of formalization concludes and the name appears in GEOLEX (Rick Berquist, Jr., College of William & Mary, pers. comm., 2022). There are 16 identified stratotypes located within 48 km (30 mi) of RICH boundaries that are provided in Appendix C for reference in case of future battlefield park boundary expansion.

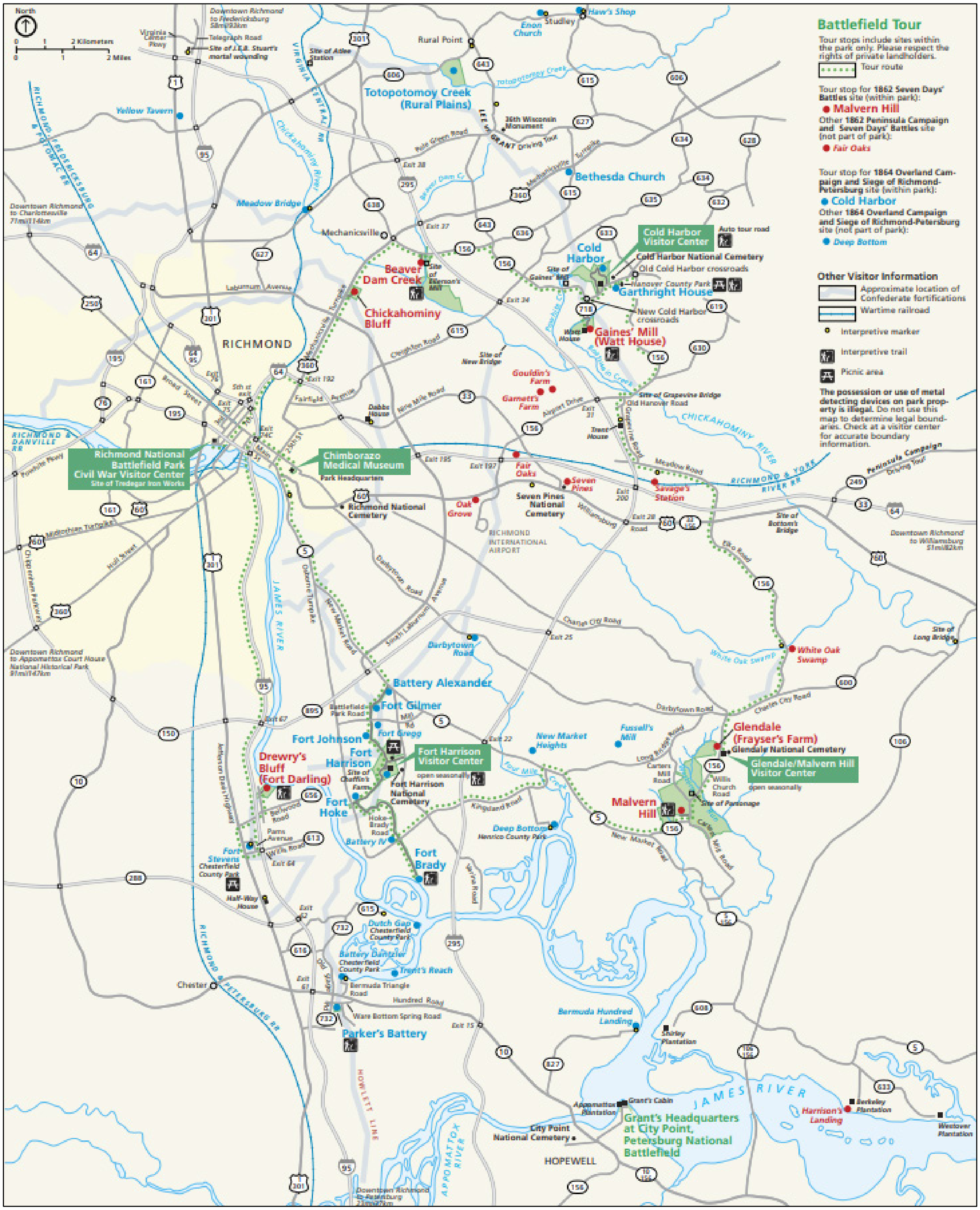


Figure 23. Park map of RICH, Virginia (NPS).

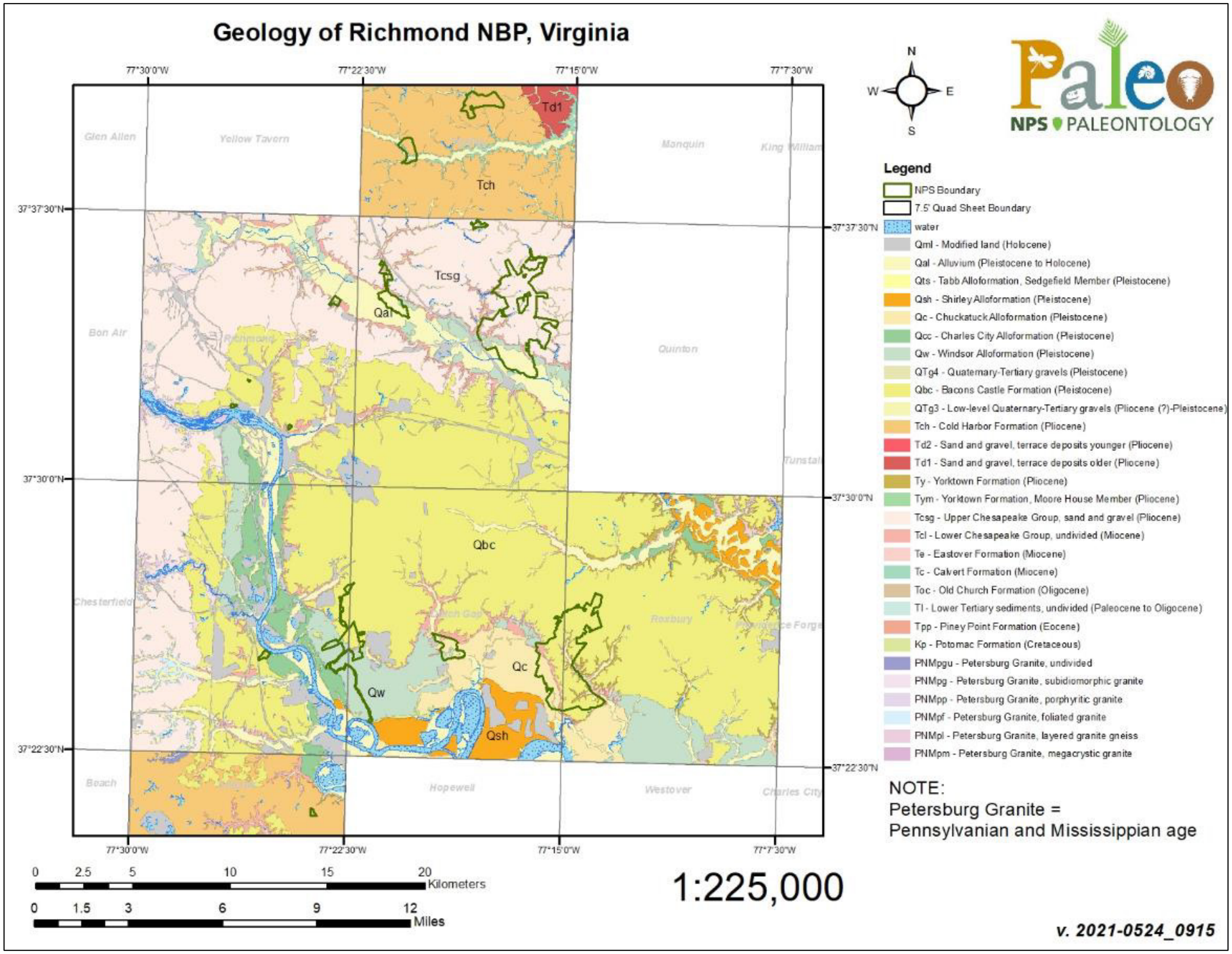


Figure 24. Geologic map of RICH, Virginia. Data modified from RICH GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/2208910.

Shenandoah National Park (SHEN)

Park Establishment

Shenandoah National Park (SHEN) is located less than 145 km (90 mi) southwest of Washington, D.C. along the crest of the Blue Ridge Mountains in Albemarle, Augusta, Greene, Madison, Page, Rappahannock, Rockingham, and Warren Counties, Virginia (Figure 25). The park was authorized by Congress on May 22, 1926 to preserve and protect nationally significant natural and cultural resources, scenic beauty, and designated wilderness within Virginia's northern Blue Ridge Mountains. SHEN encompasses about 80,580 hectares (199,117 acres) of mountains, forests, meadows, and culturally and historically significant areas (National Park Service 2016). An abundant and diverse array of wildlife are found in SHEN, as well as 805 km (500 mi) of hiking trails, including 163 km (101 mi) of the Appalachian Trail. Several historically significant landmarks are preserved in SHEN, including Skyland, Rapidan Camp, and structures built by the Civilian Conservation Corps.

