National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

National Park Service Geologic Type Section Inventory

Northeast Coastal and Barrier Inventory & Monitoring Network

Natural Resource Report NPS/NCBN/NRR—2021/2287

ON THE COVER

Lithified shelly sands of the type section bluff exposure of the Pliocene Moore House Member of the Yorktown Formation along the southern bank of the York River, Colonial National Historic Park, Virginia. Photo courtesy of Mackenzie Chriscoe.

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

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

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

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

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Executive Summary

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

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

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

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

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

The goal of this project is to consolidate information pertaining to geologic type sections 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 landmarks and geologic heritage resources. The review of stratotype occurrences for the NCBN shows there are currently no designated stratotypes for ASIS, CACO, FIIS, GATE, GEWA, SAHI, and THST; COLO has one type section.

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

Acknowledgments

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

We 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 interns and other ventures. 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 Coastal and Barrier Inventory and Monitoring Network and various network parks, including Sara Nerone and Dennis Skidds (NCBN); Bill Hulslander (ASIS); Geoff Sanders (CACO); Dorothy Geyer (COLO); Mike Bielecki (FIIS); Patricia Rafferty (GATE); Melissa Cobern (GEWA); and David Lassman (THST). Additional thanks go to Carmen Chapin and Seth Lerman for their continued support for this and other important geology projects in the Northeast Region of the NPS (DOI Unified Region 1); Rowan Lockwood and Rick Berquist, Jr. (William & Mary University); Mackenzie Chriscoe (William & Mary University; NPS intern); Norbert Psuty (Rutgers University); and Stephen Godfrey (Calvert Marine Museum).

This project is possible through the support from research associates and staff in the National Park Service Geologic Resources Division and we extend our thanks to Hal Pranger, Julia Brunner, Jason Kenworthy, Rebecca Beavers, and Jim Wood.

Dedication

This Northeast Coastal and Barrier Inventory and Monitoring Network Geologic Type Section Inventory is dedicated to Carmen Chapin (Chief of Natural Resources) and Seth Lerman (Natural Resources Support Coordinator) from Interior Region 1—North Atlantic Appalachian. We recognize and appreciate the valuable support from Carmen and Seth for geology and paleontology issues in the national parks within the parks of the North Atlantic Appalachian Region.

Carmen Chapin

Seth Lerman

Introduction

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

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

The goals of this project are to (1) systematically report the assigned stratotypes that occur within national park boundaries, (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. Additionally, numerous stratotypes are located geographically outside of national park boundaries, but only those within 48 km (30 mi) of park boundaries will be presented in this report.

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

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

- Geologic stratotypes are a part of our national geologic heritage and are a cornerstone of the scientific value used to define the societal significance of geoheritage sites (https://www.nps.gov/articles/scientific-value.htm);
- Geologic stratotypes are important geologic landmarks and reference locations that define important scientific information associated with geologic strata. Geologic formations are commonly named after topographic or geologic features and landmarks that are recognizable to park staff;
- Geologic stratotypes are both historically and scientifically important components of earth science investigations and mapping;
- Understanding and interpretation of the geologic record depends upon the stratigraphic occurrences of mappable lithologic units (formations, members). These geologic units are the foundational attributes of geologic maps;
- Geologic maps are important tools for science, resource management, land use planning, and other areas and disciplines;
- Geologic stratotypes are similar in nature to type specimens in biology and paleontology, serving as a "gold standard" which helps to define characteristics used in classification;
- Geologic stratotypes within NPS areas have not been previously inventoried and there is a general absence of baseline information for this geologic resource category;
- In general, NPS staff in parks are not aware of the concept of geologic type sections and therefore may not understand the significance or occurrence of these natural landmarks in parks;
- Given the importance of geologic stratotypes as geologic references and geologic heritage resources, these locations should be afforded some level of preservation or protection when they occur within NPS areas;
- If NPS staff are unaware of geologic type sections within parks, the NPS would not proactively monitor the stability, condition, or potential impacts to these locations during normal park operations or planning. The lack of baseline information pertaining to the geologic type sections in parks is detrimental to the protection of these localities from activities which may involve ground disturbance or construction. Therefore, consideration needs to be given about how the NPS may preserve geologic type sections and better inform NPS staff about their existence in the park;
- 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, the hope is there will be an increased awareness about these important geologic landmarks in parks. In turn, the awareness of these resources and their significance may be recognized in park planning and operations, to ensure that geologic stratotypes are preserved and available for future study.

Geology and Stratigraphy of the NCBN I&M Network Parks

The Northeast Coastal and Barrier Network (NCBN) consists of eight national park units along the eastern coast of Maryland, Massachusetts, New Jersey, New York, and Virginia (Figure 1). Assateague Island National Seashore (ASIS), Cape Cod National Seashore (CACO), Colonial National Historical Park (COLO), Fire Island National Seashore (FIIS), Gateway National Recreation Area (GATE), George Washington Birthplace National Monument (GEWA), Sagamore Hill National Historic Site (SAHI), and Thomas Stone National Historic Site (THST) span the northeast and mid-Atlantic Coastal Plain from Massachusetts in the north, to Virginia in the south. The geographic distribution and low elevations of the NCBN parks along the Atlantic Ocean place the network parks in the path of Atlantic storms and hurricanes, especially resources associated with the barrier islands and seashores. Geologically, the NCBN are largely represented by surficial deposits with limited exposures of Cenozoic bedrock (see Appendix B for a geologic time scale). Consequently, only one geologic type section is identified for the parks of the NCBN.

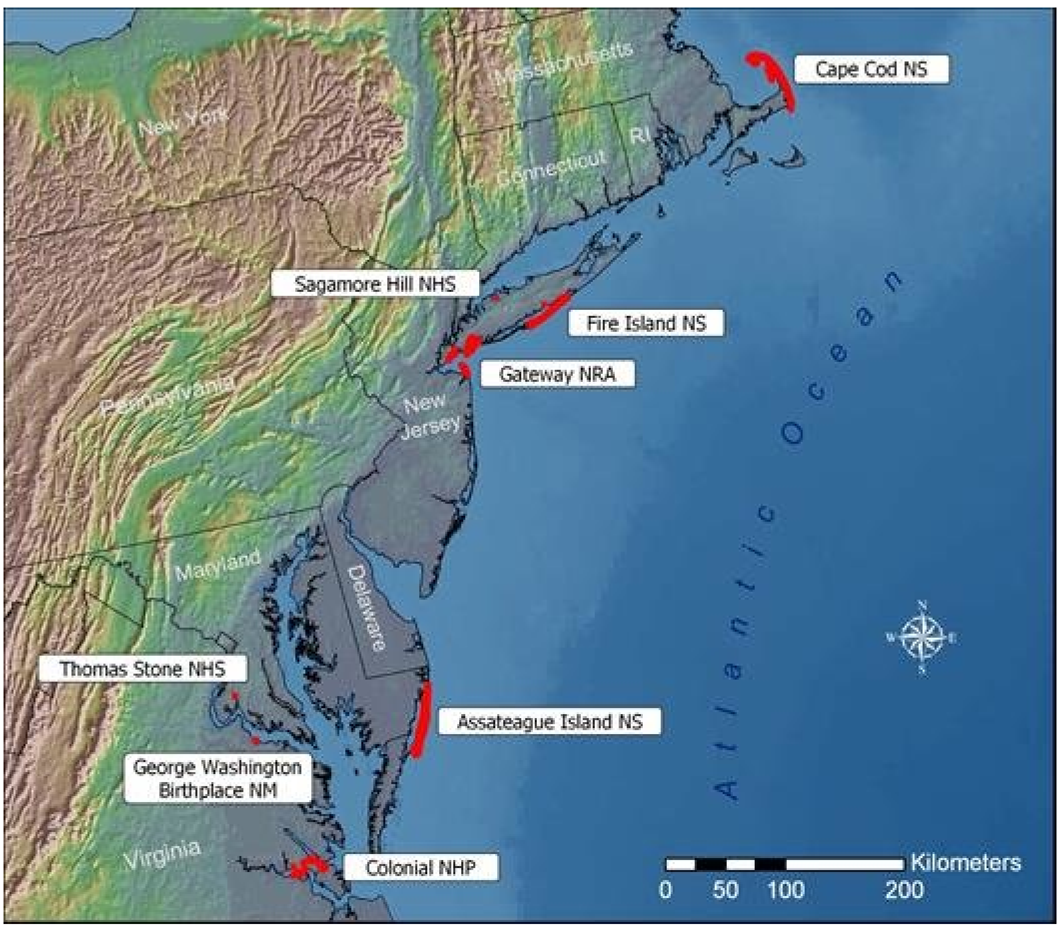


Figure 1. Distribution of Northeast Coastal and Barrier I&M Network parks, including Assateague Island National Seashore (ASIS), Cape Cod National Seashore (CACO), Colonial National Historical Park (COLO), Fire Island National Seashore (FIIS), Gateway National Recreation Area (GATE), George Washington Birthplace National Monument (GEWA), Sagamore Hill National Historic Site (SAHI), and Thomas Stone National Historic Site (THST) (NPS).

Precambrian

No Precambrian rocks are exposed at the surface within any of the NCBN parks.

Paleozoic

No Paleozoic rocks are exposed at the surface within any of the NCBN parks.

Mesozoic

No Mesozoic rocks are exposed at the surface within any of the NCBN parks. Late Cretaceous coastal sediments are mapped subsurface (Raritan Formation) at SAHI.

Cenozoic

The oldest Cenozoic unit exposed within the NCBN is the early Eocene Nanjemoy Formation, a shallow marine deposit exposed in THST. The early–middle Miocene Calvert Formation is exposed in several of the mid-Atlantic parks including GATE, GEWA and THST. The late Miocene Eastover Formation, a shallow marine unit, is exposed in COLO. The Pliocene Yorktown and Cold Harbor Formations are also exposed at COLO.

In the NCBN, several Pleistocene map units in Virginia's Coastal Plain are referred to as alloformations, defined as sedimentary sequences bound by unconformities resulting from erosion during sea level lowstand and deposition within drainages during marine transgressions (sea level rise). Alloformations typically have a gravelly or coarse base possibly overlain by marsh or swamp sediments, overlain by sand and clay (R. Berquist, William & Mary University, pers. comm., 2021). Alloformations and formations may be used or understood as lithologic map units similarly.

Surficial Quaternary and Holocene units occur in most of the NCBN parks. However, most of these units are not formally named. A few named Pleistocene formations or alloformations are mapped in several parks, including the Bacons Castle Formation, Windsor Formation, Charles City Alloformation, Chuckatuck Alloformation, Shirley Alloformation, Elsing Green Alloformation, and Tabb Alloformation at COLO and late Pleistocene Tabb Alloformation at GEWA. The late Pleistocene Sinepuxent Formation occurs in the subsurface at ASIS.

National Park Service Geologic Resource Inventory

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

GRI Products

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

Scoping meetings bring together park staff and geologic experts to review and assess available geologic maps, develop a geologic mapping plan, and discuss geologic features, processes, and resource management issues that should be addressed in the GRI report. Scoping sessions were held on the following dates for the NCBN parks: GEWA on July 25, 2005; THST on July 26, 2005; ASIS on July 26–28, 2005; COLO on August 1, 2005; CACO on June 12–13, 2008; GATE on June 21, 2010; SAHI on June 23, 2010; and FIIS on June 24, 2010.

Following the scoping meeting, the GRI map team converts the geologic maps identified in the mapping plan to GIS data in accordance with the GRI data model. After the map is completed, the GRI report team uses these data, as well as the scoping summary and additional research, to prepare the GRI report. As of 2021, GRI reports have been completed for ASIS, COLO, GEWA, and THST. The GRI team conducts no new field work in association with their products.

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

Geologic Map Data

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

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

Geologic Maps

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

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

Source Maps

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

GRI GIS Data

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

GRI GIS data are available on the GRI publications website (https://www.nps.gov/subjects/geology/geologic-resources-inventory-products.htm) and through the NPS Integrated Resource Management Applications (IRMA) Data Store portal (https://irma.nps.gov/DataStore/Search/Quick). Enter "GRI" as the search text and select ASIS, CACO, COLO, FIIS, GATE, GEWA, SAHI, or THST from the unit list.

The following components are part of the data set:

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

GRI Map Posters

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

Use Constraints

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

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

Methods

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

There are a number of considerations to be addressed throughout this inventory. The most up-to-date information available is necessary, either found online or in published articles and maps. Occasionally, there is a lack of specific information that limits the information contained in the final report. 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 transcend state boundaries. Geologic formations and other units that cross state boundaries may be referenced with different names in each of the states where the units are mapped. An example would be the Triassic Chugwater Formation in Wyoming, which is equivalent to the Spearfish Formation in the Black Hills of South Dakota.

