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Roosevelt-Vanderbilt National Historic Sites

Geologic Resources Inventory Report

Scenic view from the top of the Vanderbilt mansion looking west across the Hudson River. Both the Roosevelt and Vanderbilt estates are perched above the river valley on steep slopes capped by Pleistocene glacial till (unconsolidated, poorly sorted material consisting of fine- to coarse-grained sediment) deposited approximately 17,000 years ago. The Hudson River Valley has a rich glacial history that helped define the current landscape of the historic sites.

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Roosevelt-Vanderbilt National Historic Sites: Geologic resources inventory report

Science Report NPS/SR—2024/171

Tim C. Henderson

Colorado State University Research Associate
National Park Service Geologic Resources Division
Geologic Resources Inventory
PO Box 25287
Denver, CO 80225

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Contents

Contents (continued)

Contents (continued)

Page

Contents (continued)

Figures

Figures (continued)

Tables

Abstract

Geologic Resources Inventory reports provide information and resources to help park managers make decisions for visitor safety, planning and protection of infrastructure, and preservation of natural and cultural resources. Information in GRI reports may also be useful for interpretation. This report synthesizes discussions from a scoping meeting held in 2007 and a follow-up conference call in 2023. Chapters of this report discuss the geologic heritage, geologic history, geologic features and processes, and geologic resource management issues of Roosevelt-Vanderbilt National Historic Sites. Guidance for resource management and information about the previously completed GRI GIS data and poster (separate products) are also provided.

Acknowledgements

The GRI team thanks the participants of the 2007 scoping meeting and 2023 follow-up meeting for their assistance in this inventory. The lists of participants are in alphabetical order by last name and reflect the names and affiliations of these participants at the time of the meeting and call. Because the GRI team does not conduct original geologic mapping, we are particularly thankful for the New York State Museum/Geological Survey and New York State Department of Transportation for their maps of the area. This report and accompanying GIS data could not have been completed without them. Thanks to Trista Thornberry-Ehrlich (Colorado State University) for producing some of the figures in this report. Additional thanks to Bridgette Moore (Geological Society of America), Michelle Frauenberger (FDR Presidential Library and Museum), Richard Frieman (New York State Museum/Geological Survey), Alex Fries (NPS Harpers Ferry Center), Jonathan Hendricks (Paleontological Research Institution), Dr. Paul Karabinos (Williams College), Dr. Robert Titus (Hartwick College, retired), and Dr. Nick Ratcliffe (United States Geological Survey, retired) for their professional assistance in writing this report.

Scoping Participants

Tim Connors (NPS Geologic Resources Division)

Bruce Heise (NPS Geologic Resources Division)

Beth Johnson (NPS Northeast Region)

Dave Hayes (NPS Roosevelt-Vanderbilt National Historic Sites)

Chris Martin (NPS Saratoga National Historical Park)

Bill Kelly (New York State Museum/Geological Survey)

Dave DeSimone (Vermont Geological Survey; DeSimone Geoscience Investigations)

Trista Thornberry-Ehrlich (Colorado State University)

Don Wise (University of Massachusetts, Amherst)

Follow-up Meeting Participants

Jason Kenworthy (NPS Geologic Resources Division)

Cullen Scheland (NPS Geologic Resources Division)

Amy Bracewell (NPS Home of Franklin D. Roosevelt National Historic Site)

David Hayes (NPS Home of Franklin D. Roosevelt National Historic Site)

Aaron Weed (NPS Northeast Temperate Inventory and Monitoring Network)

Adam Kozlowski (NPS Northeast Temperate Inventory and Monitoring Network)

Edmund Sharron (NPS Northeast Temperate Inventory and Monitoring Network)

Jessica Pollack (NPS Northeast Temperate Inventory and Monitoring Network)

Karl Backhaus (New York State Museum/Geological Survey)

Suzanne McKetta (Colorado State University)

Matt Harrington (Colorado State University)

Tim C. Henderson (Colorado State University)

Report Review

Jason Kenworthy (NPS Geologic Resources Division)

Cullen Scheland (NPS Geologic Resources Division)

Adam Kozlowski (NPS Northeast Temperate Network)

Karl Backhaus (New York State Museum/Geological Survey)

Steve Schimmrich (SUNY Ulster)

Suzanne McKetta (Colorado State University)