Geologic Summary

SHEN showcases the geology and high elevation hydrology of the Appalachian Mountains, one of the oldest mountain ranges on earth. The bedrock geology of SHEN can be subdivided into four main types of rock: (1) Mesoproterozoic metamorphic and igneous rocks that are approximately 1.2–1.0 billion years old; (2) Neoproterozoic metamorphic and igneous rocks that are approximately 800–570 million years old; (3) Paleozoic metamorphosed and non-metamorphosed sedimentary rocks that are approximately 540–420 million years old; and (4) isolated intrusions of Jurassic igneous rocks that are approximately 200–150 million years old (Figures 26 and 27; Southworth et al. 2009a, 2010). Structurally, SHEN straddles the Blue Ridge–South Mountain anticlinorium, characterized by steep-sloped topographic highs consisting of resistant Mesoproterozoic gneisses and granites, Neoproterozoic greenstones and metasedimentary rocks, and Cambrian quartzites or sandstones. SHEN offers opportunities to examine the core of an ancient mountain fold-and-thrust belt, providing a view into some of the oldest rocks of the eastern United States (Thornberry-Ehrlich 2014).

Stratotypes

SHEN contains three identified stratotypes that represent the Mesoproterozoic Old Rag Granite and Neoproterozoic Swift Run Formation (Table 3; Figure 28). In addition to the designated stratotypes located within SHEN, there are 30 identified stratotypes located within 48 km (30 mi) of SHEN boundaries that are provided in Appendix C for reference in case of future park boundary expansion.

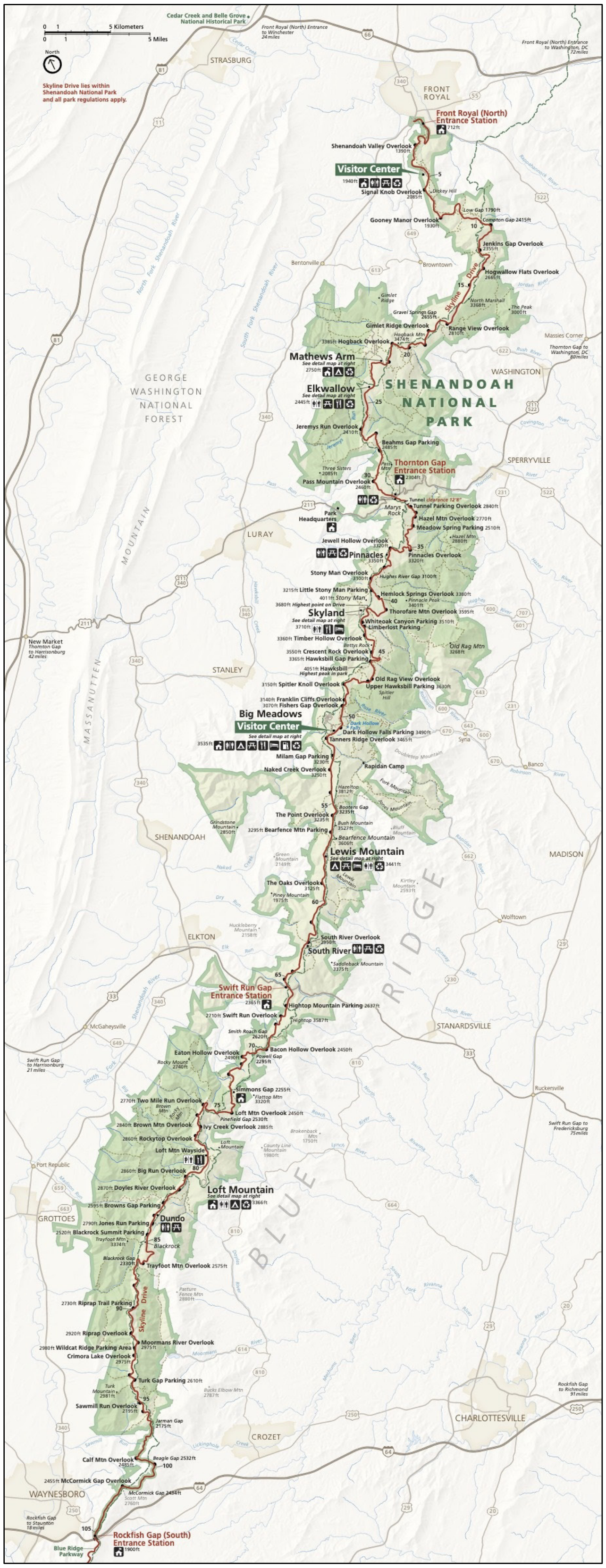


Figure 25. Park map of SHEN, Virginia (NPS).

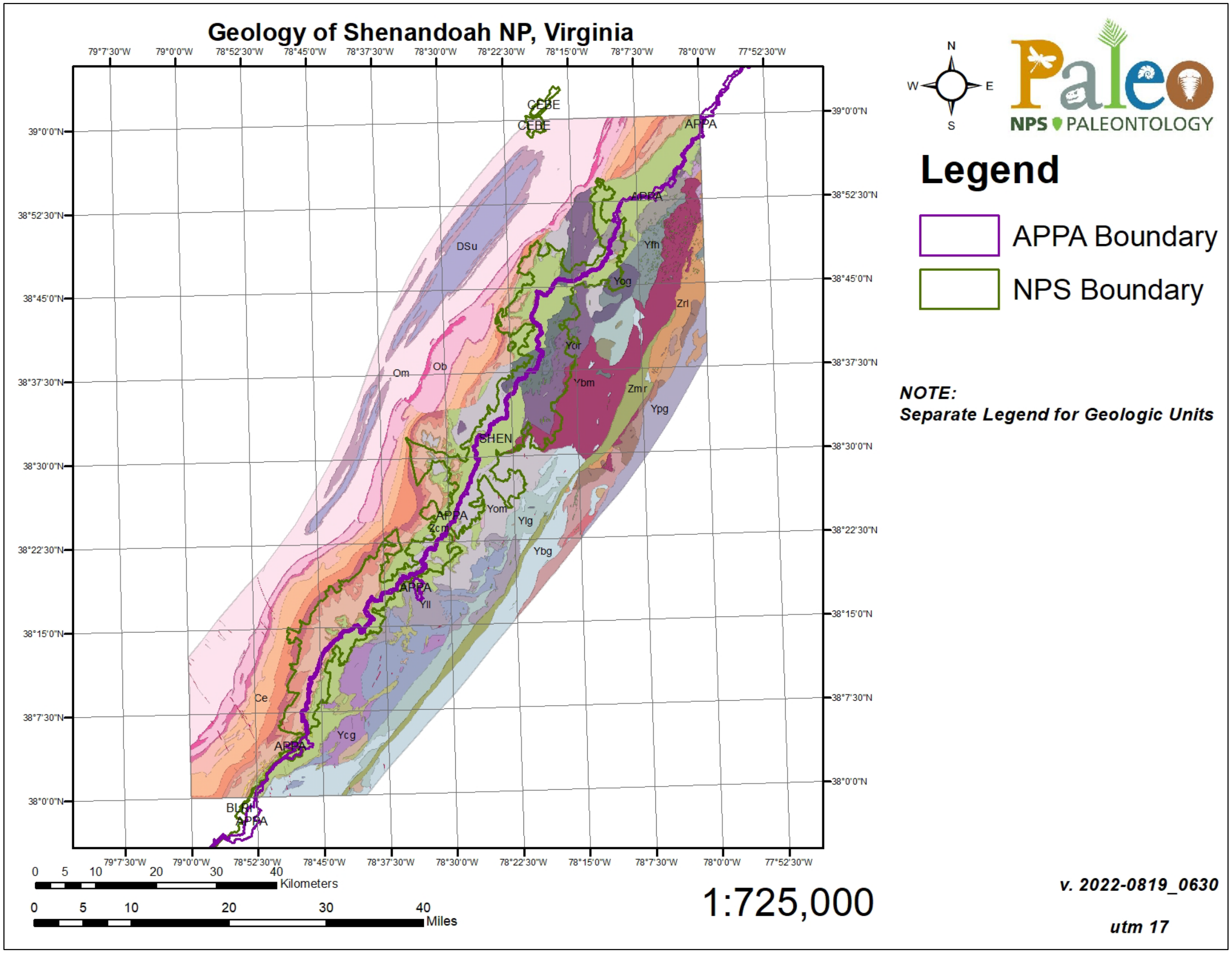


Figure 26. Geologic map of SHEN, Virginia; see Figure 27 for legend. Data modified from SHEN GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1048482.