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

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

Methodology

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

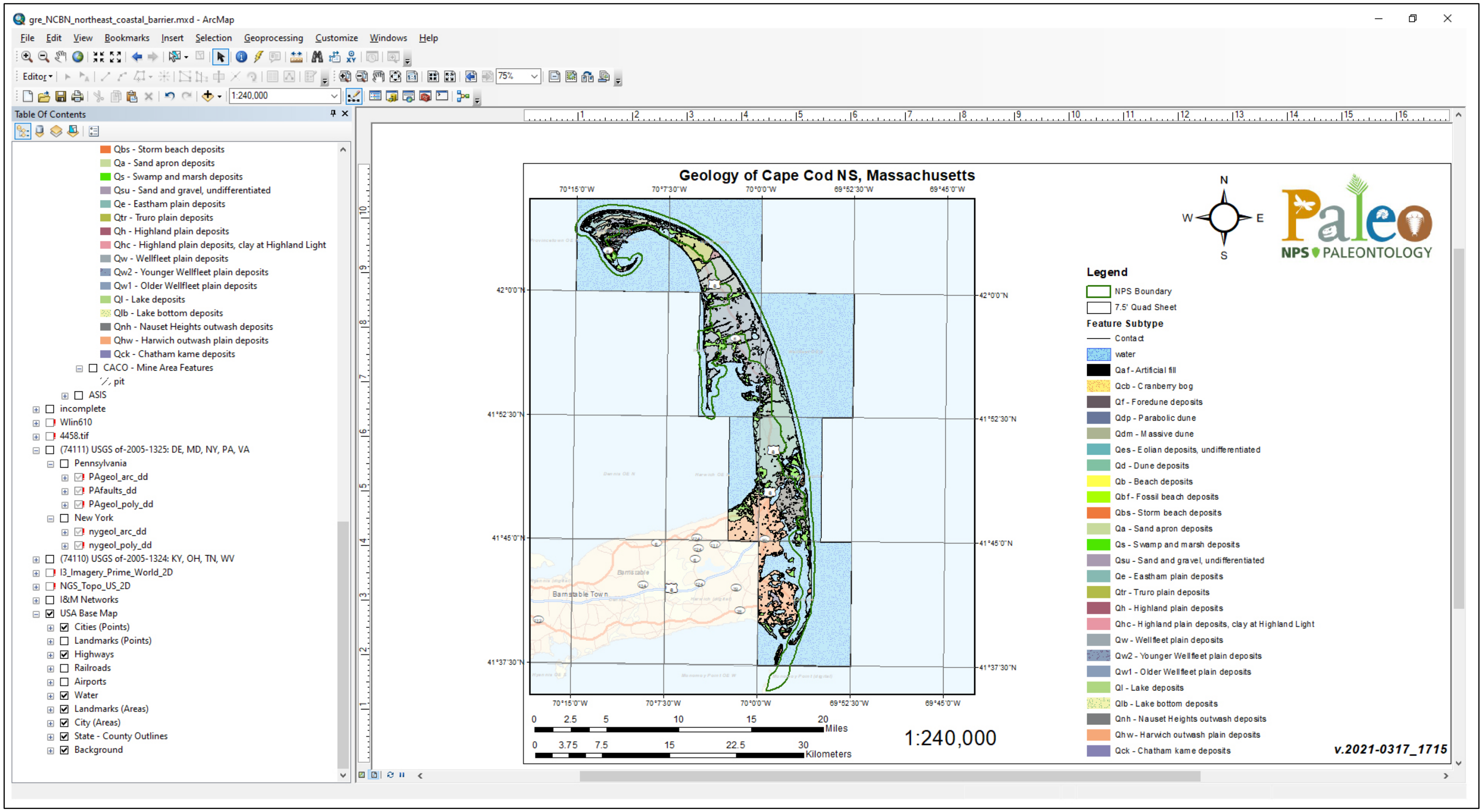


Figure 2. Screenshot of digital geologic map of Cape Cod National Seashore showing mapped units.

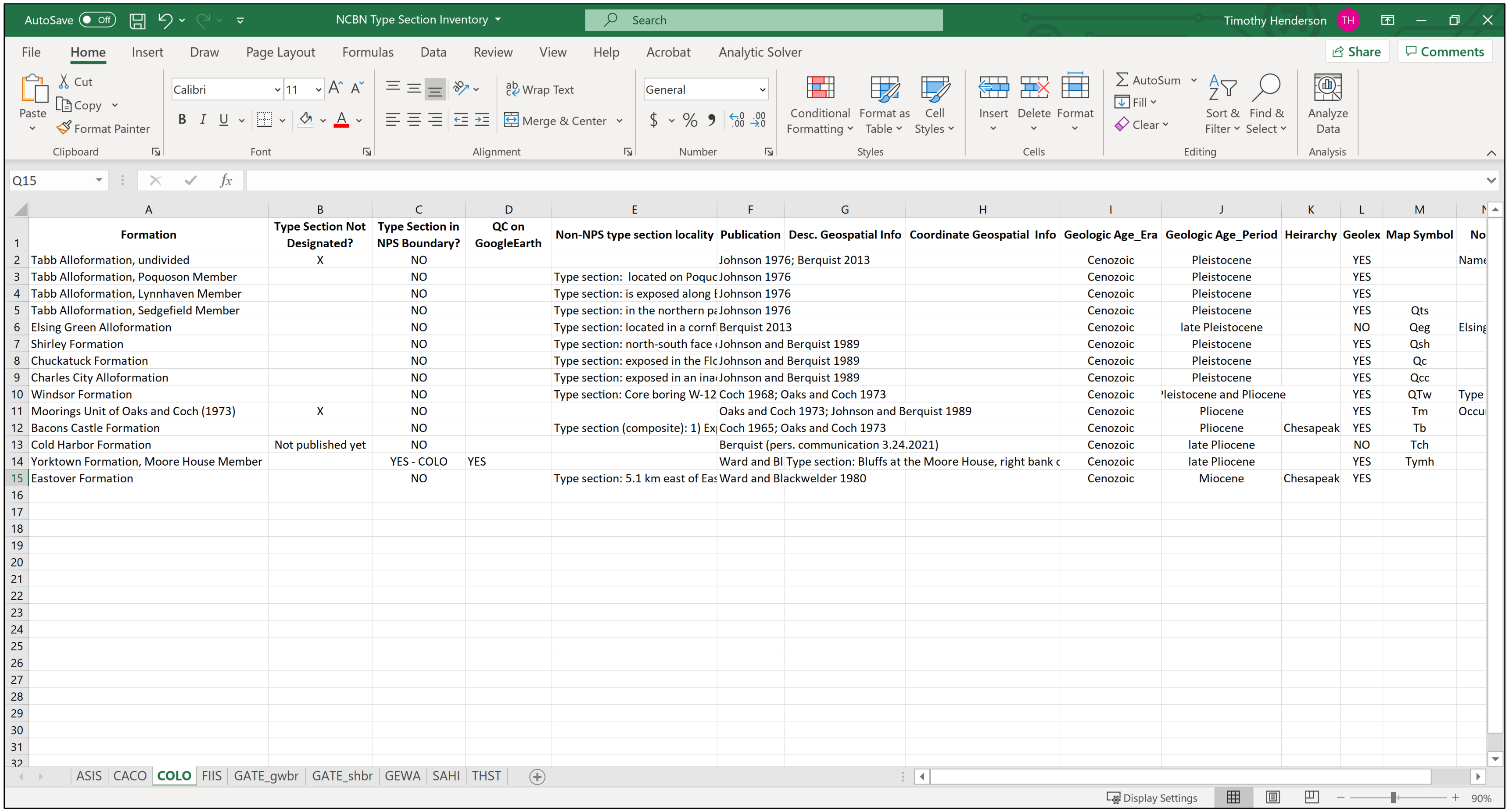
Each map unit name is then queried in the U.S. Geologic Names Lexicon online database ("GEOLEX", a national compilation of names and descriptions of geologic units) at https://ngmdb.usgs.gov/Geolex/search. Information provided by GEOLEX includes unit name, stratigraphic nomenclature usage, geologic age,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

Figure 3. GEOLEX search result for the Moore House Member of the Yorktown Formation.

Published GEOLEX stratotype spatial information is provided in three formats: (1) descriptive, using distance from nearby points of interest; (2) latitude and longitude coordinates; or (3) Township/Range/Section (TRS) coordinates. TRS coordinates are based on subdivisions of a single 93.2 km^2 (36 mi^2) township into 36 individual 2.59 km^2 (1 mi^2) sections, and were converted into

Google Earth (.kmz file) locations using Earth Point (https://www.earthpoint.us/TownshipsSearchByDescription.aspx). The most accurate GEOLEX descriptions using TRS coordinates can help locate features within 0.1618 km^2 (0.0625 mi^2). Once stratotype locality information provided for a given unit is geolocated using Google Earth, a GRI digital geologic map of the national park is draped over it. This step serves two functions: to improve accuracy in locating the stratotype, and validating the geologic polygon for agreement with GEOLEX nomenclature. Geolocations in Google Earth are then converted into an ArcGIS format using a "KML to Layer" conversion tool in ArcMap.

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



	Formation	Type Section Not Designated?	Type Section in NPS Boundary?	QC on GoogleEarth	Non-NPS type section locality	Publication	Desc. Geospatial Info	Coordinate Geospatial Info	Geologic Age_Era	Geologic Age_Period	Heirarchy	Geolex	Map Symbol	No
2	Tabb Alloformation, undivided	X	NO			Johnson 1976; Berquist 2013			Cenozoic	Pleistocene		YES		Name
3	Tabb Alloformation, Poquoson Member		NO		Type section: located on Poquc	Johnson 1976			Cenozoic	Pleistocene		YES		
4	Tabb Alloformation, Lynnhaven Member		NO		Type section: is exposed along E	Johnson 1976			Cenozoic	Pleistocene		YES		
5	Tabb Alloformation, Sedgefield Member		NO		Type section: in the northern pa	Johnson 1976			Cenozoic	Pleistocene		YES	Qts	
6	Elsing Green Alloformation		NO		Type section: located in a cornfi	Berquist 2013			Cenozoic	late Pleistocene		NO	Qeg	Elsing
7	Shirley Formation		NO		Type section: north-south face (	Johnson and Berquist 1989			Cenozoic	Pleistocene		YES	Qsh	
8	Chuckatuck Formation		NO		Type section: exposed in the Flc	Johnson and Berquist 1989			Cenozoic	Pleistocene		YES	Qc	
9	Charles City Alloformation		NO		Type section: exposed in an ina	Johnson and Berquist 1989			Cenozoic	Pleistocene		YES	Qcc	
10	Windsor Formation		NO		Type section: Core boring W-12	Coch 1968; Oaks and Coch 1973			Cenozoic	Pleistocene and Pliocene		YES	QTw	Type
11	Moorings Unit of Oaks and Coch (1973)	X	NO			Oaks and Coch 1973; Johnson and Berquist 1989			Cenozoic	Pliocene		YES	Tm	Occu
12	Bacons Castle Formation		NO		Type section (composite): 1) Ex	Coch 1965; Oaks and Coch 1973			Cenozoic	Pliocene	Chesapeak	YES	Tb	
13	Cold Harbor Formation	Not published yet	NO			Berquist (pers. communication 3.24.2021)			Cenozoic	late Pliocene		NO	Tch	
14	Yorktown Formation, Moore House Member		YES - COLO	YES		Ward and Bl	Type section: Bluffs at the Moore House, right bank c		Cenozoic	late Pliocene		YES	Tymh	
15	Eastover Formation		NO		Type section: 5.1 km east of Eas	Ward and Blackwelder 1980			Cenozoic	Miocene	Chesapeak	YES		

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

Definitions

In order to clarify, standardize, and consistently reference stratigraphic concepts, principles, and definitions, the North American Stratigraphic Code is recognized and adopted for this inventory. This code 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 that constitutes the basis for definition or recognition of that unit or boundary (North American Commission on Stratigraphic Nomenclature 2005). There are several variations of stratotype referred to in the literature and this report, and they are defined as 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 2005). Once a unit stratotype is assigned, it is never changed. The term "unit stratotype" is commonly referred to as "type section" and "type area" in this report.

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

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

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

Assateague Island National Seashore (ASIS)

Assateague Island National Seashore (ASIS) is located within the Atlantic Coastal Plain physiographic province on the Delmarva (Delaware–Maryland–Virginia) Peninsula in Worcester County, Maryland and Accomack County, Virginia (Figure 5). Established on September 21, 1965, ASIS encompasses approximately 16,732 hectares (41,347 acres) of the Atlantic Coast (Anderson 2017). The National Seashore protects 60 km (37 mi) of sandy beaches, salt marshes, dunes, maritime forest, surrounding ocean, and bay waters for public outdoor recreation use and enjoyment (Anderson 2017). Dynamic coastal processes such as waves, wind, and tides continuously reshape the barrier island landscape. Visitors to ASIS can explore a wide range of recreational opportunities that include crabbing, surf fishing, bicycling, hiking, horseback riding, camping, swimming, and wildlife viewing.

The geology of ASIS consists of young, unconsolidated or partially consolidated sediments such as sand, silt, and clay that are Holocene (<11,700 years old) in age (Figure 6). Assateague Island formed approximately 5,000 years ago, representing a very young geologic landscape. Sediments and landforms exposed on the national seashore tell a story of the barrier island's response to climate-related changes, including sea-level rise, storm frequency and intensity, and changes in precipitation. (Schupp 2013). As sea level has gradually risen, the barrier island has slowly migrated toward land creating a westward shift in depositional environments. Beach and sand dunes are pushed west onto salt marsh and estuary deposits, resulting in a stack of interbedded layers of sand, mud, and peat (Schupp 2013). The continuous re-working of the landscape by dynamic coastal processes, combined with the island's geologic foundation, shape the character and locations of the island's many habitat types.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of ASIS. There are four identified stratotypes located within 48 km (30 mi) of ASIS boundaries, for the Pliocene Tunnels Mill Member of the Yorktown Formation (type section), and the Pleistocene Accomack Member of the Omar Formation (3 reference sections)

Figure 5. Park map of ASIS, Maryland–Virginia (NPS).