Report Editing

Suzanne McKetta (Colorado State University)

Report Formatting and Distribution

Rebecca Port (NPS Geologic Resources Division)

Suzanne McKetta (Colorado State University)

Cullen Scheland (NPS Geologic Resources Division)

Source Maps

Donald W. Fisher (New York State Museum/Geological Survey)

New York State Department of Transportation

GRI GIS Data Production

Stephanie O'Meara (Colorado State University)

James Winter (Colorado State University)

Kajsa Holland-Goon (Colorado State University)

GRI Poster Design

Cullen Scheland (NPS Geologic Resources Division)

Executive Summary

Comprehensive park management to fulfill the mission of the National Park Service (NPS) requires an accurate inventory of the geologic features of a park unit, but park managers may not have the necessary information, geologic expertise, or means to complete such an undertaking; therefore, the Geologic Resources Inventory (GRI) provides information and resources to help park managers make decisions for visitor safety, planning and protection of infrastructure, and preservation of natural and cultural resources. Information in this GRI report may also be useful for interpretation.

Roosevelt-Vanderbilt National Historic Sites (referred to as the "historic sites" throughout this report) consist of three cooperatively managed historic sites located on top of the scenic river bluffs that rise above the Hudson River in Hyde Park, New York: (1) Eleanor Roosevelt National Historic Site; (2) Home of Franklin D. Roosevelt National Historic Site; and (3) Vanderbilt Mansion National Historic Site. Eleanor Roosevelt National Historic Site protects Val-Kill—the retreat, office, and cherished home of First Lady Eleanor Roosevelt. Home of Franklin D. Roosevelt National Historic Site preserves the birthplace, home (Springwood), and personal retreat (Top Cottage) of the 32nd United States President Franklin Delano Roosevelt ("FDR"). Vanderbilt Mansion National Historic Site encompasses a small portion of the former estate of Frederick W. Vanderbilt, including the Vanderbilt mansion and ornate formal gardens that provide an intimate look into the life of an American aristocrat during the Gilded Age. Geologic processes, features, and resources within the historic sites are integral to their history and identity. This report outlines these connections and is one of the most comprehensive, park-specific geologic reports known for the historic sites.

The landscape of the historic sites features steep hillslopes and ravines flanking the Hudson River, low-lying floodplains, rocky spurs (elevated ridges), rolling meadows, tidal wetlands, and tributary streams, in addition to historic structures, artificial ponds, roads, and trailways. The geology of the historic sites is dominated by Paleozoic Era (Ordovician Period, approximately 485 million to 444 million years ago) sedimentary rocks that are partially covered by younger Cenozoic Era (Pleistocene Epoch, approximately 2.5 million to 11,700 years ago) deposits.

This GRI report is supported by one GRI-compiled map of the surficial and bedrock geology of the historic sites. The source map used to compile the GRI Geographic Information Systems (GIS) data was originally produced by Donald Fisher (New York State Museum/Geological Survey). The GRI GIS data was first compiled in 2010 and updated in 2022. The GRI GIS data may undergo additional updates if new, more accurate geologic maps become available or if software advances require an update to the digital format. A geologic poster of the GRI GIS data draped over a shaded relief image of the historic sites and surrounding area is the primary figure referenced throughout this GRI report. Geologic map units in the GRI GIS data are referenced in this report and on the poster using map unit symbols (e.g., the Ordovician Austin Glen Formation geologic unit is referenced using the symbol **Oag**).

This GRI report is based on the most accurate, up-to-date geologic mapping known at the time of writing and compiles and summarizes park-specific, geologic information and research. It was written with park management in mind and incorporates the historic site’s significance as expressed in its foundation document.

This report contains the following chapters:

Introduction—This chapter provides background information about the GRI, highlights the GRI process and products, and recognizes GRI collaborators. This chapter highlights the GRI GIS data, which are the principal deliverable of the GRI, as well as the geologic map that served as the source map used by the GRI team in compiling the GRI GIS data. The chapter also calls attention to the poster, which illustrates the GRI GIS data. In addition, this chapter summarizes the establishment of the historic sites and describes their physiographic setting.

Geologic Heritage—This chapter highlights the significant geologic features, landforms, landscapes, and stories of the historic sites preserved for their heritage values. These stories include (1) the Taconic orogeny that deposited and deformed the bedrock underlying the historic sites, (2) the Pleistocene glacial history of the Hudson River corridor, and (3) the Maurice D. Hinchey Hudson River Valley National Heritage Area.