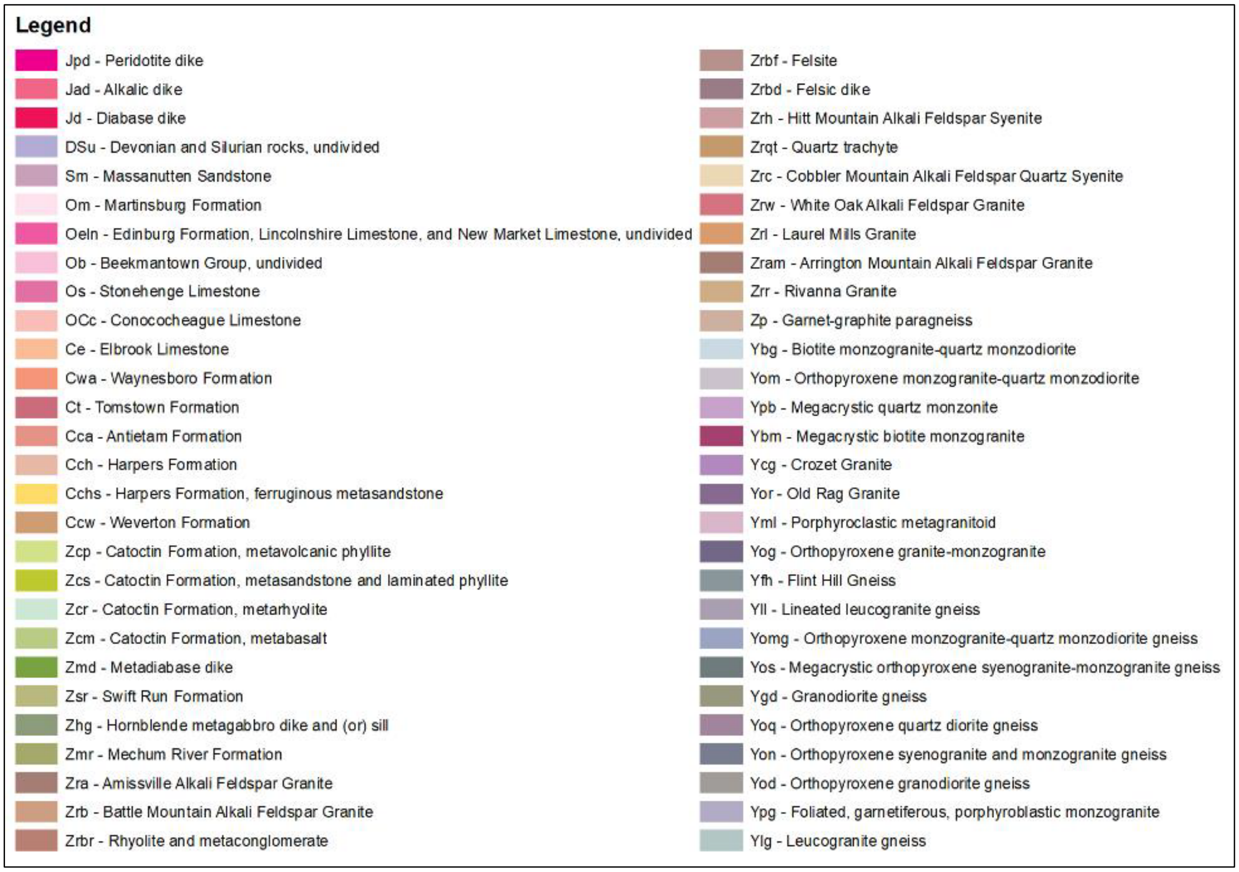


Figure 27. Geologic map legend of SHEN, Virginia.

Table 3. List of SHEN stratotype units sorted by age with associated reference publications and locations.

Unit Name (GRI map symbol)	Reference	Stratotype Location	Age
Swift Run Formation (Zsr)	Jonas and Stose 1939; King 1950; Bailey et al. 2012	Type locality: exposures along US Highway 33, about 1.9 km (1.2 mi) east of Swift Run Gap and on the Skyline Drive just north of the gap, a few miles southeast of the Elkton area in Greene County, Virginia. Principal reference section: an exposure 1.6 km (1 mi) east of the original type locality along a tributary to the north of U.S. Route 33, in Greene County, Virginia.	Neoproterozoic
Old Rag Granite (Yo)	Furcron 1934; Lukert 1982; Blackburn et al. 1994	Type locality: exposures on Old Rag Mountain, in Madison County, Virginia.	Mesoproterozoic

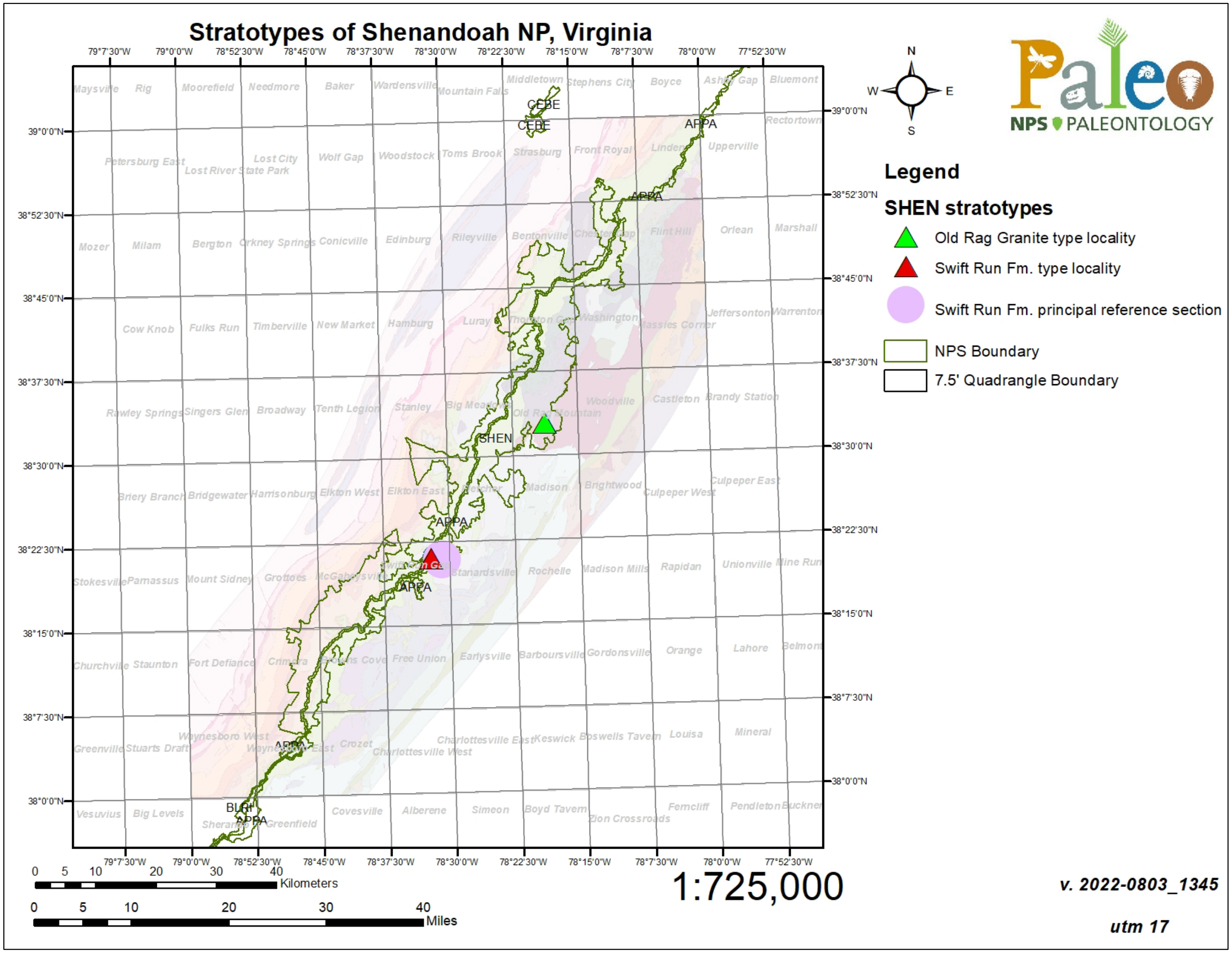


Figure 28. Modified geologic map of SHEN showing stratotype locations. The transparency of the geologic units layer has been increased.

Old Rag Granite

The Mesoproterozoic Old Rag Granite was proposed by Furcron (1934) and named after its type locality exposures at Old Rag Mountain in Madison County, Virginia (Table 3; Figures 28–30). In northern SHEN the Old Rag Granite is intermittently exposed for approximately 80 km (50 mi) in the core of the Catoctin–Blue Ridge anticlinorium (Lukert 1982; Blackburn et al. 1994). The granite is characterized as a white- to light-gray, medium- to coarse-grained, alkali-feldspar-rich granite with blue or smoky quartz and containing minor or no mafic minerals (Blackburn et al. 1994; Southworth et al. 2009a). The Old Rag Granite is unconformably overlain by the Neoproterozoic Catoctin Formation and Swift Run Formation and is in contact with Mesoproterozoic igneous and metamorphic rocks including the Flint Hill Gneiss (Lukert 1982; Southworth et al. 2009a).