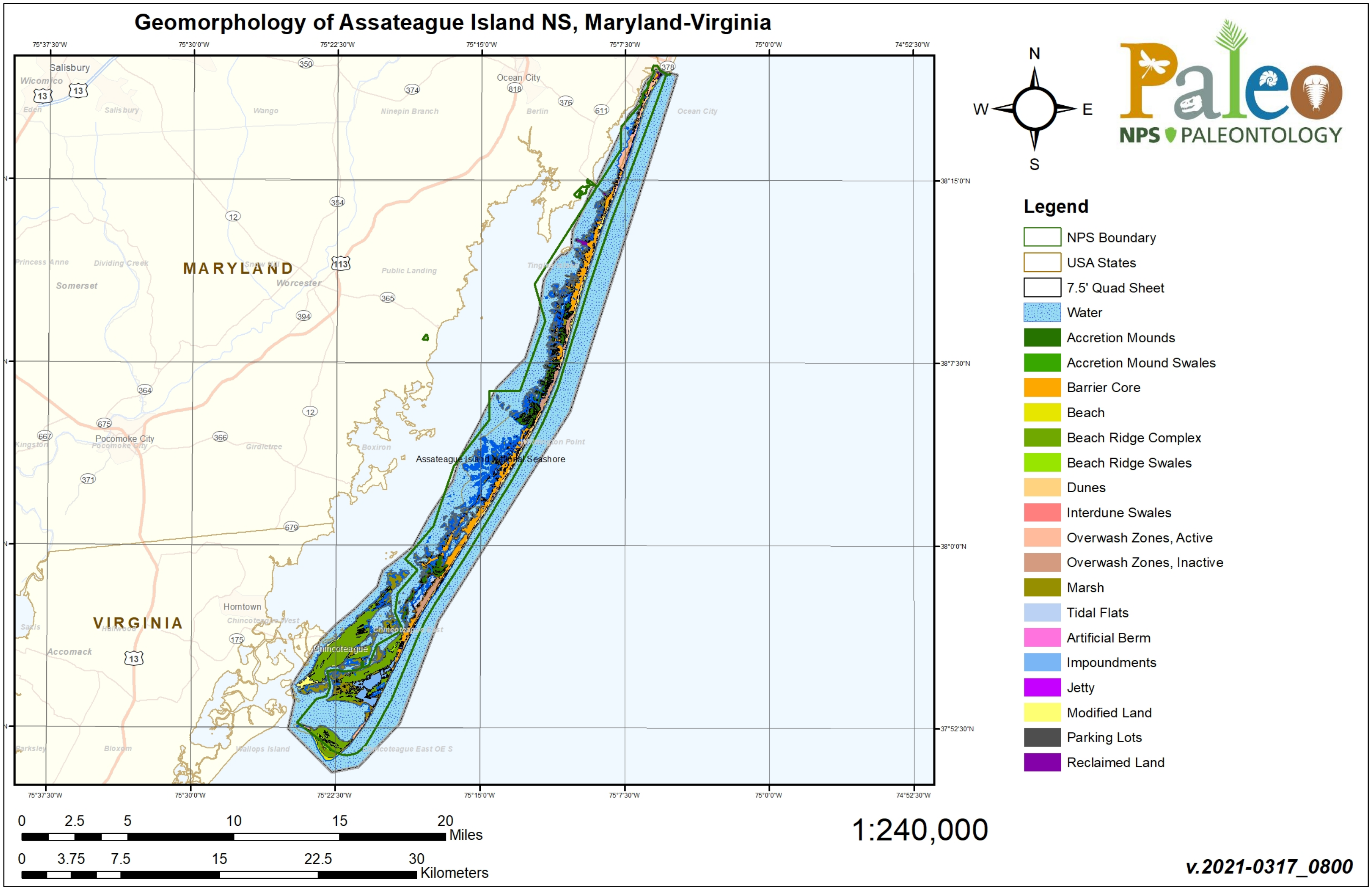


Figure 6. Geologic and geomorphologic map of ASIS, Maryland–Virginia.

Cape Cod National Seashore (CACO)

Cape Cod National Seashore (CACO) is located along the Atlantic-facing eastern shore of Cape Cod in Barnstable County, Massachusetts (Figure 7). Established June 1, 1966, CACO protects approximately 17,647 hectares (43,607 acres) of sandy beaches, dunes, woodlands, freshwater ponds, and salt marshes that stretch nearly 64 km (40 mi) from Chatham to Provincetown (Anderson 2017). CACO contains numerous cultural resources that include archeological sites, lighthouses, cultural landscapes, the Old Harbor Life-Saving Station Museum, and the historic Marconi Station Site where transatlantic wireless communication was achieved in 1903. Visitors at CACO can enjoy a wide range of recreational activities that include swimming, fishing, hiking, bicycling, canoeing, snorkeling, and sightseeing.

The coastal landscape of CACO is about 15,000 years old, making the national seashore a geologically new landform (Giese et al. 2015). The geology of CACO consists of unconsolidated and partially consolidated sediments of gravel, sand, silt, and mud deposited by ice sheets of Wisconsinan age (~75,000–11,000 years ago) (Figure 8; Giese et al. 2015). Since the last glacial retreat, climate-related change has produced a global sea level rise of approximately 400 m (120 m) that has submerged much of the former coast that once extended ~6.4 km (4.0 mi) seaward of its present location. The modern coastal landforms of CACO are temporary holding patterns that will inevitably change due to the dynamic processes of wind, waves, and human activities.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of CACO. There are no identified stratotypes located within 48 km (30 mi) of CACO boundaries.

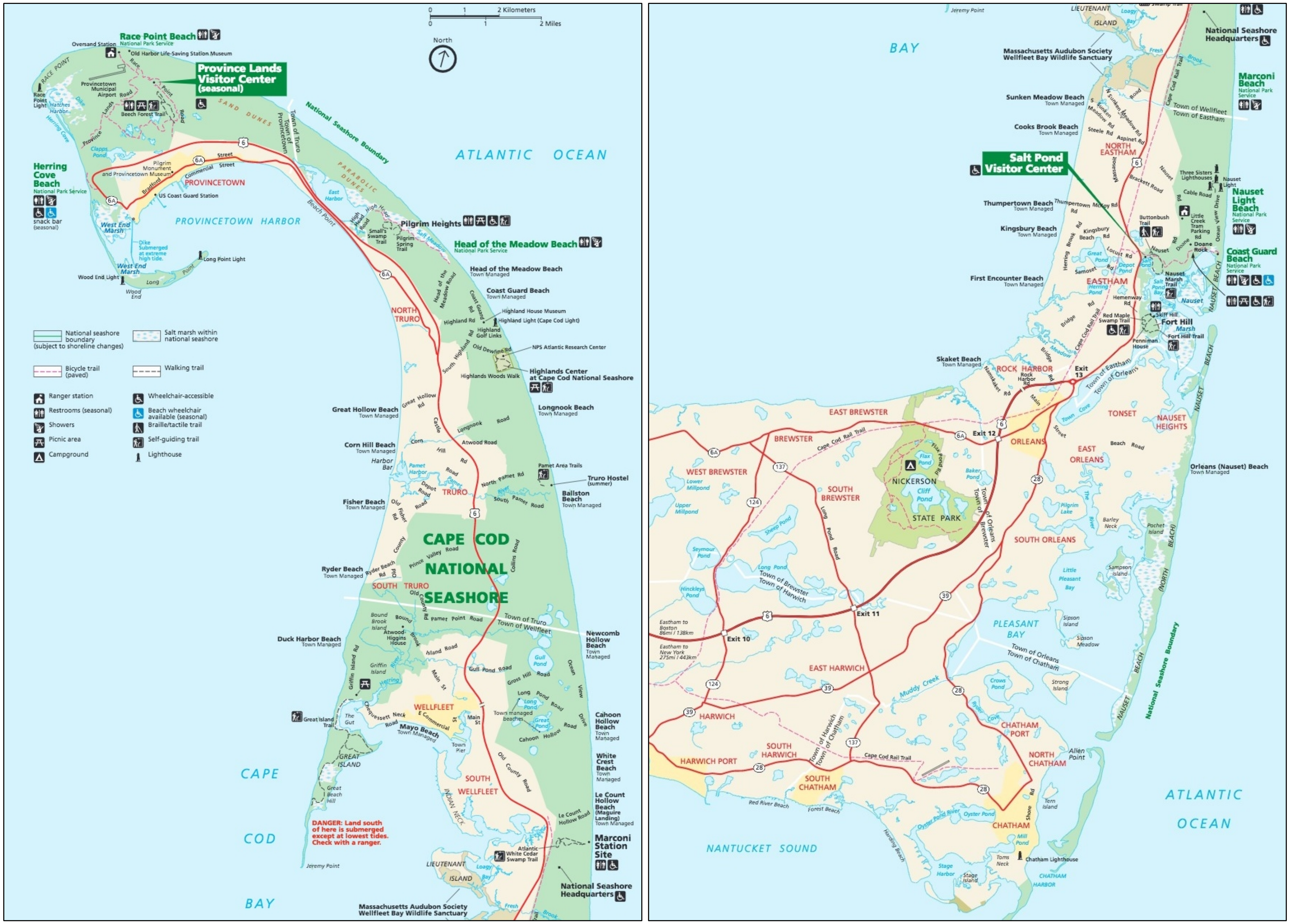


Figure 7. Park map of CACO, Massachusetts (NPS).

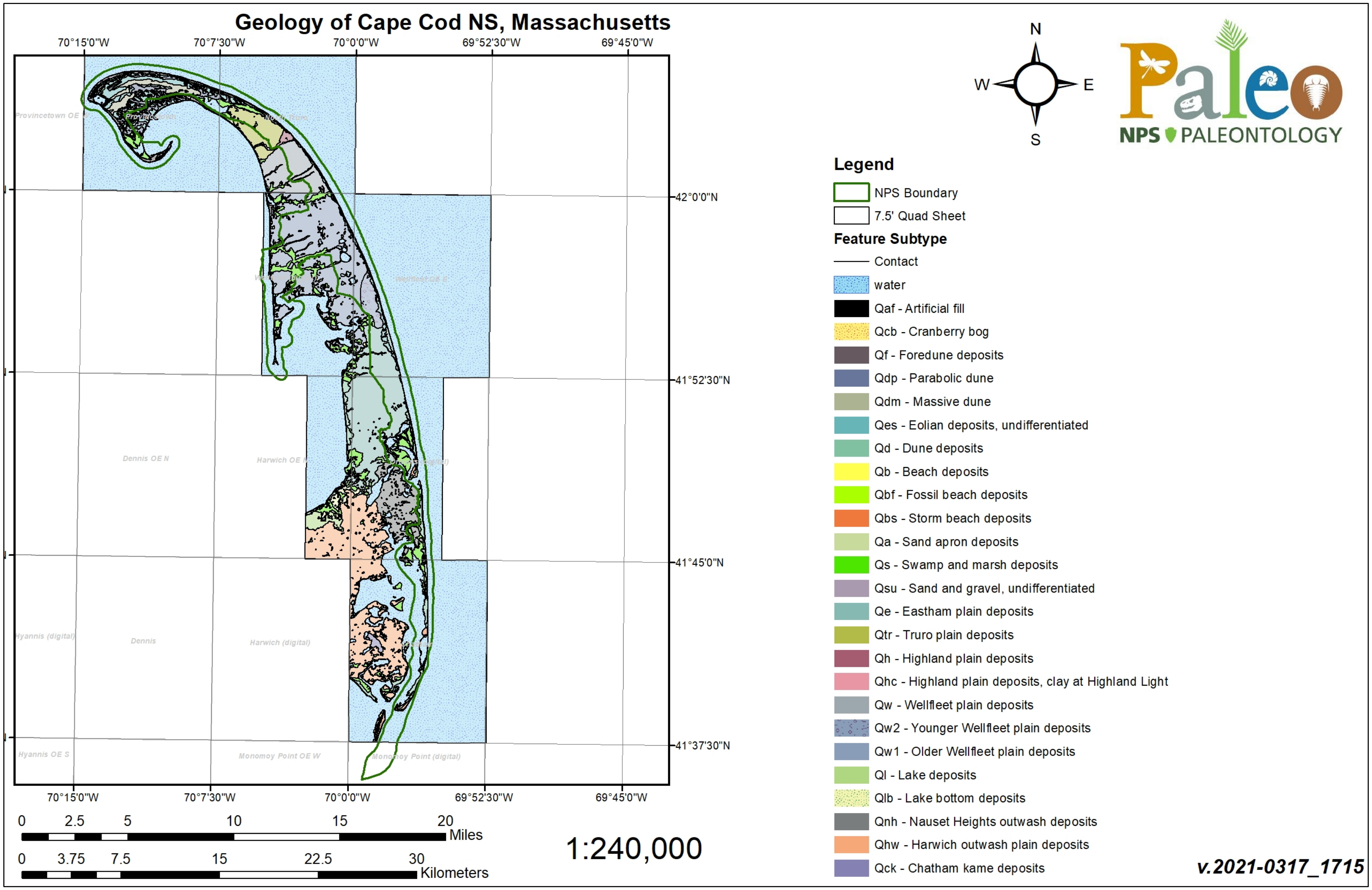


Figure 8. Geologic and geomorphologic map of CACO, Massachusetts.

Colonial National Historical Park (COLO)

Colonial National Historical Park (COLO) is situated in the Coastal Plain physiographic province and spans the Virginia Peninsula between the James and York Rivers in Williamsburg City and James and York Counties, Virginia (Figure 9). Originally established as Colonial National Monument on December 30, 1930, COLO was re-designated as a park on June 5, 1936 (Anderson 2017). The park encompasses approximately 3,511 hectares (8,677 acres) of significant historic resources that commemorate the origins of America as well as natural resources that include wetlands, upland forests, bluffs, fields, streams, and shorelines. Seven historic units comprise COLO: 1) historic Jamestown, the site of America's first permanent English settlement in 1607; 2) Yorktown Battlefield, the backdrop of the 1781 culminating battle of the American Revolutionary War; 3) the 37 km (23 mi)-long Colonial Parkway; 4) Green Spring Plantation; 5) Cape Henry Memorial, the first landing site of the Jamestown colonists in 1607; 6) Tyndall's Point; and 7) Swann's Point (Thornberry-Ehrlich 2016).