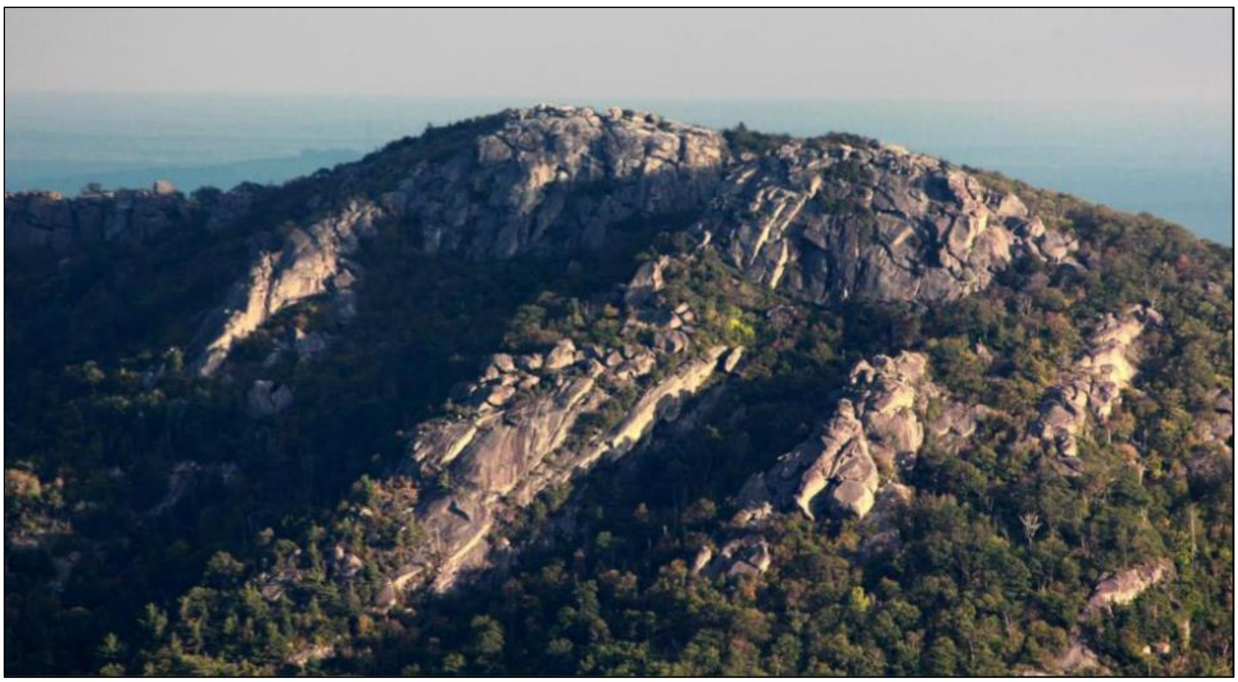


Figure 29. View looking southeast from Thorofare Mountain Overlook toward Old Rag Mountain, type locality of the Old Rag Granite (NPS).

Figure 30. Visitors along the top of the boulders at the summit of Old Rag Mountain, SHEN (IAN MACURDY, available at https://npgallery.nps.gov/AssetDetail/e10d86cd-2df6-427f-8288-58d74007423f).

Swift Run Formation

The Neoproterozoic Swift Run Formation was originally referred to as the “Swift Run tuff” by Stose and Stose (1944) for a series of heterogeneous tuffaceous and arkosic sedimentary rocks that underlie Catoctin greenstone on the west limb of the Catoctin–Blue Ridge anticlinorium, Virginia. King (1950) revised the unit as a formation and designated the type locality 1.9 km (1.2 mi) east of Swift Run Gap on U.S. Highway 33, a few miles southeast of the Elkton area (Table 3; Figures 28 and 31; see also Jonas and Stose 1939). However, the type locality of King (1950) was destroyed well over 50 years ago during roadway construction that widened U.S. Route 33 (Furcron 1969; Bailey et al. 2012; Christopher Bailey, College of William & Mary, pers. comm., 2022). A principal reference section for the Swift Run Formation was proposed by Bailey et al. (2012) at an exposure 1.6 km (1 mi) east of the original type locality along a tributary to the north of U.S. Route 33 in SHEN (Table 3; Figure 28). The Swift Run Formation consists of vitreous, well-bedded, arkosic phyllite, meta-arkose, laminated metasiltstone, and pebble to cobble metaconglomerate (King 1950; Southworth et al. 2009b; Bailey et al. 2012). In the Swift Run 7.5′ Quadrangle, the thickness of the unit varies considerably from absent to up to 90 m (0–300 ft) thick (Bailey et al. 2012). In the type locality and principal reference section region, the Swift Run Formation underlies the Catoctin Formation and unconformably overlies older Mesoproterozoic rocks.

Figure 31. Type locality exposure of the Swift Run Formation located east of Swift Run Gap, SHEN. Hammer rests on the upper contact with the Catoctin Formation to the right. Figure 1 from Jonas and Stose (1939); reproduced with permission of the American Journal of Science.

Valley Forge National Historical Park (VAFO)

Park Establishment

Valley Forge National Historical Park (VAFO) is located approximately 29 km (18 mi) northwest of downtown Philadelphia along the boundary of Chester and Montgomery Counties, Pennsylvania (Figure 32). Authorized as a national park unit on July 4, 1976, VAFO encompasses about 1,403 hectares (3,468 acres) and the site of the storied winter encampment of General George Washington and the Continental Army during 1777–1778 (National Park Service 2016). VAFO conserves and interprets the land and resources associated with the encampment site, commemorating the sacrifices and achievements made during the six-month stay as the army was transformed into a cohesive and disciplined fighting force. The historical park preserves historic landscapes, earthworks, archeological sites, and historic structures including Washington's Headquarters.

Geologic Summary

Located in the eastern Piedmont physiographic province, the rocks of the VAFO area range from metamorphosed and deformed Precambrian gneisses and Paleozoic metamorphosed sedimentary rocks, to the gently tilted, younger sedimentary strata of the Mesozoic rift basins (Thornberry-Ehrlich 2010d). In the northern area of VAFO, generally flat-lying Triassic-age sediments of the Stockton Formation overlap older Cambrian rocks of the Chickies, Antietam, Harpers, and Ledger Formations. The older Paleozoic geologic units in the Valley Forge area are faulted, deformed, and record varying degrees of metamorphism in surface exposures (Thornberry-Ehrlich 2010d). Scattered Cretaceous and Cenozoic units crop out in the central and southern portions of the park and include the Patapsco Formation, Bryn Mawr Formation, Pensauken Formation, and Bridgeton Formation (Figure 33).

Stratotypes

There are no designated stratotypes identified within the boundaries of VAFO. There are three identified stratotypes located within 48 km (30 mi) of VAFO boundaries that are provided in Appendix C for reference in case of future historical park boundary expansion.

Figure 32. Park map of VAFO, Pennsylvania (NPS).

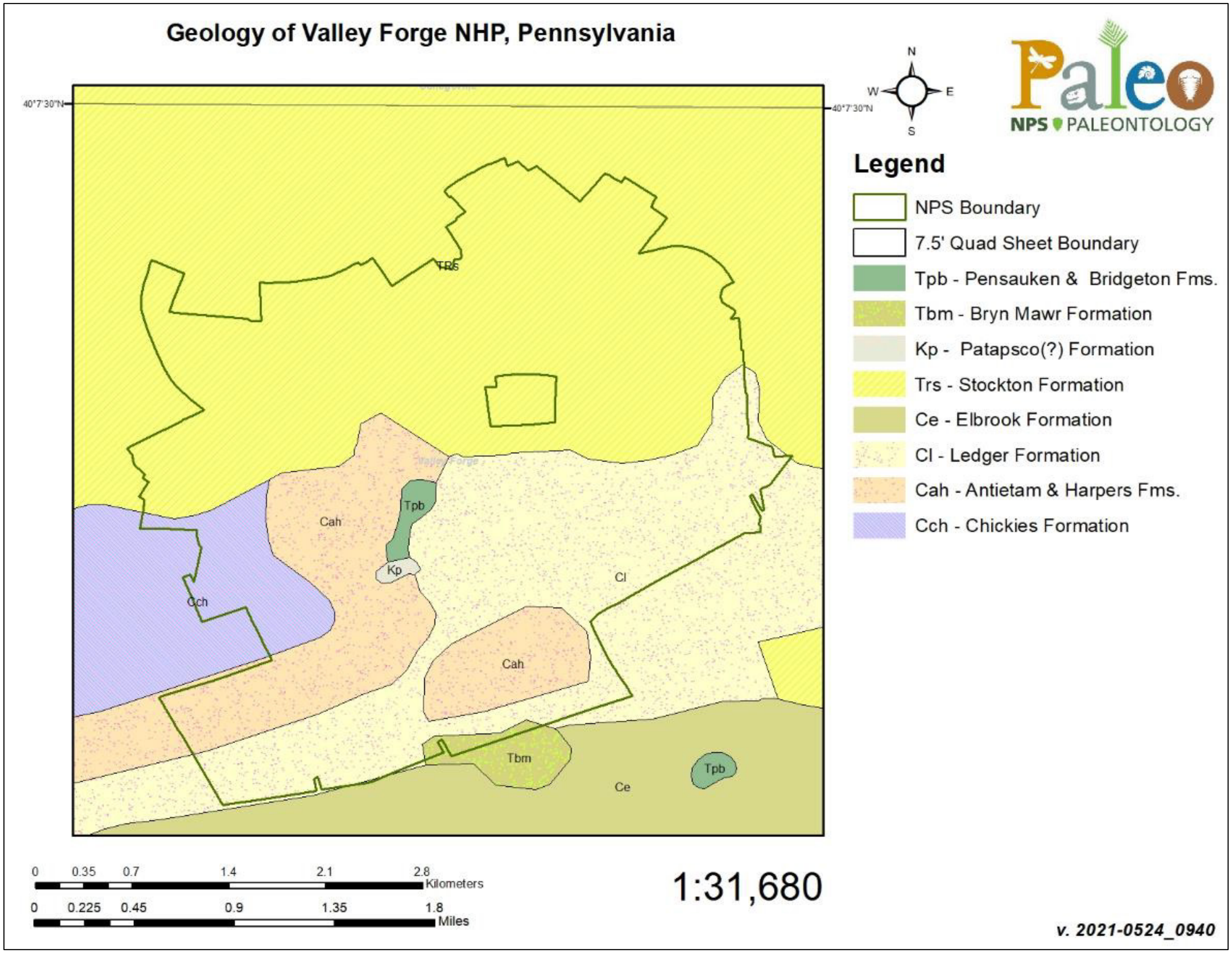


Figure 33. Geologic map of VAFO, Pennsylvania. Data modified from VAFO GRI digital geologic map data at https://irma.nps.gov/DataStore/Reference/Profile/1045747.

Recommendations

Stratotypes represent unique geologic exposures and are important to manage due to the scientific and educational values they hold for future generations. Stratotypes occur where rocks are exposed naturally (cliff face, river bluff, canyon wall, etc.) or artificially (quarry wall, road/rail/trail/canal cut, tunnel). Therefore, continued stratotype utility derives from the following three characteristics:

- Visibility: described rock layers remain visible and not totally or partially obscured
- Accessibility: the exposures at the stratotype remain reasonably accessible via road, trail, or other method
- Unaltered Integrity: the rock exposures are not altered significantly following description

Stratotype management strategies should focus on maintaining these characteristics to the extent practical when there are multiple management priorities at the site. The extent of the stratotype also impacts resource management considerations. For example, type areas occur over large geographic areas with less emphasis or significance placed on individual exposures, while type sections are specific localities that may warrant more focused management attention.

The recommendations below generally follow the protocol suggested by Brocx et al. (2019) with changes to fit NPS resource management framework.

1. The NPS Geologic Resources Division should work with park, regional and network staff to increase their awareness and understanding about the historic and geologic heritage significance of geologic stratotypes (type sections/localities/areas, reference sections, lithodemes). This report is a first step toward building that awareness.
2. The NPS Geologic Resources Division should work with park, regional and network staff to ensure they are aware of the locations of stratotypes in park areas. This information is necessary to ensure that proposed park activities or development do not adversely impact the stability and condition of these geologic exposures. Preservation of stratotypes should not limit accessibility for future scientific research but help safeguard these exposures from infrastructure development.
3. For significant sites without formal stratotype designations, GRD can provide assistance and liaison with the U.S. Geological Survey or other agencies to establish formal designations. It is recommended that stratotype designations of the following units be made to: (A) provide a standard reference for scientific research; (B) educate park staff and visitors about the geoheritage significance of these units; and (C) help safeguard these exposures.
    a. The Triassic Gettysburg Shale was defined by Stose and Bascom (1929) for exposures at Gettysburg in southeastern Pennsylvania. Glaeser (1963) designated the composite type section as a series of measured sections in and around Gettysburg in the Gettysburg 7.5′ Quadrangle in Adams County, Pennsylvania, but provided no detailed information on the geology or location of any specific section. Due to the ambiguous nature of the measured section locations, we recommend that a detailed reference section of the Gettysburg Shale be designated.

4. For stratotypes designated external to an NPS area that may face destruction, alteration, or other significant impacts, GRD can work with park staff to potentially set up a reference section within an NPS area, which affords a baseline level of protection.
5. The NPS Geologic Resources Division should work with park, regional, 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 (after Brocx et al. 2019).
6. From the assessment in (5), the NPS Geologic Resources Division, the U.S. Geological Survey, state geologic surveys, academic geologists, and other partners 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 (after Brocx et al. 2019).
7. The NPS Geologic Resources Division should work with park, regional and network staff to:
    a. Compile, update, and maintain a central inventory of all designated stratotypes and potential future nominations. The USGS GEOLEX serves this function for the United States. This report is part of an effort to inventory stratotypes specific to National Park Service areas and eventually provide that data in a spatial, searchable format and integrate with GEOLEX.
    b. Establish appropriate monitoring protocols to regularly assess stratotype locations to identify any threats or impacts to these geologic heritage features in parks. See bullet points below for potential threats. Crofts et al. (2020) provides additional details on potential threats. Brocx et al. (2019) includes examples of destroyed stratotypes and suggests protocols for conservation in Australia. Criteria to access the stability of stratotype exposure sites should follow the guidance of the Unstable Slope Management Program (USMP) for federal land management agencies found here: https://highways.dot.gov/sites/fhwa.dot.gov/files/docs/federal-lands/tech-resources/31011/usmp-field-manual.pdf.
    c. Develop appropriate management actions based on significance of site and consideration of other resource management needs. See bullet points below for suggested management considerations.
    d. Obtain good photographs of each geologic stratotype within the parks. Photographs of each stratotype are rare and thus obtaining photographs of NPS stratotypes is a first step for resource management. 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 stratotypes. GPS locations should also be recorded and kept in a database when the photographs are taken.
    e. Consider the collection and curation of geologic samples (new or extant) from stratotypes within respective NPS areas. Samples collected from stratotype exposures

can be useful as reference specimens to support future studies, especially where stratotypes may be lost through natural processes or human activities.

f. Use selected robust internationally and nationally significant stratotypes as formal teaching/interpretation sites and for geotourism so that the importance of the national- and international-level assets are more widely (and publicly) known, using wayside panels, educational sites (on site or virtual), and walkways (after Brocx et al. 2019).

g. Develop conservation protocols of significant stratotypes, either by appropriate fencing, guard rails, trails, boardwalks, and information boards or other means (e.g., phone apps) (after Brocx et al. 2019).

Natural processes that have the potential to impact visibility, accessibility, or unaltered integrity of stratotypes include the following:

- Slope movements (e.g., rock falls, landslides)
- Erosion
- Vegetation encroachment (exotic, invasive, or native)
- Sea level rise (e.g., inundation and submersion)
- Tectonism and volcanism
- Climate change

Note that the rate, frequency, or severity of these natural processes will likely change as climate continues to change.

Human activities that have the potential to impact visibility, accessibility, or unaltered integrity of stratotypes include the following:

- Road, trail, or other infrastructure development that may remove or obscure stratotypes.
- Installation of guard rails, sprayed concrete (e.g., "Shotcrete" or gunite), wire mesh, rock bolts, or other cliff stabilization techniques.
- Restoration of a quarry or other abandoned site that was used as a stratotype location
- Graffiti, vandalism, or unauthorized fossil/mineral/rock collection
- Scientific research permits that include fossil/mineral/rock sampling or paleomagnetism coring.
- Visitor use (e.g., trails that cross stratotypes) can degrade stratotype integrity.

Potential resource management actions include the following:

- As general guidance, NPS Management Policies (section 4.8.2) states that "The Service will protect geologic features from the unacceptable impacts of human activity while allowing natural processes to continue" (National Park Service 2006).
- All stratotypes should, at minimum, be photographed at high resolution with a common object or scale bar included.
- Photogrammetry is an ideal documentation method for significant stratotypes.

- If obscuring or destruction of the outcrop is necessary for other resource management priorities (e.g., road/trail alterations, AML [Abandoned Mineral Lands] restoration [should consider stratotypes where possible], visitor safety concerns, natural rockfall or slope movement at/near the stratotype) photogrammetric documentation should be considered. Designation of a reference section at a less threatened or dangerous exposure is another possibility.
- If other geologic resources are present at the stratotype, such as fossils, significant minerals, or cave features, additional resource management and monitoring may be necessary. See for example Young and Norby (2009).
- Clear exotic or invasive vegetation from stratotypes or manage native vegetation to maximize visibility and accessibility.
- Utilize the Unstable Slope Monitoring Program (USMP) Tool to determine stability of stratotype exposure and potential hazards to human safety.
- For exceptionally significant stratotypes (international, national, or related to park fundamental purposes), consider utilizing them as formal interpretation or education sites (on site or virtual), or protecting them with fencing/guard rails, constructing boardwalks or trails to focus visitor access, or installing wayside panels.

Literature Cited

Bailey, C. M., K. M. Wooton, A. M. Forte, B. A. Hasty, L. A. Goldenbaum, and C. R. Shirvell. 2012. Geologic map of the Swift Run Gap Quadrangle, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. Publication 179. Scale 1:24,000. Available at: https://energy.virginia.gov/commerce/ProductDetails.aspx?productID=2645 (accessed August 19, 2022).

Blackburn, W. H., R. V. Metcalf, and P. C. Ragland. 1994. Geochemical evolution of the Precambrian Old Rag Granite, Virginia, USA: testing a U–Th exploration model. Chemical Geology 111:177–206.

Brocx, M., C. Brown, and V. Semeniuk. 2019. Geoheritage importance of stratigraphic type sections, type localities and reference sites—review, discussion and protocols for geoconservation. Australian Journal of Earth Sciences 66(6):823–836.

Crofts, R., J. E. Gordon, J. Brilha, M. Gray, J. Gunn, J. Larwood, V. L. Santucci, D. Tormey, and G. L. Worboys. 2020. Guidelines for geoconservation in protected and conserved areas. International Union for Conservation of Nature (IUCN), Gland, Switzerland. Best Practice Protected Area Guidelines Series 31. Available at: https://portals.iucn.org/library/node/49132 (accessed August 19, 2022).