The geology of COLO is representative of the Coastal Plain province and predominantly consists of soft, mostly unconsolidated to partially consolidated sediments that were shed from the Appalachian Mountains to the west (Bailey 1999). The eroded sediments form a thick wedge of sediments that extend the plain eastward and are dominated by a series of step-wise river terraces that locally decrease in elevation toward the Chesapeake Bay (Thornberry-Ehrlich 2016). Geologic units of COLO range in age from the Miocene Eastover Formation (~11 million years old) to recent deposits associated with salt marshes, swamps, and rivers (Figure 10; Ward and Blackwelder 1980). The geologic foundations of COLO have strongly influenced the history of the region, from the prehistoric American Indian inhabitants to the early European settlements and American struggles for independence and unity during the American Revolutionary and Civil wars (Thornberry-Ehrlich 2016).

COLO contains one identified stratotype: the Pliocene Moore House Member of the Yorktown Formation (Figure 11; Table 1). In addition to the designated stratotypes located within COLO, a list of stratotypes located within 48 km (30 mi) of park boundaries is included here for reference. These nearby stratotypes include the Miocene Eastover Formation (type section), Claremont Manor Member of the Eastover Formation (type section), and Cobham Bay Member of the Eastover Formation (type section); the Pliocene Bacons Castle Formation (type section), Barhamsville member of the Bacons Castle Formation (type section), Yorktown Formation (principal reference section), Yorktown Formation (coquina facies reference section), Sunken Meadow Member of the Yorktown Formation (type section), Rushmere Member of the Yorktown Formation (type locality), and Morgarts Beach Member of the Yorktown Formation (type section); and the Pleistocene Chuckatuck Alloformation (type section), Poquoson Allomember of the Tabb Alloformation (type section), Sedgefield Allomember of the Tabb Alloformation (type section), Lynnhaven Allomember of the Tabb Alloformation (type section), Charles City Alloformation (type section), Shirley Alloformation (type section), Elsing Green Alloformation (type section), and Windsor Alloformation (type section).

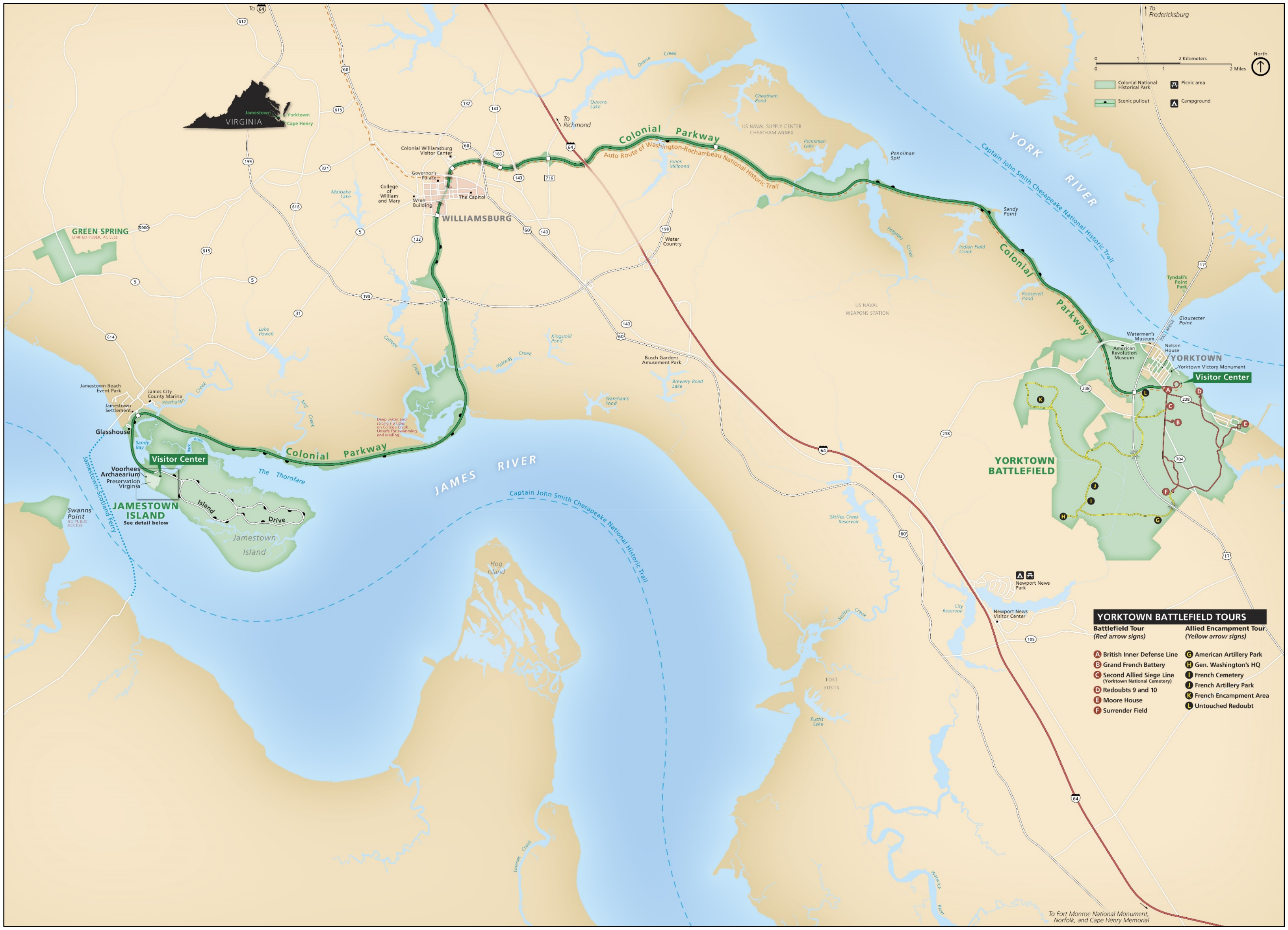


Figure 9. Park map of COLO, Virginia (NPS).

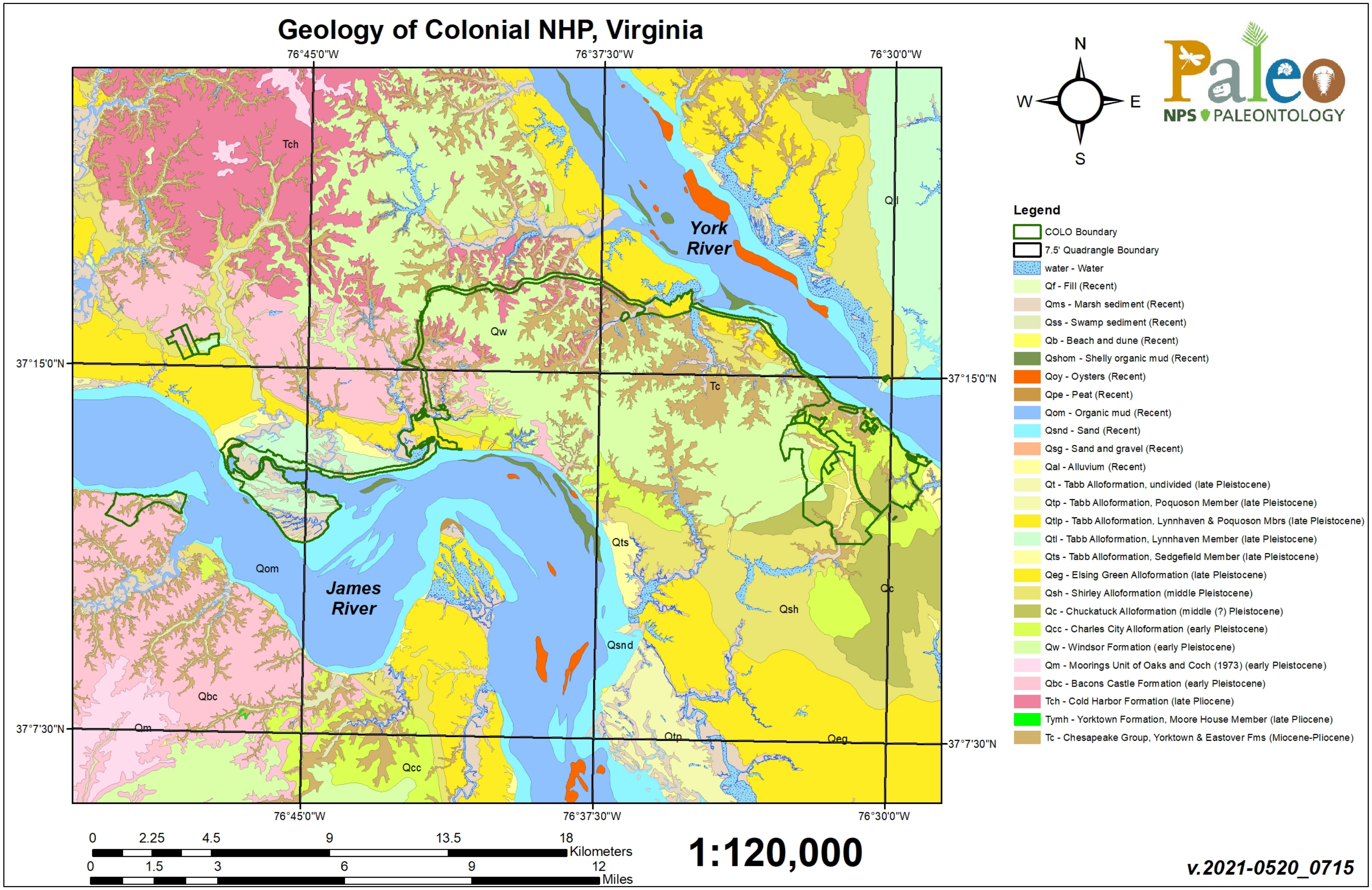


Figure 10. Geologic and geomorphologic map of COLO, Virginia.

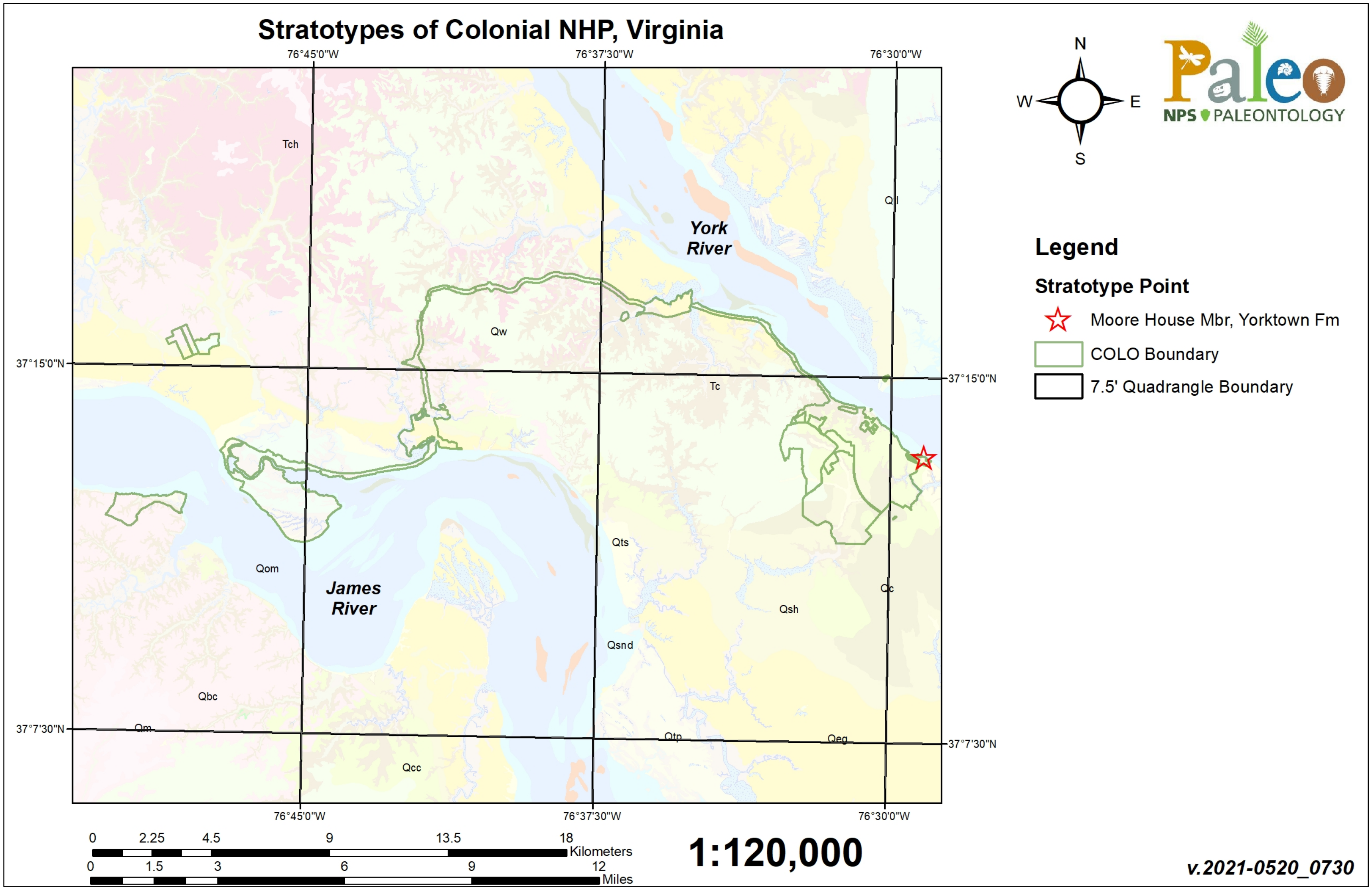


Figure 11. Modified geologic map of COLO showing stratotype locations. The transparency of the geologic units layer has been increased.