Cuffey, R. J., J. D. Inners, G. M. Fleeger, R. C. Smith, II., J. C. Neubaum, R. C. Keen, L. Butts, H. L. Delano, V. A. Neubaum, and R. H. Howe. 2006. Geology of the Gettysburg battlefield: how Mesozoic events and processes impacted American history. Pages 1–16 *in* F. J. Pazzaglia, editor. Excursions in geology and history: field trips in the Middle Atlantic states. Geological Society of America, Boulder, Colorado. Field Guide 8.

Epstein, J. B., R. C. Orndorff, and E. K. Rader. 1995. Middle Ordovician Stickley Run Member (new name) of the Martinsburg Formation, Shenandoah Valley, northern Virginia. Pages 1–13 *in* Stratigraphic notes, 1994. U.S. Geological Survey, Reston, Virginia. Bulletin 2135. Available at: https://pubs.er.usgs.gov/publication/b2135 (accessed August 19, 2022).

Furcron, A. S. 1934. Igneous rocks of the Shenandoah National Park area. Journal of Geology 42(4):400–410.

Furcron, A. S. 1969. Late Precambrian and early Paleozoic erosional and depositional sequences of northern and central Virginia. Pages 57–88 *in* Precambrian-Paleozoic Appalachian problems. Georgia Department of Mines, Mining, and Geology, Georgia Geological Survey, Atlanta, Georgia. Bulletin 80.

Glaeser, J. D. 1963. Lithostratigraphic nomenclature of the Triassic Newark-Gettysburg basin. Pennsylvania Academy of Science Proceedings 37:179–188.

Gradstein, F. M., J. G. Ogg, M. D. Schmitz, and G. M. Ogg, editors. 2020. Geologic time scale 2020. Elsevier, Amsterdam, Netherlands.

Henderson, T., V. L. Santucci, T. Connors, and J. S. Tweet. 2020. National Park Service geologic type section inventory: Greater Yellowstone Inventory & Monitoring Network. Natural Resource Report NPS/GRYN/NRR—2020/2198. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2280034 (accessed August 2, 2022).

Jonas, A. I. 1928. Geological map of Virginia; preliminary edition. Virginia Geological Survey, Charlottesville, Virginia.

Jonas, A. I., and G. W. Stose. 1939. Age relation of the Precambrian rocks in the Catoctin Mountain-Blue Ridge and Mount Rogers anticlinoria in Virginia. American Journal of Science 237(8):575–593.

Keroher, G. C., and others. 1966. Lexicon of geologic names of the United States for 1936–1960. U.S. Geological Survey, Washington, D.C. Bulletin 1200. Available at: https://pubs.er.usgs.gov/publication/b1200 (accessed August 19, 2022).

King, P. B. 1950. Geology of the Elkton area, Virginia. U.S. Geological Survey, Washington, D.C. Professional Paper 230. Available at: https://pubs.er.usgs.gov/publication/pp230 (accessed August 19, 2022).

Lukert, M. T. 1982. Uranium-lead isotope age of the Old Rag Granite, northern Virginia. American Journal of Science 282:391–398.

National Park Service. 2006. National Park Service management policies. National Park Service, U.S. Department of the Interior, Washington, D.C. Available at: https://www.nps.gov/orgs/1548/upload/ManagementPolicies2006.pdf (accessed August 19, 2022).

National Park Service. 2016. National Parks Index: 2012–2016. Official index of the National Park Service. Available at: https://www.nps.gov/aboutus/upload/npindex2012-2016.pdf (accessed August 19, 2022).

National Park Service. 2018. Cedar Creek and Belle Grove National Historical Park, Virginia. National Park Service Foundation Document. Available at: http://www.npshistory.com/publications/foundation-documents/cebe-fd-2018.pdf (accessed August 19, 2022).

North American Commission on Stratigraphic Nomenclature. 2021. North American stratigraphic code. Stratigraphy 18(3):153–204. Available at: https://ngmdb.usgs.gov/Geolex/resources/docs/NACSN_Code_2021.pdf (accessed August 19, 2022).

Orndorff, R. C., J. B. Epstein, and R. C. McDowell. 1999. Geologic map of the Middletown Quadrangle, Frederick, Shenandoah and Warren Counties, Virginia. U.S. Geological Survey, Reston, Virginia. Geologic Quadrangle Map 1803. Scale 1:24,000. Available at: https://pubs.usgs.gov/gq/gq-1803/ (accessed August 19, 2022).

Southworth, S., J. N. Aleinikoff, C. M. Bailey, W. C. Burton, E. A. Crider, P. C. Hackley, J. P. Smoot, and R. P. Tollo. 2009a. Geologic map of the Shenandoah National Park region, Virginia. U.S. Geological Survey, Reston, Virginia. Open-File Report 2009-1153. Scale 1:100,000. Available at: https://pubs.usgs.gov/of/2009/1153/ (accessed August 19, 2022).

Southworth, S., L. S. Eaton, M. H. Lamoreaux, W. C. Burton, C. M. Bailey, G. Hancock, R. J. Litwin, and J. Whitten. 2009b. Geology of the Shenandoah National Park region. Virginia Geological Field Conference, Charlottesville, Virginia. Field Conference 39.

Southworth, S., J. N. Aleinikoff, R. P. Tollo, C. M. Bailey, W. C. Burton, P. C. Hackley, and C. M. Fanning. 2010. Mesoproterozoic magmatism and deformation in the northern Blue Ridge, Virginia and Maryland: application of SHRIMP U-Pb geochronology and integrated field studies in the definition of Grenvillian tectonic history. Pages 795–836 *in* R. P. Tollo, M. J. Bartholomew, J. P. Hibbard, and P. M. Karabinos, editors. From Rodinia to Pangea: the lithotectonic record of the Appalachian region: Geological Society of America, Boulder, Colorado. Memoir 206.

Stose, G. W., and F. Bascom. 1929. Fairfield-Gettysburg folio, Pennsylvania. U.S. Geological Survey, Washington, D.C. Folio of the Geologic Atlas 225. Available at: https://pubs.er.usgs.gov/publication/gf225 (accessed August 19, 2022).

Stose, G. W., and A. J. Stose. 1944. The Chilhowee group and Ocoee series of the southern Appalachians. American Journal of Science 242(8):401–416.

Thornberry-Ehrlich, T. L. 2009a. Appomattox Court House National Historical Park Geologic Resources Inventory Report. Natural Resource Report NPS/NRPC/GRD/NRR—2009/145. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/662746 (accessed August 19, 2022).

Thornberry-Ehrlich, T. L. 2009b. Gettysburg National Military Park and Eisenhower National Historic Site Geologic Resources Inventory Report. Natural Resource Report NPS/NRPC/GRD/NRR—2009/083. National Park Service, Denver, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/661529 (accessed August 19, 2022).

Thornberry-Ehrlich, T. L. 2010a. Booker T. Washington National Monument: Geologic Resources Inventory Report. Natural Resource Report NPS/NRPC/GRD/NRR—2010/234. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2164835 (accessed August 19, 2022).

Thornberry-Ehrlich, T. L. 2010b. Fredericksburg and Spotsylvania County Battlefields Memorial National Military Park: Geologic Resources Inventory Report. Natural Resource Report NPS/NRPC/GRD/NRR—2010/229. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2124945 (accessed August 19, 2022).

Thornberry-Ehrlich, T. L. 2010c. Hopewell Furnace National Historic Site: Geologic Resources Inventory Report. Natural Resource Report NPS/NRPC/GRD/NRR—2010/214. National Park Service, Ft. Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2124877 (accessed August 19, 2022).

Thornberry-Ehrlich, T. L. 2010d. Valley Forge National Historical Park: Geologic Resources Inventory Report. Natural Resource Report NPS/NRPC/GRD/NRR—2010/236. National Park Service, Ft. Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2164847 (accessed August 19, 2022).

Thornberry-Ehrlich, T. L. 2014. Shenandoah National Park: Geologic Resources Inventory Report. Natural Resource Report NPS/NRSS/GRD/NRR—2014/767. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2207690 (accessed August 19, 2022).

Wilmarth, M. G. 1938. Lexicon of geologic names of the United States (including Alaska). U.S. Geological Survey, Washington, D.C. Bulletin 896. Available at: https://pubs.er.usgs.gov/publication/b896 (accessed August 19, 2022).

Young, R., and L. Norby, editors. 2009. Geological monitoring. Geological Society of America, Boulder, Colorado.

Appendix A: Source Information for GRI Maps of MIDN Parks

GMAP = Unique identifier assigned to geologic source maps by the GRI program.

The GRI program converted these source maps to the GRI digital geologic map data for each park. GRI data sets are available at their publications page: https://www.nps.gov/subjects/geology/geologic-resources-inventory-products.htm. For information on how source maps are converted and what the GRI data model includes, refer to the GRI data models here: https://irma.nps.gov/DataStore/Reference/Profile/2259192.

APCO

- GMAP 7294: Virginia Division of Mineral Resources. 2003. Digital representation of the 1993 geologic map of Virginia. Virginia Division of Mineral Resources, Charlottesville, Virginia. Publication 174. Scale 1:500,000. Available at: https://energy.virginia.gov/commerce/ProductDetails.aspx?productID=1286 (accessed August 19, 2022).