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

Unit Name (map symbol)	Reference	Stratotype Location	Age
Moore House Member, Yorktown Formation (Tymh)	Ward and Blackwelder 1980	Type section: Bluffs at the Moore House, south bank of the York River, in the Colonial National Historical Park, York County, Virginia. [Poquoson West 7 1/2-minute Quadrangle]	late Pliocene

The Pliocene Moore House Member of the Yorktown Formation was named by Ward and Blackwelder (1980) after the historic Moore House in COLO. Ward and Blackwelder (1980) designated the type section at the bluffs just north of the Moore House, situated along the southern bank of the York River in York County, Virginia (Figures 11 and 12; Table 1). The type section exposure measures approximately 8 m (26 ft) thick and consists of orange, fragmental, sandy shell beds and cross-bedded shell hash that is locally cemented and contains disarticulated fossils of bryozoans and mollusks (Figure 13; Ward and Blackwelder 1980). Stratigraphically, the Moore House Member conformably overlies the Morgarts Beach Member in its outcrop area and the upper contact is not exposed (Ward and Blackwelder 1980).

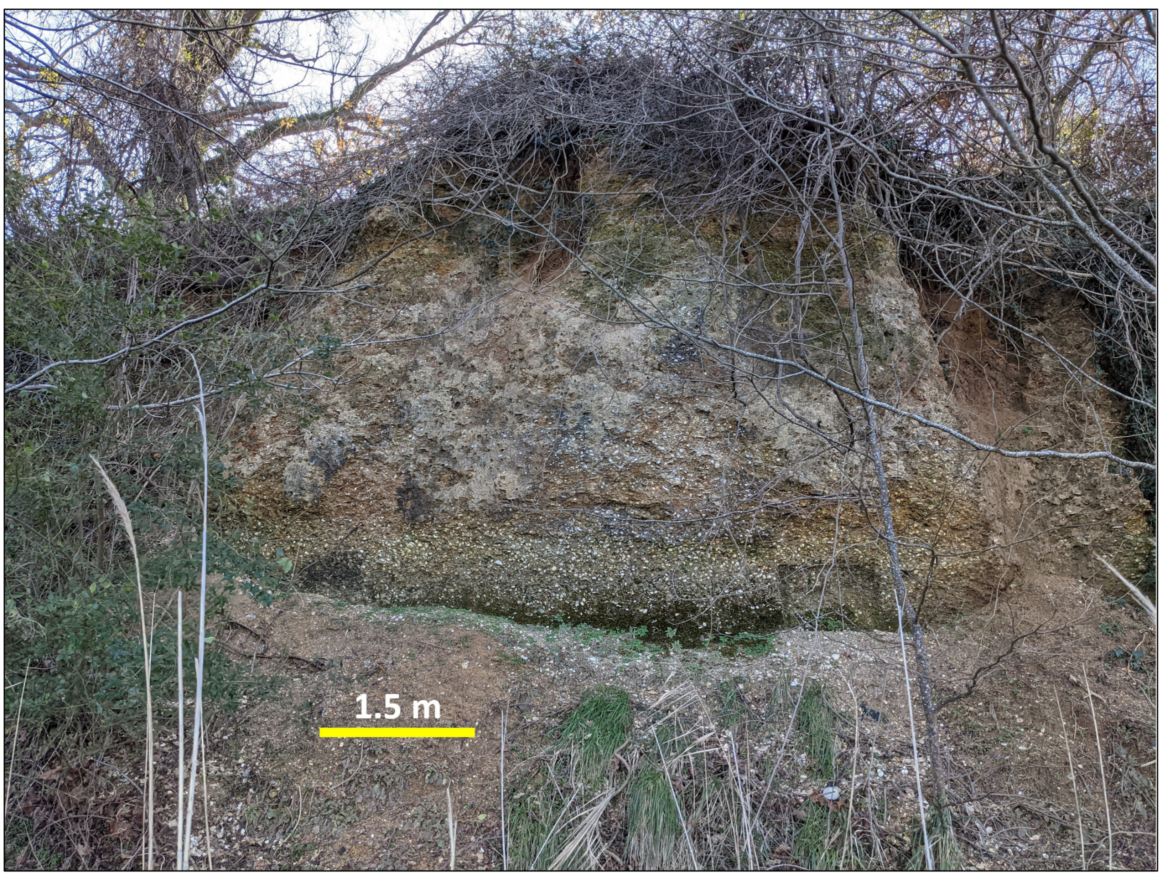


Figure 12. Type section bluff exposure of the Moore House Member of the Yorktown Formation along the southern bank of the York River, COLO. Scale bar is 1.5 m (5 ft) (MACKENZIE CHRISCOE).

Figure 13. Shelly sand beds of the Moore House Member of the Yorktown Formation at the type section exposure along the southern bank of the York River (ROWAN LOCKWOOD).

Fire Island National Seashore (FIIS)

Fire Island National Seashore (FIIS) encompasses a 42 km (26 mi) section of Fire Island, a barrier island separated from Long Island by the Great South Bay in Suffolk County, New York (Figure 14). Established on September 11, 1984, FIIS protects approximately 7,923 hectares (19,580 acres) of cultural and natural resources that include sandy beaches, dunes, intertidal scrub, maritime forest, wetlands, the Fire Island Lighthouse, and the William Floyd Estate. The William Floyd Estate, once home to the signer of the Declaration of Independence, was authorized as an addition to FIIS in 1978 and preserves 250 years of history. Visitors to FIIS can explore a diverse range of recreational activities that include swimming, boating, beachcombing, birdwatching, fishing, camping, hiking, stargazing, and wildlife gazing.

Situated in the Atlantic Coastal Plain physiographic province, the geology of FIIS is dominated by young, unconsolidated, and partially consolidated sediments of gravel, sand, silt, and mud. Much of the barrier island is composed of recent dune sand, beach deposits, and swamp and marsh deposits (Figure 15). The oldest geologic units in FIIS are represented by Pleistocene-age (~30,000 years old) outwash deposits from ice along the Ronkonkoma Drift with outcrops of the Manhasset Formation located at the William Floyd Estate on the mainland of Long Island (Frye et al. 1968; Sirkin 1982). Dynamic coastal processes such as wind, waves, tides, and human interaction, in combination with the geologic foundation of FIIS, help control the shape and distribution of the diverse habitats that make up the Seashore.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of FIIS. There are no identified stratotypes located within 48 km (30 mi) of FIIS boundaries.

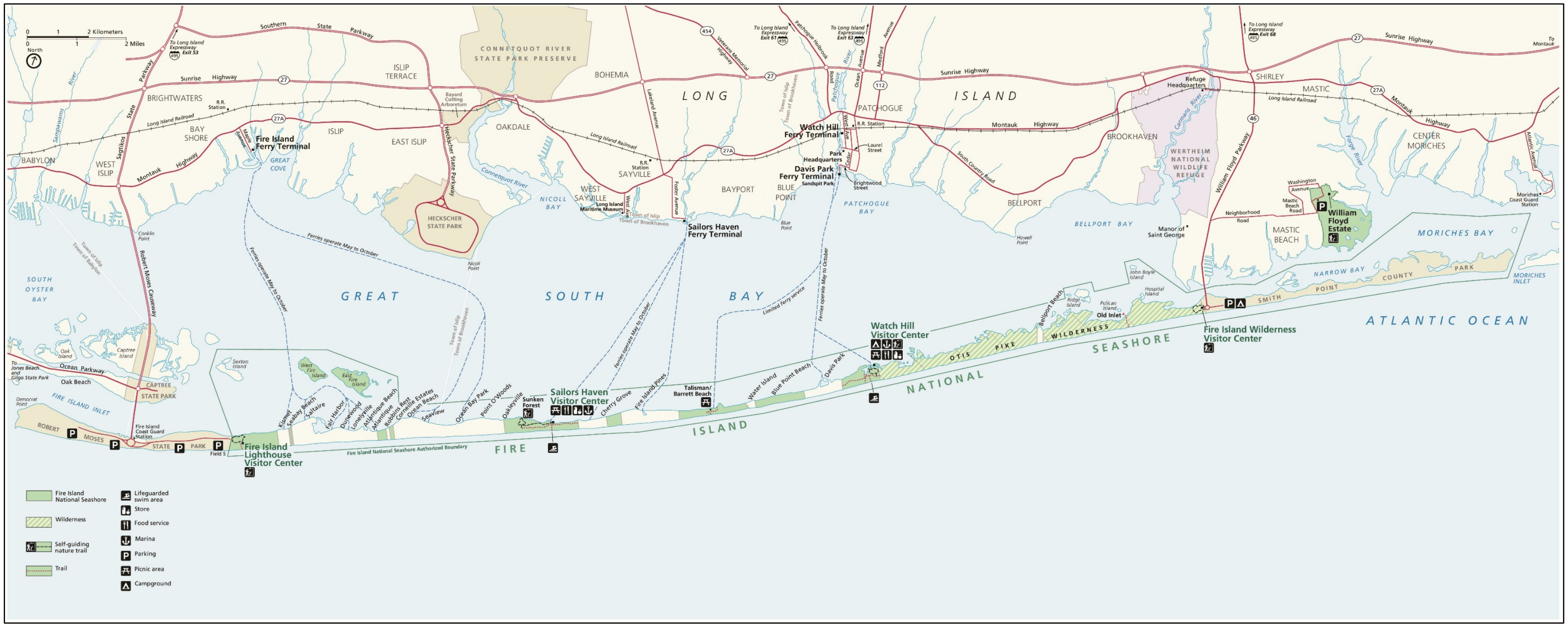


Figure 14. Park map of FIIS, New York (NPS).

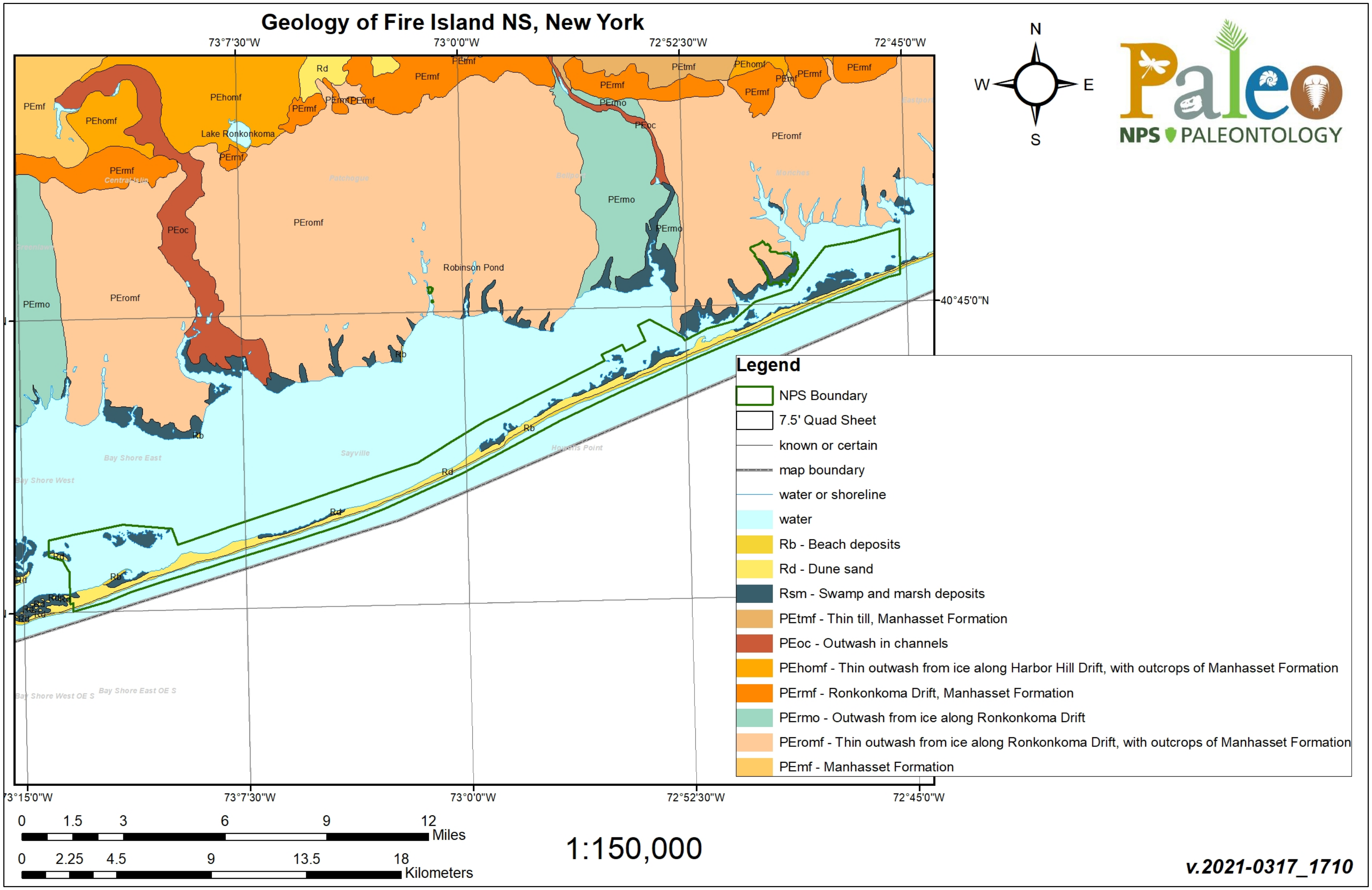


Figure 15. Geologic and geomorphologic map of FIIS, New York.

Gateway National Recreation Area (GATE)

Gateway National Recreation Area (GATE) is located along the eastern shores of Monmouth County, New Jersey and Kings, Queens, and Richmond Counties, New York (Figure 16). Established on October 27, 1972, GATE protects approximately 10,767 hectares (26,607 acres) of sandy beaches, salt marshes, grasslands, ponds, forests, wildlife sanctuaries, recreational and athletic facilities, historic structures, old military installations, airfields, a lighthouse, and the waters around New York Harbor (Anderson 2017). The recreation area consists of three different coastal units: 1) the Sandy Hook unit in New Jersey; 2) the Staten Island unit in New York; and 3) the Jamaica Bay unit in New York. Visitors to GATE can enjoy a wide variety of activities that include archery, bicycling, bird watching, boating, camping, fishing, hiking, picnicking, swimming, sunbathing, and sightseeing.