BOWA

- GMAP 2395: Henika, W. S. 1997. Geologic map of the Roanoke 30 x 60 Minute Quadrangle. Virginia Division of Mineral Resources, Charlottesville, Virginia. Publication 148. Scale 1:100,000. Available at: https://energy.virginia.gov/commerce/ProductDetails.aspx?productID=1437 (accessed August 19, 2022).
- GMAP 74611: Henika, W. S. 2001. Digital spatial data for a portion of the Roanoke, Virginia 1:100,000 30 x 60′ Quadrangle—Hardy, Goodview, Redwood, Moneta SW 7.5′ Quadrangles. Unpublished. Scale 1:100,000.

EISE and GETT

- GMAP 7256: Stose, G. W., and F. Bascom. 1929. Fairfield-Gettysburg folio, Pennsylvania. U.S. Geological Survey, Washington, D.C. Folio of the Geologic Atlas 225. Scale 1:62,500. Available at: https://pubs.er.usgs.gov/publication/gf225 (accessed August 19, 2022).
- GMAP 74480: Stose, G. W. 1929. Fairfield-Gettysburg folio, Pennsylvania: structure sections of the Fairfield Quadrangle. U.S. Geological Survey, Washington, D.C. Folio of the Geologic Atlas 225. Scale 1:62,500. Available at: https://pubs.er.usgs.gov/publication/gf225 (accessed August 19, 2022).
- GMAP 7257: Stose, G. W. 1929. Fairfield-Gettysburg folio, Pennsylvania: economic geology of the Gettysburg Quadrangle. U.S. Geological Survey, Washington, D.C. Folio of the Geologic Atlas 225. Scale 1:62,500. Available at: https://pubs.er.usgs.gov/publication/gf225 (accessed August 19, 2022).
- GMAP 74481: Stose, G. W. 1929. Fairfield-Gettysburg folio, Pennsylvania: structure sections of the Gettysburg Quadrangle. U.S. Geological Survey, Washington, D.C. Folio of the Geologic Atlas 225. Scale 1:62,500. Available at: https://pubs.er.usgs.gov/publication/gf225 (accessed August 19, 2022).

FRSP

- GMAP 2540: Mixon, R. B., L. Pavlides, D. S. Powars, A. J. Froelich, R. E. Weems, J. S. Schindler, W. L. Newell, L. E. Edwards, and L. W. Ward. 2000. Geologic map of the Fredericksburg 30′ x 60′ Quadrangle, Virginia and Maryland. U.S. Geological Survey, Reston, Virginia. Geologic Investigations Series Map 2607. Scale 1:100,000. Available at: https://pubs.er.usgs.gov/publication/i2607 (accessed August 19, 2022).

HOFU and VAFO

- GMAP 74890: Berg, T. M., W. E. Edmunds, A. R. Geyer, A. D. Glover, D. M. Hoskins, D. B. MacLachlan, S. I. Root, W. D. Sevon, and A. A. Socolow, compilers. 1980. Geologic map of Pennsylvania. Pennsylvania Geological Survey, Harrisburg, Pennsylvania. Map 1. Scale 1:250,000. Available at: https://maps.dcnr.pa.gov/publications/Default.aspx?id=712 (accessed August 19, 2022).

PETE

- GMAP 76287: Occhi, M. E., C. R. Berquist, V. M. Latane, and J. M. Blanchette. 2018. Geologic map of the Petersburg National Battlefield and adjacent areas, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. Unpublished map and digital data. Scale 1:24,000.
- GMAP 2430: Dischinger, J. B. 1987. Late Mesozoic and Cenozoic stratigraphic and structural framework near Hopewell, Virginia. U.S Geological Survey, Washington, D.C. Bulletin 1567. Scale 1:24,000. Available at: https://pubs.er.usgs.gov/publication/b1567 (accessed August 19, 2022).

RICH

- GMAP 2877: Daniels, P. A. Jr., and F. E. May. 1974. Geology of the Studley, Yellow Tavern, Richmond and Seven Pines Quadrangles, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. Report of Investigations 38. Plate 1. Scale 1:24,000. Available at: https://energy.virginia.gov/commerce/ProductDetails.aspx?productID=2185 (accessed August 19, 2022).
- GMAP 75760: Bondurant, A. K., H. A. Bleick, C. R. Berquist, Jr., and M. W. Carter. 2011. Geologic map of the Seven Pines Quadrangle, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. Open-File Report 11-15. Scale 1:24,000. Available at: https://energy.virginia.gov/commerce/ProductDetails.aspx?productID=3045 (accessed August 19, 2022).
- GMAP 75761: Bleick, H. A., M. W. Carter, and C. R. Berquist. 2007. Geologic map of the Richmond Quadrangle, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. 2006 STATEMAP Deliverable, unpublished map and digital data. Scale 1:24,000.
- GMAP 75762: Gilmer, A. K., and C. R. Berquist. 2011. Geologic map of the Roxbury Quadrangle, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. 2011 STATEMAP Deliverable, unpublished map and digital data. Scale 1:24,000.

- GMAP 75763: Berquist, C. R., and M. W. Carter. 2009. Geologic map of the Dutch Gap Quadrangle, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. 2008 STATEMAP Deliverable, unpublished map and digital data. Scale 1:24,000.
- GMAP 75764: Bondurant, A. K. et al. 2011. Geologic map of the Drewrys Bluff Quadrangle, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. 2011 STATEMAP Deliverable, unpublished map and digital data. Scale 1:24,000.
- GMAP 76134: Occhi, M. E., J. S. Blanchette, and C. R. Berquist, Jr. 2017. Geologic map of the Chester Quadrangle, Virginia. Virginia Division of Geology and Mineral Resources, Charlottesville, Virginia. 2017 STATEMAP Deliverable, unpublished map and digital data. Scale 1:24,000.

SHEN

- GMAP 75180: Southworth, S., . N. Aleinikoff, C. M. Bailey, W. C. Burton, E. A. Crider, P. C. Hackley, J. P. Smoot, and R. P. Tollo. 2009. Geologic map of the Shenandoah National Park region, Virginia. U.S. Geological Survey, Reston, Virginia. Open-File Report 2009-1153. Scale 1:100,000. Available at: https://pubs.usgs.gov/of/2009/1153/ (accessed August 19, 2022).

Appendix B: Geologic Time Scale

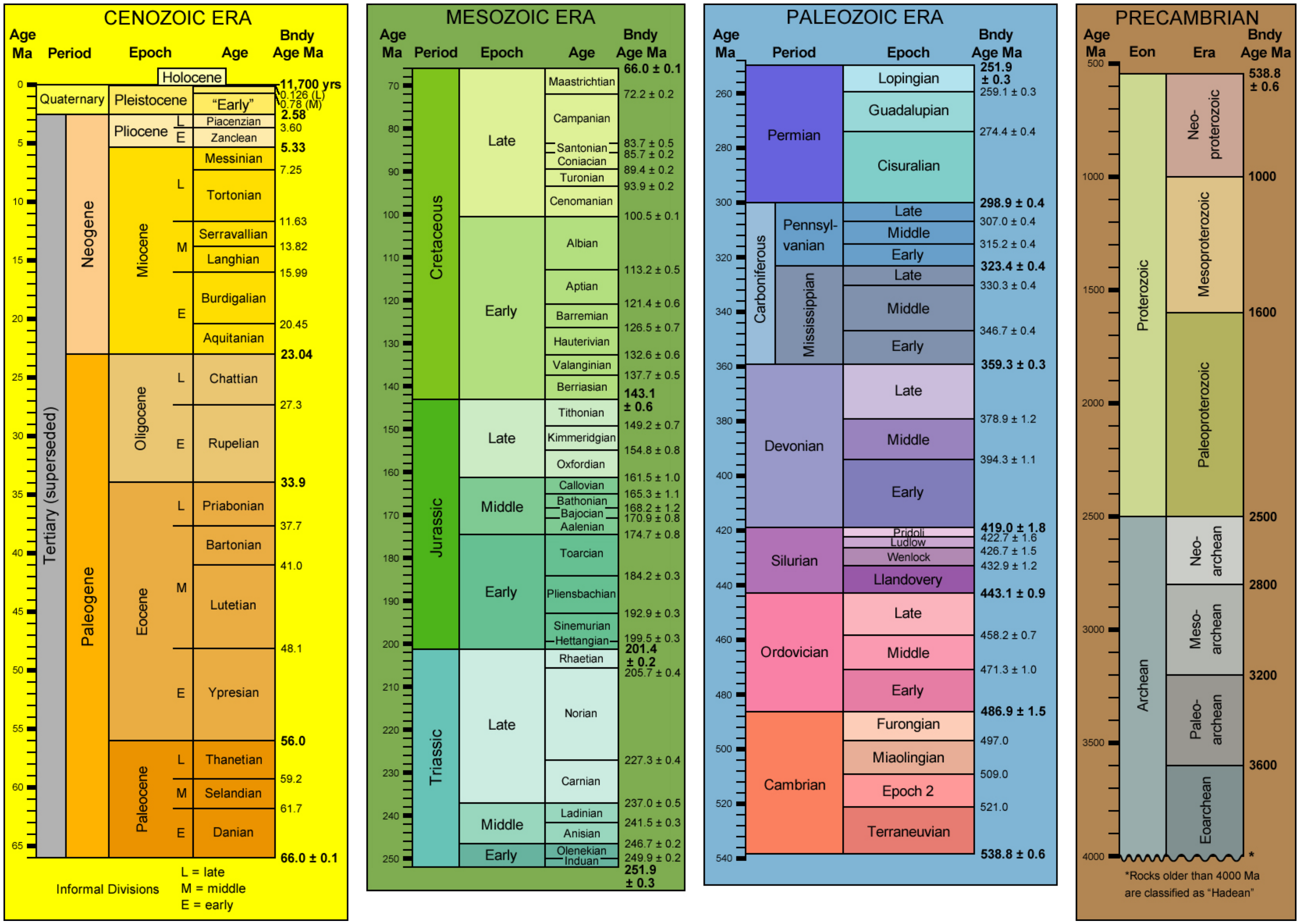


Figure B1. Geologic Time Scale. Ma=Millions of years old. Bndy Age=Boundary Age. Layout after 1999 Geological Society of America Time Scale (https://www.geosociety.org/documents/gsa/timescale/timescl-1999.pdf). Dates after Gradstein et al. (2020).