Situated in the Coastal Plain physiographic province, GATE shares its geologic history and some characteristic geologic formations with a region that extends well beyond the park unit boundaries. The geology of GATE, beneath surficial deposits, consists entirely of Cretaceous-age (~100–66 million years old) formations that vary among each coastal unit of the recreation area (Figure 17). The southern Sandy Hook unit of GATE is the most geologically diverse, consisting of the Red Bank, Navesink, Mount Laurel, Wenonah, Marshalltown, Englishtown, and Woodbury Formations. The western Staten Island unit and associated Hoffman and Swinburne islands are composed of the Raritan Formation. The eastern Jamaica Bay unit consists of an undivided assemblage of the Monmouth Group, Matawan Group, and Magothy Formation. As with many park units of NCBN, the dynamic coastal processes of wind, water, and tides continuously re-shape the landscape of GATE.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of GATE. There are 10 identified stratotypes located within 48 km (30 mi) of GATE boundaries, for the Cretaceous Raritan Formation (type locality), Cheesequake Formation (type locality), Englishtown Formation (type locality), Red Bank Formation (type area), Sandy Hook Member of the Red Bank Formation (type area), Tinton Formation (type section), and Navesink Formation (type section); and the Eocene Shark River Formation (type locality), Farmingdale Member of the Manasquan Formation (type section), and Deal Member of the Manasquan Formation (type section).

Figure 16. Park map of GATE, New Jersey–New York (NPS).

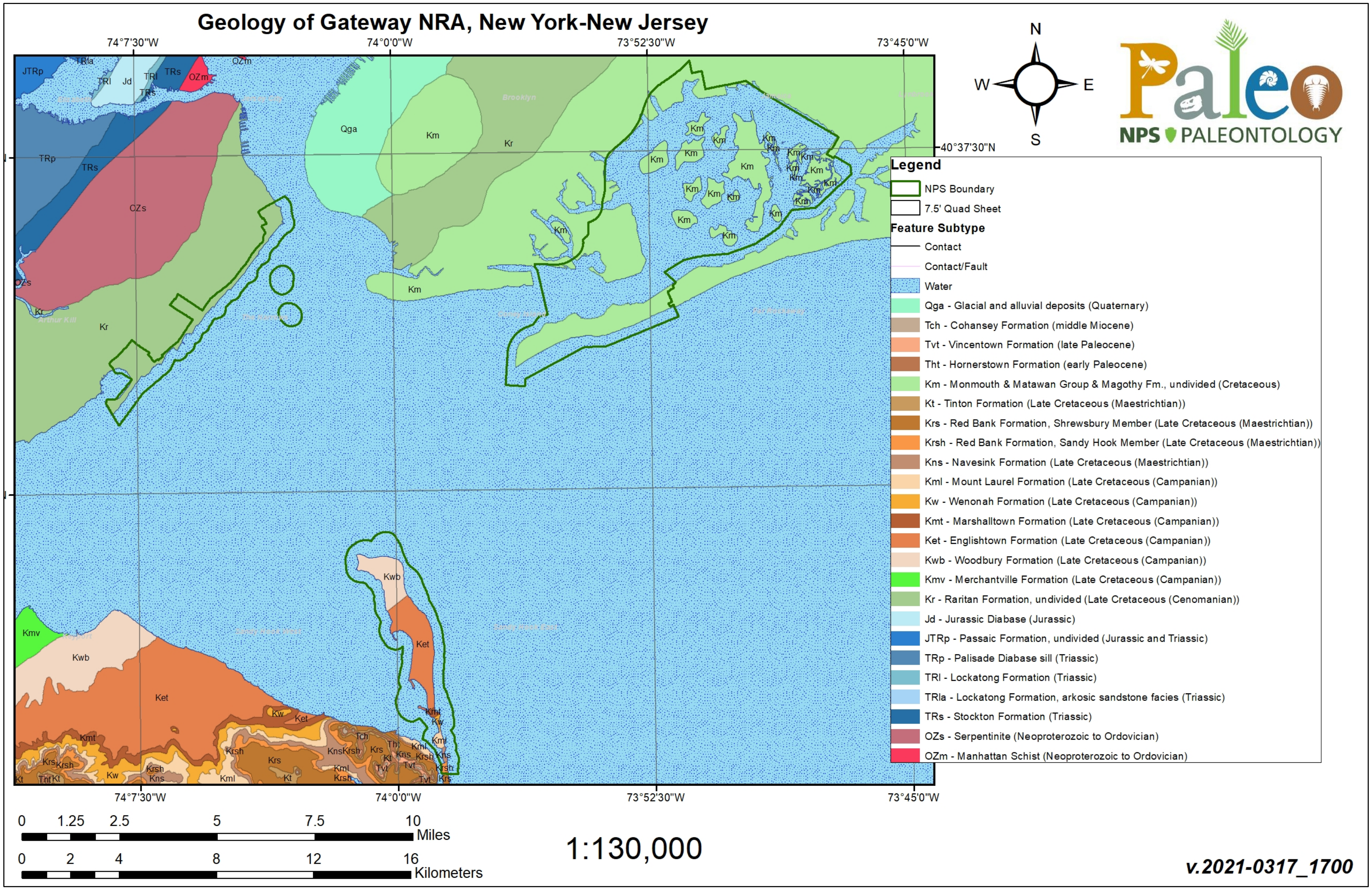


Figure 17. Geologic and geomorphologic map of GATE, New Jersey–New York.

George Washington Birthplace National Monument (GEWA)

George Washington Birthplace National Monument (GEWA) is situated in the Atlantic Coastal Plain physiographic province along the Potomac River in Westmoreland County, Virginia (Figure 18). Established on January 23, 1930, GEWA protects approximately 267 hectares (662 acres) of historic resources that include the foundation of the home where Washington was born, the archeological remains of outbuildings, a commemorative colonial revival plantation, and the family burial grounds (Anderson 2017). Visitors to GEWA can enjoy a variety of activities such as hiking, picnicking, fishing, bicycling, horseback riding, as well as exploring the historical sites or the Potomac River Beach.

The geology of GEWA and the associated Atlantic Coastal Plain province consists predominantly of young, relatively flat-lying, unconsolidated to partially consolidated units (Figure 19; Thornberry-Ehrlich 2009). The oldest geologic exposures within GEWA are found along the estuarine mouth of Pope's Creek and the Potomac riverbank and are represented by Miocene-age (~11 million years old) formations of the Chesapeake Group (Ward and Blackwelder 1980). A major portion of the monument's geologic foundation is composed of the Pleistocene (~13,000 years old) Tabb Alloformation and its members (Rader and Evans 1993). A variety of more recent units exist at Longwood Swamp, Digwood Swamp, and Dancing Marsh that consist of salt marsh, swamp, beach, and alluvium deposits.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of GEWA. There are nine identified stratotypes located within 48 km (30 mi) of GEWA boundaries, for the Paleocene Aquia Formation (type locality and principal reference section), Piscataway Member of the Aquia Formation (type section), and Paspotansa Member of the Aquia Formation (type section); the Eocene Woodstock Member of the Nanjemoy Formation (principal reference section) and Potapaco Member of the Nanjemoy Formation (type area); and the Miocene Choptank Formation (principal reference section), St. Leonard Member of the Choptank Formation (type section), Drumcliff Member of the Choptank Formation (type section), and Popes Creek Sand Member of the Calvert Formation (type section).

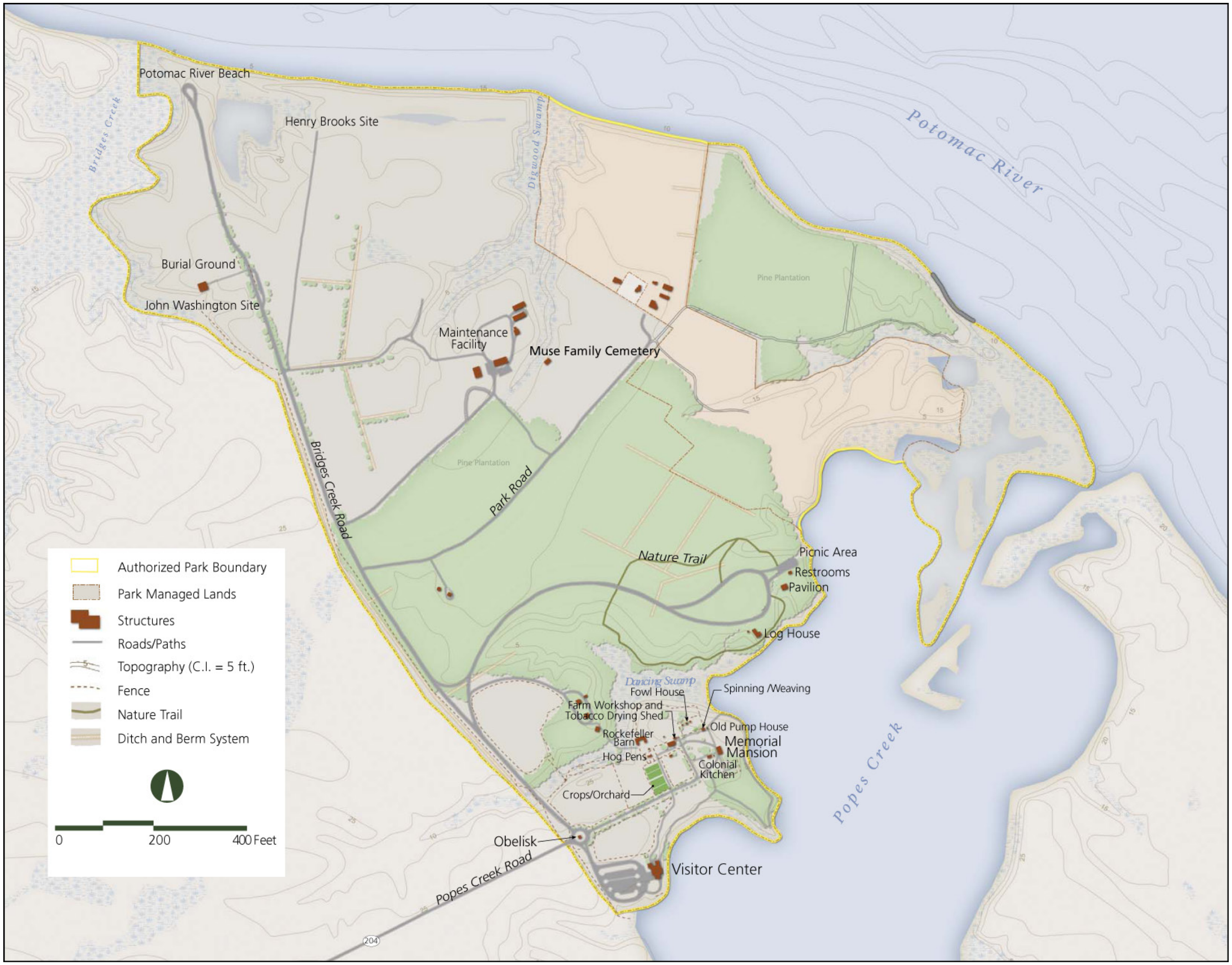


Figure 18. Park map of GEWA, Virginia (modified from NPS map courtesy Rijk Morawe).

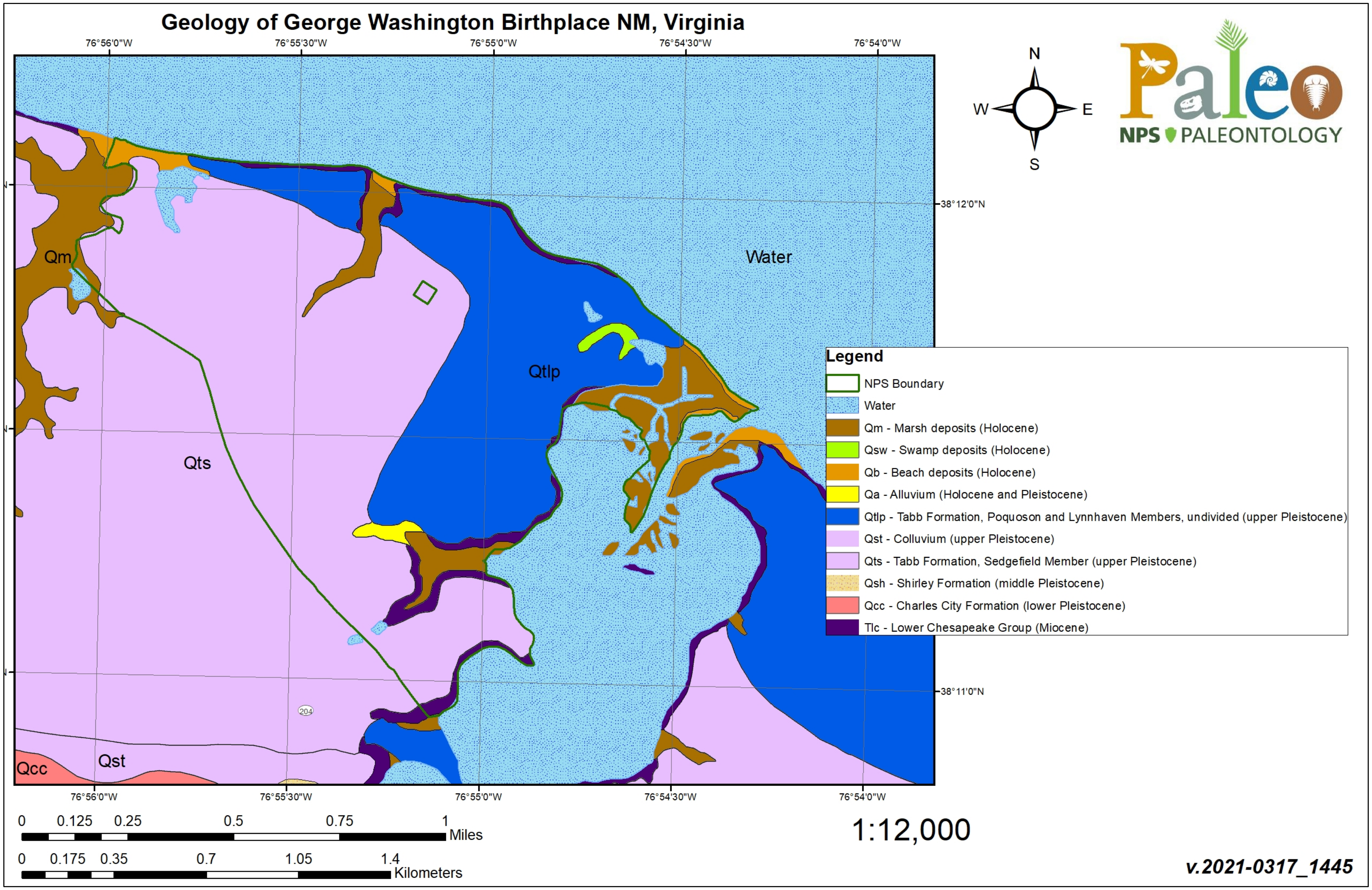


Figure 19. Geologic and geomorphologic map of GEWA, Virginia.

Sagamore Hill National Historic Site (SAHI)

Sagamore Hill National Historic Site (SAHI) is located along Oyster Bay on northern Long Island in Nassau County, New York (Figure 20). Sagamore Hill was the home of President Theodore Roosevelt from 1885 until his death in 1919 and served as the "Summer White House" during the Roosevelt administration. Established on July 10, 1963, SAHI protects approximately 33 hectares (83 acres) of the historic estate and its natural surroundings. Built in 1885 from a sketch made by Theodore Roosevelt himself, the Queen Anne home contains 23 rooms and almost all the furnishings are original (Anderson 2017). The great natural resource value of SAHI lies in the diverse habitat types found within and around the site, including oak–tulip forests, meadows, ponds, salt marshes, and beaches that are home to numerous flora and fauna. Visitors to SAHI are encouraged to tour Roosevelt's home, explore the nature trail, enjoy a picnic, and explore the nearby attractions such as Oyster Bay.

As part of the Coastal Plain physiographic province, the geology of SAHI consists of young, relatively flat-lying, unconsolidated to partially consolidated sediments of gravel, sand, silt, and mud that are constantly reworked by dynamic coastal processes (Figure 21). A major portion of SAHI, including the estate grounds, is composed of Quaternary-age (~75,000–11,000 years old) Harbor Hill ground moraine deposits (unconsolidated rock and soil debris deposited by a glacier) left behind as glaciers retreated north. The easternmost portion of the historic site along Cold Spring Harbor contains marsh deposits of similar age.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of SAHI. There are no identified stratotypes located within 48 km (30 mi) of SAHI boundaries.

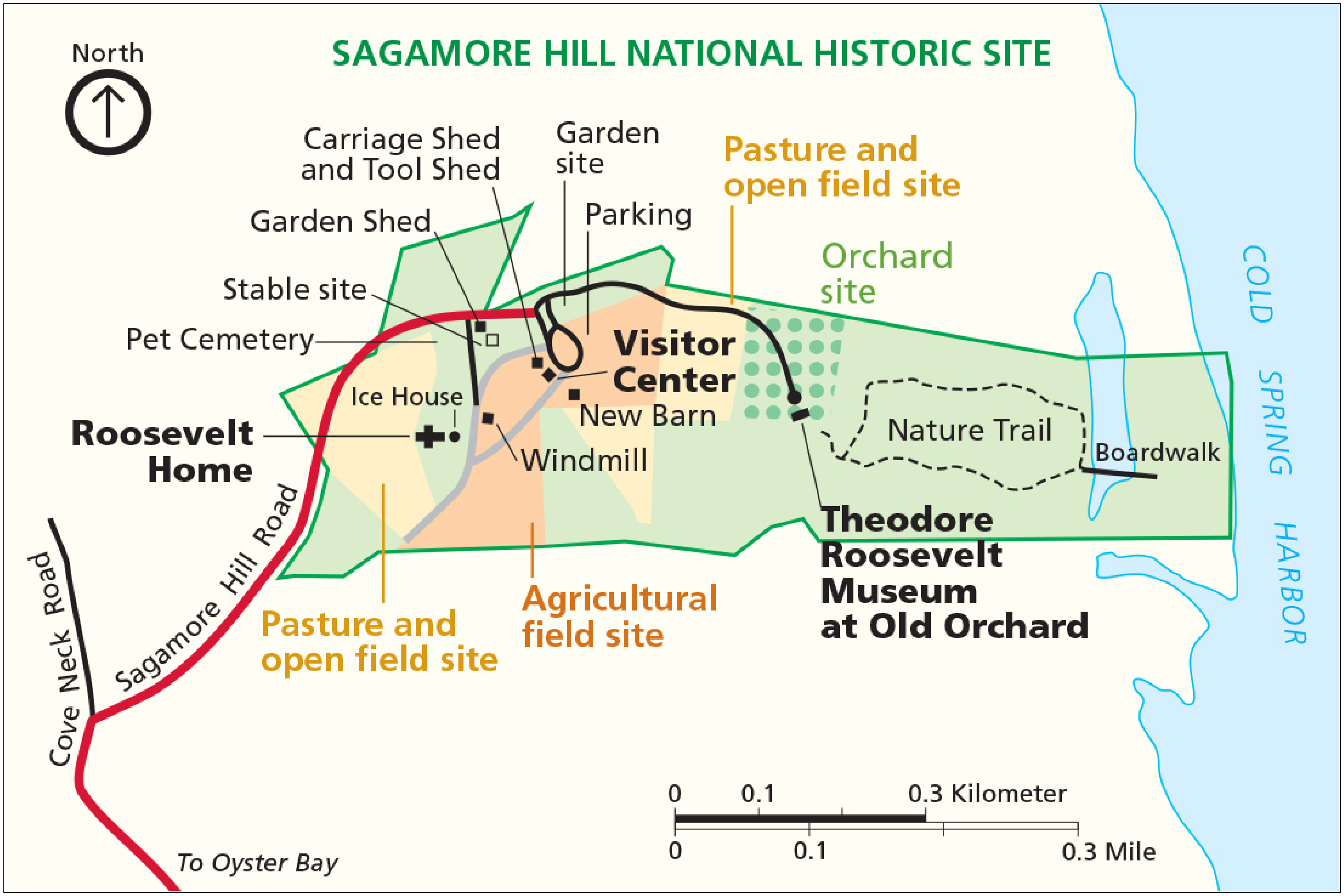


Figure 20. Park map of SAHI, New York (NPS).

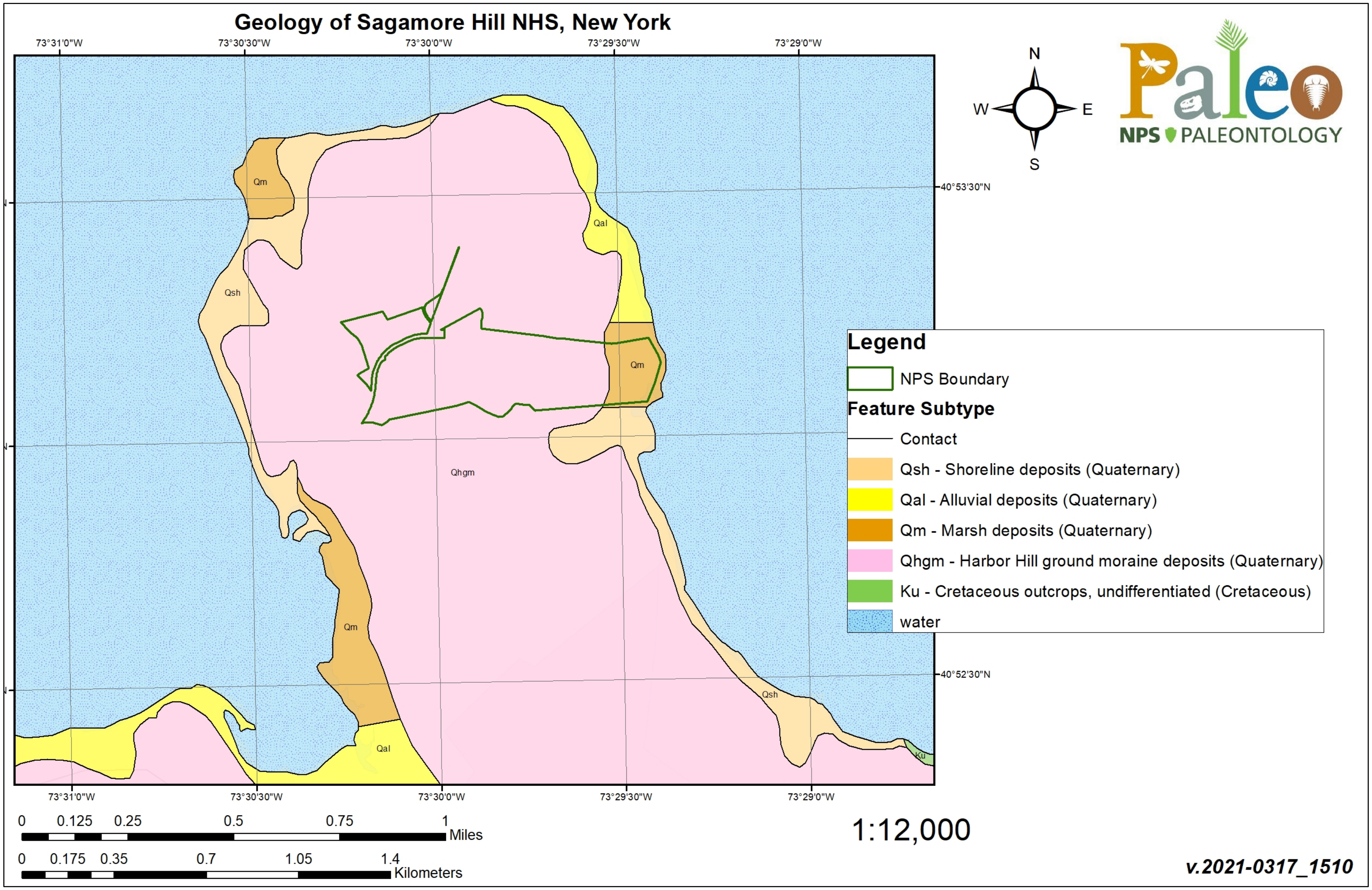


Figure 21. Geologic and geomorphologic map of SAHI, New York.

Thomas Stone National Historic Site (THST)

Thomas Stone National Historic Site (THST) is situated in the Atlantic Coastal Plain physiographic province on the eastern side of the Potomac River Valley in Charles County, Maryland (Figure 22). The historic site commemorates Thomas Stone, a signer of the Declaration of Independence and early Maryland state senator. Established on November 10, 1978, THST preserves approximately 132 hectares (328 acres) of protected pastoral fields, forest, outbuildings, Stone's home, and the Stone family cemetery (Anderson 2017). Built in 1771, Stone's home is a unique, five-part Georgian-style mansion nicknamed "Haberdeventure" that was restored after a 1977 fire (Thornberry-Ehrlich 2009). Visitors to THST are encouraged to explore the historic estate through several walking trails.

The geology of THST generally consists of flat-lying and undeformed units with subtle topographic variations resulting from erosion and river downcutting through the horizontal layers. The oldest geologic exposures at the historic site can be seen along Hoghole Run and are represented by sand, silt, and clay of the Eocene Nanjemoy Formation and Miocene Calvert Formation (Figure 23). A large portion of the Stone estate is positioned on a broad upland between Hoghole Run and the upper Port Tobacco River and consists of younger Pliocene upland gravels (Thornberry-Ehrlich 2009). The youngest deposits at THST include alluvial deposits (unconsolidated sand, gravel, silt, clay), marsh deposits along larger stream bottoms, shelly sands, and artificial fill from human activity.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of THST. There are 14 identified stratotypes located within 48 km (30 mi) of THST boundaries, for the Proterozoic–Cambrian Annandale Group (type locality) and Accotink Schist of the Annandale Group (type locality); the Paleocene Brightseat Formation (type area), Aquia Formation (type locality and principal reference section), Piscataway Member of the Aquia Formation (type section), and Paspotansa Member of the Aquia Formation (type section); the Eocene Woodstock Member of the Nanjemoy Formation (principal reference section) and Potapaco Member of the Nanjemoy Formation (type area); and the Miocene Fairhaven Member of the Calvert Formation (type locality), Plum Point Marl Member of the Calvert Formation (type area), Popes Creek Sand Member of the Calvert Formation (type section), Choptank Formation (principal reference section), St. Leonard Member of the Choptank Formation (type section), and Drumcliff Member of the Choptank Formation (type section).