Appendix C: Stratotypes Located Within 48 km (30 mi) of MIDN Parks

APCO

- Mesoproterozoic
  - Lovingston Granite Gneiss (now Lovingston massif) (type area)
  - Archer Mountain Suite (type locality)
- Neoproterozoic
  - Rockfish Conglomerate (type locality)
  - Ball Mountain Formation (type locality)
  - Lynchburg Group (type locality)
- Ordovician
  - Arvonia Formation (type section)

BOWA

- Mesoproterozoic
  - Stewarts Knob Gneiss (type locality)
- Neoproterozoic–Cambrian
  - Fork Mountain Formation (type area)
- Cambrian
  - Waynesboro Formation (reference section)
- Triassic
  - Dry Fork Formation (type section)

CEBE

- Mesoproterozoic
  - Flint Hill Gneiss (type locality)
  - Marshall Metagranite (type area)
- Neoproterozoic
  - Amissville Alkali Feldspar Granite (type locality)
  - Battle Mountain Alkali Feldspar Granite (type locality)
  - Cobbler Mountain Alkali Feldspar Quartz Syenite (type locality)
  - Laurel Mills Granite (type locality)
  - Mechum River Formation, Blackwater Creek Rhyolite Member (type locality)
- Ordovician
  - Edinburg Formation (type locality)

  - Edinburg Formation, St. Luke Member (type locality)
  - New Market Limestone (type section)
- Silurian
  - Massanutten Sandstone (type locality)

EISE and GETT

- Cambrian
  - Waynesboro Formation (type locality)
  - Waynesboro Formation, Red Run Member (type section)
  - Waynesboro Formation, Cavetown Member (type section)
  - Waynesboro Formation, Chewsville Member (type section)
  - Elbrook Limestone (type area)
  - Tomstown Formation (type locality)
  - Tomstown Formation, Benevola Member (type section)
  - Antietam Formation (type locality)
  - Weverton Formation, Owens Creek Member (type section)
  - Weverton Formation, Buzzard Knob Member (type section)
- Cambrian–Ordovician
  - Conococheague Limestone (type section and type locality)
- Ordovician
  - Stonehenge Limestone (type section and reference section)
  - Stonehenge Limestone, Stoufferstown Member (type section)
  - Conestoga Limestone (type locality)
- Devonian
  - Old Port Formation (type section)
- Triassic
  - New Oxford Formation (type section)
  - Gettysburg Shale, Heidlersburg Member (type section)
  - Gettysburg Shale, Conewago Conglomerate Member (type section)
  - York Haven Diabase (type locality) (GETT only)

FRSP

- Neoproterozoic
  - Mechum River Formation, Blackwater Creek Rhyolite Member (type locality)
  - Amissville Alkali Feldspar Granite (type locality)

    - Arrington Mountain Alkali Feldspar Granite (type locality)
    - Battle Mountain Alkali Feldspar Granite (type locality)
    - Hitt Mountain Alkali Feldspar Granite (type locality)
    - Laurel Mills Granite (type locality)
    - White Oak Alkali Feldspar Granite (type locality)
- Neoproterozoic–Cambrian
    - Garrisonville Mafic Complex (type locality)
    - Holly Corner Gneiss (type area)
    - Po River Metamorphic Suite (type area)
    - Tomahawk Creek Formation (type area)
- Cambrian
    - Nasons Formation (type area)
- Cambrian–Ordovician
    - True Blue Formation (type locality)
    - True Blue Formation, Everona Member (type locality)
- Ordovician
    - Chopawamsic Formation (type section)
    - Ta River Metamorphic Suite (type area)
- Silurian
    - Falls Run Granite (type area)
- Mississippian–Pennsylvanian
    - Falmouth Intrusive Suite (type area)
- Triassic
    - Manassas Sandstone, Rapidan Member (type section)
    - Tibbstown Formation, Mountain Run Member (type section)
    - Doswell Formation (type section)
    - Doswell Formation, Falling Creek Member (type section)
- Paleocene
    - Aquia Formation (type locality and principal reference section)
    - Aquia Formation, Paspotansa Member (type section)
    - Aquia Formation, Piscataway Member (type section)
- Eocene
    - Nanjemoy Formation, Woodstock Member (principal reference section)
    - Nanjemoy Formation, Potapaco Member (type area)

- Miocene
    - Calvert Formation, Popes Creek Sand Member (type section)

HOFU

- Cambrian
    - Richland Formation (type locality)
    - Millbach Formation (type section)
    - Buffalo Springs Formation (type section)
    - Zooks Corner Formation (type section)
    - Kinzers Formation (type locality)
- Ordovician
    - Ontelaunee Formation (type section)
    - Rickenbach Formation (type section)
    - Stonehenge Limestone (2 reference sections)
    - Epler Formation (type section)
- Triassic
    - Hammer Creek Formation (type section)

PETE

- Eocene
    - Piney Point Formation (reference section)
- Oligocene
    - Old Church Formation (principal reference section)
- Miocene
    - Eastover Formation (type section)
    - Eastover Formation, Cobham Bay Member (type section)
    - Eastover Formation, Claremont Manor Member (type section)
- Pliocene
    - Bacons Castle Formation (type section)
    - Bacons Castle Formation, Barhamsville Member (type section)
    - Yorktown Formation, Sunken Meadow Member (type section)
- Pleistocene
    - Charles City Alloformation (type section)
    - Elsing Green Alloformation (type section)
    - Shirley Alloformation (type section)

RICH

- Neoproterozoic–Cambrian
  - Po River Metamorphic Suite (type area)
  - Holly Corner Gneiss (type area)
- Ordovician
  - Ta River Metamorphic Suite (type area)
- Mississippian–Pennsylvanian
  - Falmouth Intrusive Suite (type area)
- Triassic
  - Doswell Formation (type section)
  - Doswell Formation, Falling Creek Member (type section)
- Eocene
  - Piney Point Formation (reference section)
- Oligocene
  - Old Church Formation (principal reference section)
- Miocene
  - Eastover Formation (type section)
  - Eastover Formation, Claremont Manor Member (type section)
- Pliocene
  - Bacons Castle Formation (type section)
  - Bacons Castle Formation, Barhamsville Member (type section)
  - Yorktown Formation, Sunken Meadow Member (type section)
- Pleistocene
  - Shirley Alloformation (type section)
  - Charles City Alloformation (type section)
  - Elsing Green Alloformation (type section)

SHEN

- Mesoproterozoic
  - Pedlar River Charnockite Suite (type section)
  - Archer Mountain Suite (type locality)
  - Lovingston Granite Gneiss (type area)
  - Flint Hill Gneiss (type locality)
  - Marshall Metagranite (type area)

- Neoproterozoic
  - Amissville Alkali Feldspar Granite (type locality)
  - Arrington Mountain Alkali Feldspar Granite (type locality)
  - Battle Mountain Alkali Feldspar Granite (type locality)
  - Cobbler Mountain Alkali Feldspar Quartz Syenite (type locality)
  - Hitt Mountain Alkali Feldspar Granite (type locality)
  - Laurel Mills Granite (type locality)
  - Rivanna Granite (type locality)
  - White Oak Alkali Feldspar Granite (type locality)
  - Swift Run Formation (reference section)
  - Charlottesville Formation (type locality)
  - Rockfish Conglomerate (type locality)
  - Mechum River Formation, Blackwater Creek Rhyolite Member (type locality)
  - Ball Mountain Formation (type locality)
  - Ball Mountain Formation, Johnson Mill Member (type locality)
- Neoproterozoic–Cambrian
  - Tomahawk Creek Formation (type area)
- Cambrian
  - Nasons Formation (type area)
- Cambrian–Ordovician
  - True Blue Formation (type locality)
  - True Blue Formation, Everona Member (type locality)
- Ordovician
  - Edinburg Formation (type locality)
  - Edinburg Formation, St. Luke Member (type locality)
  - New Market Limestone (type section)
- Silurian
  - Massanutten Sandstone (type locality)
- Triassic
  - Manassas Sandstone, Rapidan Member (type section)
  - Tibbstown Formation, Mountain Run Member (type section)
- Triassic–Jurassic
  - Catharpin Creek Formation (type section)

VAFO

- Ordovician
  - Stonehenge Formation (reference section),
- Triassic
  - Lockatong Formation (type section)
- Miocene
  - Kirkwood Formation, Grenloch Sand Member (type area)

The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 956/184079, September 2022

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525