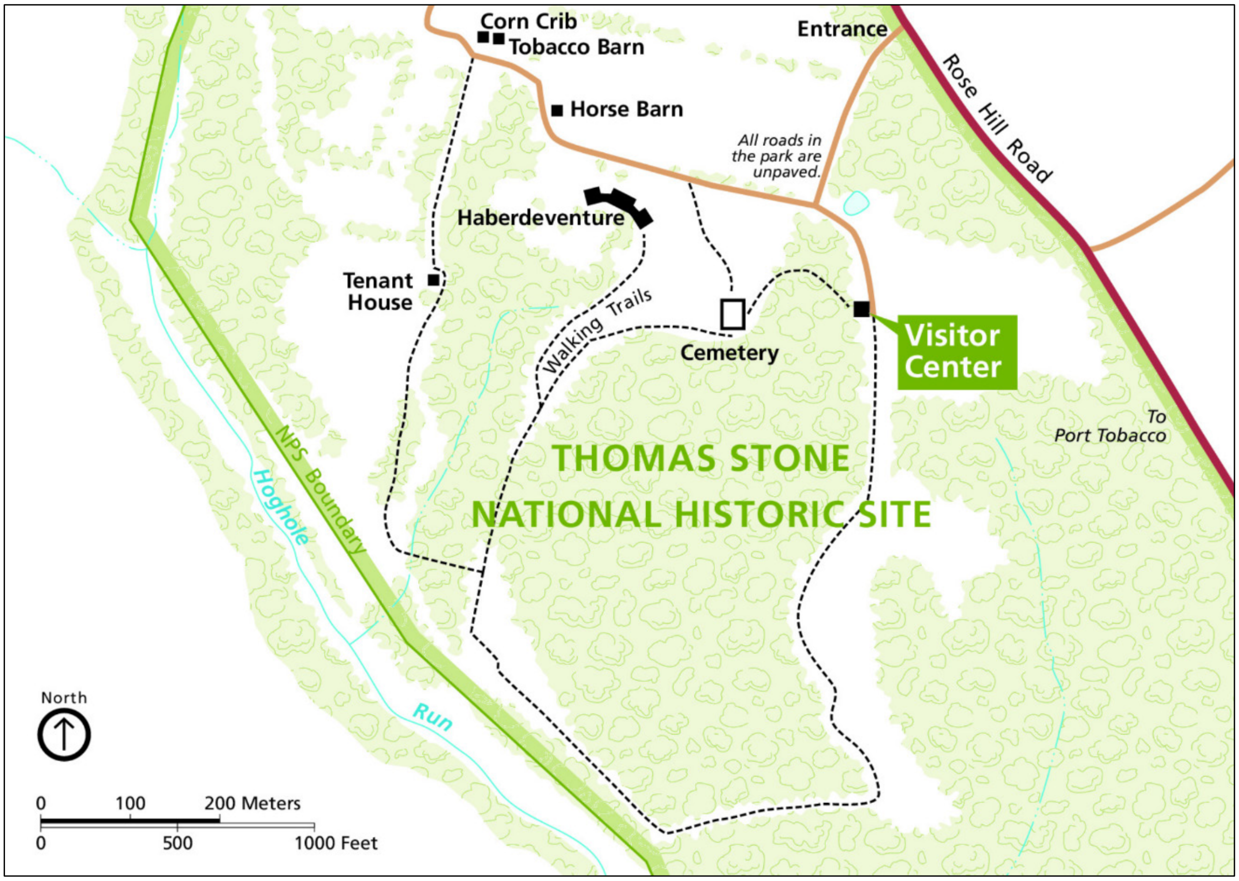


Figure 22. Park map of THST, Maryland (NPS).

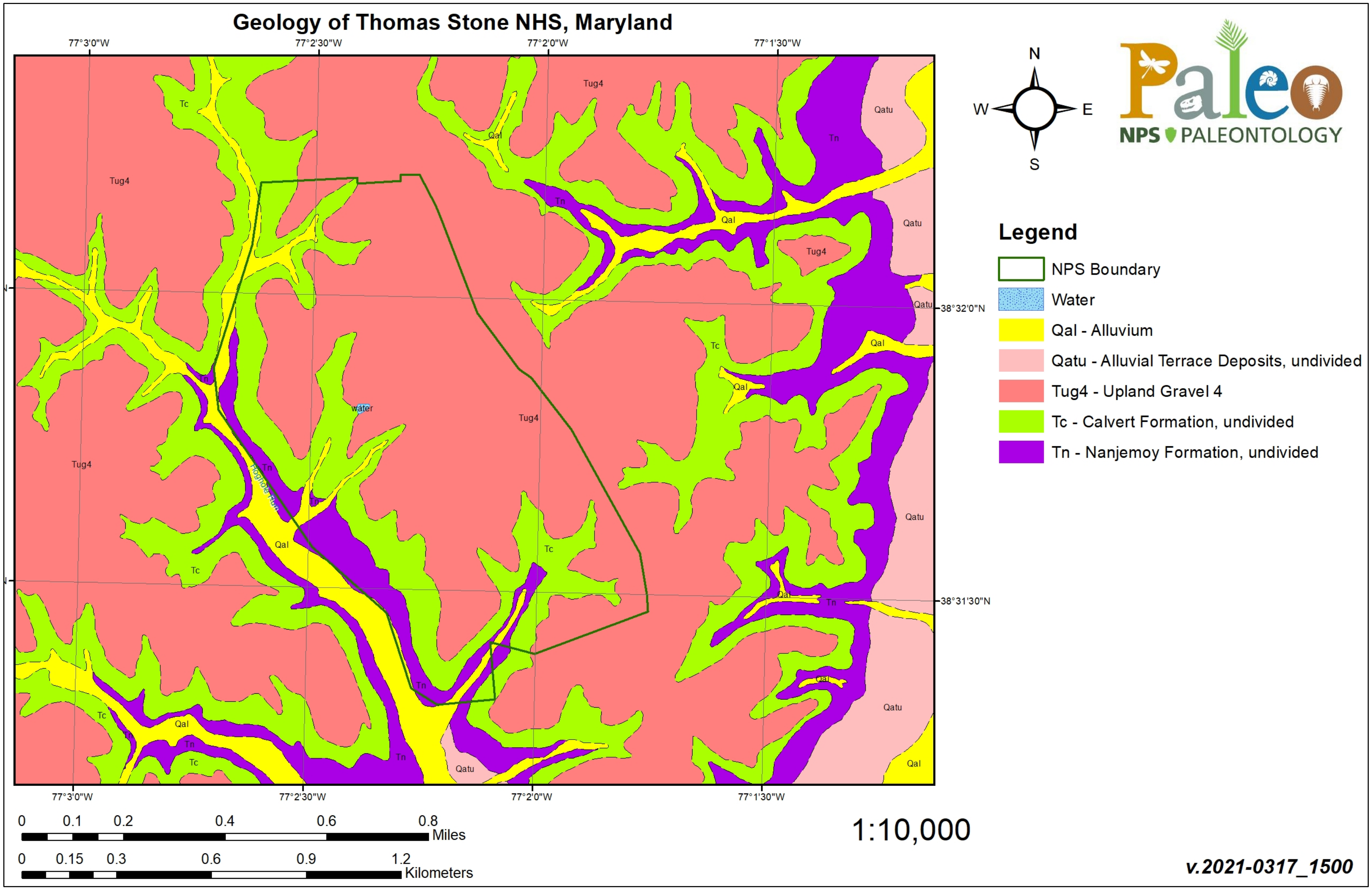


Figure 23. Geologic and geomorphologic map of THST, Maryland.

Recommendations

1) The NPS Geologic Resources Division should work with park and network staff to increase their awareness and understanding about the scientific, historic and geologic heritage significance of geologic stratotypes (type sections/localities/areas, reference sections, lithodemes). *Stratotypes represent unique geologic exposures and should be considered extremely important to protect for the advancement of the scientific community for future generations.*

2) Once the NCBN Geologic Type Section Inventory report is finalized, the NPS Geologic Resources Division should schedule a briefing for NCBN staff and respective network parks.

3) The NPS Geologic Resources Division should work with park and network staff to ensure they are aware of the location of stratotypes in park areas. This information would be important to ensure that proposed park activities or development would not adversely impact the stability and condition of these geologic exposures. Preservation of stratotypes should not limit availability for future scientific research but help safeguard these exposures from infrastructure development.

4) The NPS Geologic Resources Division should work with park and network staff, the U.S. Geological Survey, state geological surveys, academic geologists, and other partners to formally assess potential new stratotypes as to their significance (international, national, or statewide), based on lithology, stratigraphy, fossils, or notable features using procedural code outlined by the North American Commission on Stratigraphic Nomenclature.

5) From the assessment in (4), NPS staff should focus on registering new stratotypes at State and Local government levels where current legislation allows, followed by a focus on registering at Federal and State levels where current legislation allows.

6) The NPS Geologic Resources Division should work with park and network staff to compile and update a central inventory of all designated stratotypes and potential future nominations.

7) The NPS Geologic Resources Division should ensure the park-specific Geologic Type Section Inventory Reports are widely distributed and available online.

8) The NPS Geologic Resources Division should work with park and network staff to regularly monitor geologic type sections to identify any threats or impacts to these geologic heritage features in parks.

9) The NPS Geologic Resources Division should work with park and network staff to obtain good photographs of each geologic type section within the parks. In some cases, where there may be active geologic processes (rockfalls, landslides, coastal erosion, etc.), the use of photogrammetry may be considered for monitoring of geologic type sections. GPS locations should also be recorded and kept in a database when the photographs are taken.

10) The NPS Geologic Resources Division should work with park and network staff to consider the collection and curation of geologic/petrologic samples collected from type sections within

respective NPS areas. Samples collected from type section exposures can be useful as reference specimens to support future studies, especially where stratotypes may be lost through natural processes or human activities.

11) The NPS Geologic Resources Division should work with park and network staff to utilize selected robust internationally and nationally significant type sections as formal teaching/education sites and for geotourism so that the importance of the national and international assets are more widely (and publicly) known, using information boards and walkways.

12) The NPS Geologic Resources Division should work with park and network staff in developing conservation protocols of significant type sections, either by appropriate fencing, walkways, and information boards or other means (e.g., phone apps).

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Appendix A: Source Information for GRI Maps of NCBN Parks

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- GMAP 75677: Psuty, N. P, M. Patel, J. Freeman, W. Schmelz, W. Robertson, and A. Spahn. 2013. Development of the geomorphological map for Fire Island National Seashore: principal characteristics and components. Rutgers University, Institute of Marine and Coastal Sciences, New Brunswick, New Jersey. Unpublished. Scale 1:12,000.

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Appendix B: Geologic Time Scale

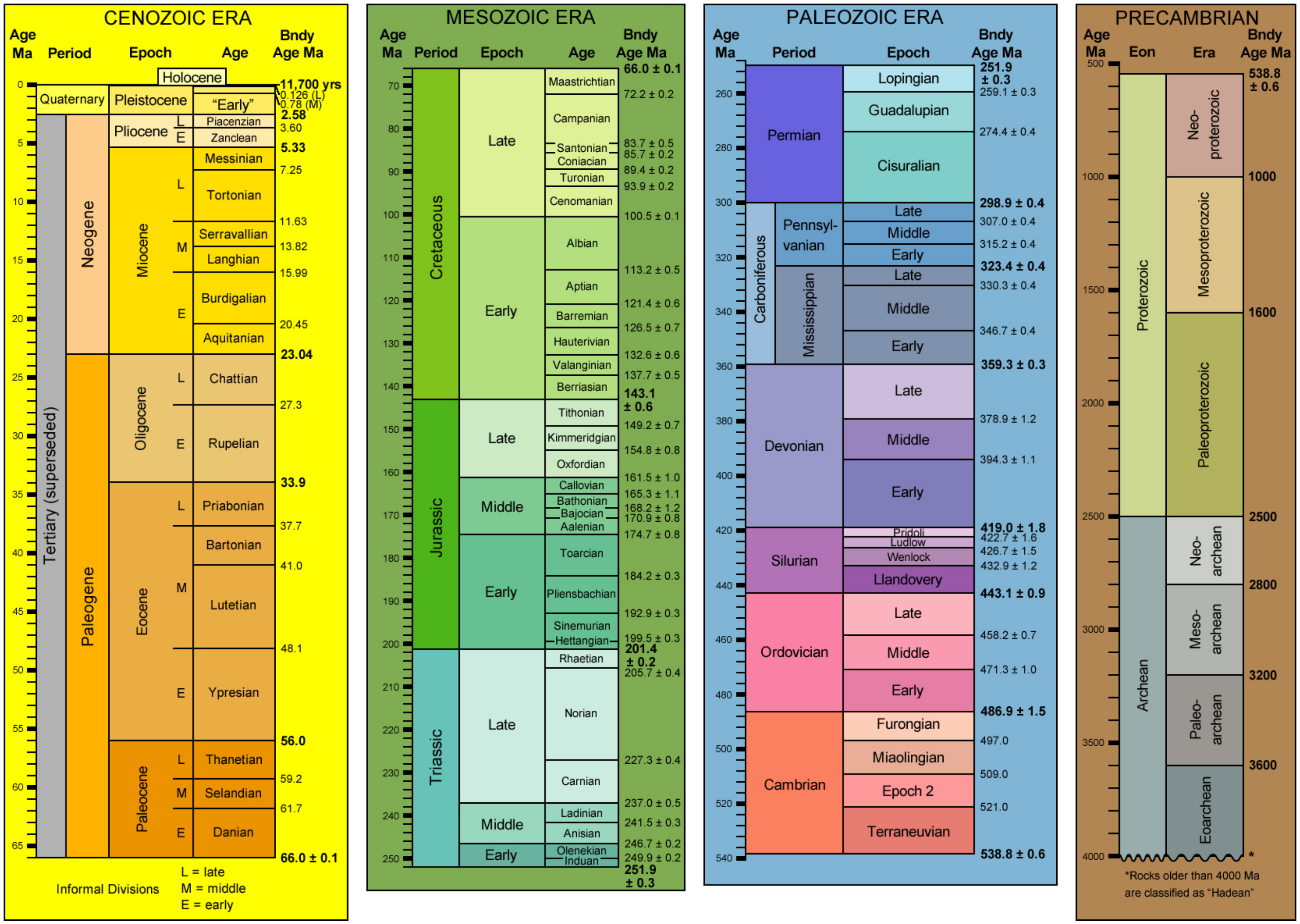

Figure B1. Geologic Time Scale. **Ma**=Millions of years old. **Bndy Age**=Boundary Age. Layout after 1999 Geological Society of America Time Scale (https://www.geosociety.org/documents/gsa/timescale/timescl-1999.pdf). Dates after Gradstein et al. (2020).

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