Geologic History—This chapter describes the chronology of geologic events that formed the present landscape. Rocks adjacent to and within the historic sites record geologic processes that took place over 1 billion years ago.

Geologic Features and Processes—This chapter describes the geologic features and processes of significance for the historic sites and highlights them in a context of geologic time. The features and processes are discussed in order of geologic time, from oldest to youngest.

Geologic Resource Management Issues—This chapter discusses management issues related to the geologic resources (features and processes) of the individual historic sites. Geologic hazard issues include: (1) flooding along the Hudson River and its tributaries; (2) Hudson River contamination issues; (3) facilities maintenance and erosion; (4) mass wasting along the Hudson River; (5) seismic activity; and (6) climate change. Information regarding these issues was compiled from the 2007 scoping summary meeting and report (Thornberry-Ehrlich 2008), individual historic site foundation documents (National Park Service 2017a, 2017b, 2017c), notes from the 2023 GRI follow-up meeting, research associated with the preparation of this report, and input from reviewers.

Guidance for Resource Management—This chapter is a follow up to the “Geologic Resource Management Issues” chapter. It provides resource managers with a variety of ways to find and receive management assistance with geologic resources. A summary of laws, regulations, and policies which apply to geologic resources is also provided.

Additional References, Resources, and Websites—This chapter provides a thorough list of additional sources of information (e.g., websites, tools, publications, organizations) that may be useful to further explore the topics presented in this report.

In addition to these chapters, a “Literature Cited” section compiles all the references cited in this GRI report. It serves as a source of park-specific geologic information that is applicable to the protection, management, and interpretation of the historic site’s geologic resources.

Introduction

Geologic Resources Inventory

The Geologic Resources Inventory (GRI), which is administered by the Geologic Resources Division of the National Park Service (NPS) Natural Resource Stewardship and Science Directorate, provides geologic map data and pertinent geologic information 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 NPS Inventory and Monitoring Program. Most inventories were point-in-time surveys to learn about the location or condition of resources, including the presence, distribution, or status of plants, animals, air, water, soils, landforms, and climate, and were completed by 2010, but several of the more extensive or complex inventories, such as vegetation and geology, are still in progress in some parks.

GRI Products

The GRI team completed the following tasks as part of the GRI process for Roosevelt-Vanderbilt National Historic Sites (referred to as the "historic sites" throughout the report): (1) conduct a scoping meeting and provide a scoping summary; (2) provide geologic map data in a geographic information system (GIS) format; (3) create a poster to display the GRI GIS data; and (4) provide a GRI report (this document). GRI products are available on the "Geologic Resources Inventory—Products" website and on the NPS DataStore through the Integrated Resource Management Applications (IRMA) portal (see "Access to GRI Products").

The information provided in GRI products is not a substitute for site-specific investigations. Ground-disturbing activities should neither be permitted nor denied based on the information provided in GRI products. Minor inaccuracies may exist regarding the locations of geologic features relative to other geologic or geographic features in the GRI GIS data or on the poster. Based on the source map scale (Fisher 1968; scale 1:24,000) and Map Accuracy Standards (US Geological Survey 1999), geologic features represented in the GRI are horizontally within 12 m (40 ft) of their true locations.

Scoping Meeting

On 9 July 2007, the NPS held a scoping meeting for the historic sites at the University of Massachusetts in Amherst, Massachusetts. The scoping meeting brought together historic site staff and geologic experts, who reviewed and assessed available geologic maps, developed a geologic mapping plan, and discussed geologic features, processes, and resource management issues to be included in the final GRI report. A scoping summary (Thornberry-Ehrlich 2008) summarizes the findings of that meeting.

GRI GIS Data

The GRI team compiled the data in 2010 and updated it in 2022. The GRI GIS data may be updated if new, more accurate geologic maps become available or if software advances require an update to the digital format. These data are the principal deliverables of the GRI. The GRI team did not conduct original geologic mapping but compiled existing geologic information (i.e., paper maps and/or digital data) into the GRI GIS data (Figure 1). Scoping participants and the GRI team identified the best available source maps based on coverage (area mapped), map scale, date of mapping, and compatibility of the mapping with the current geologic interpretation of an area.

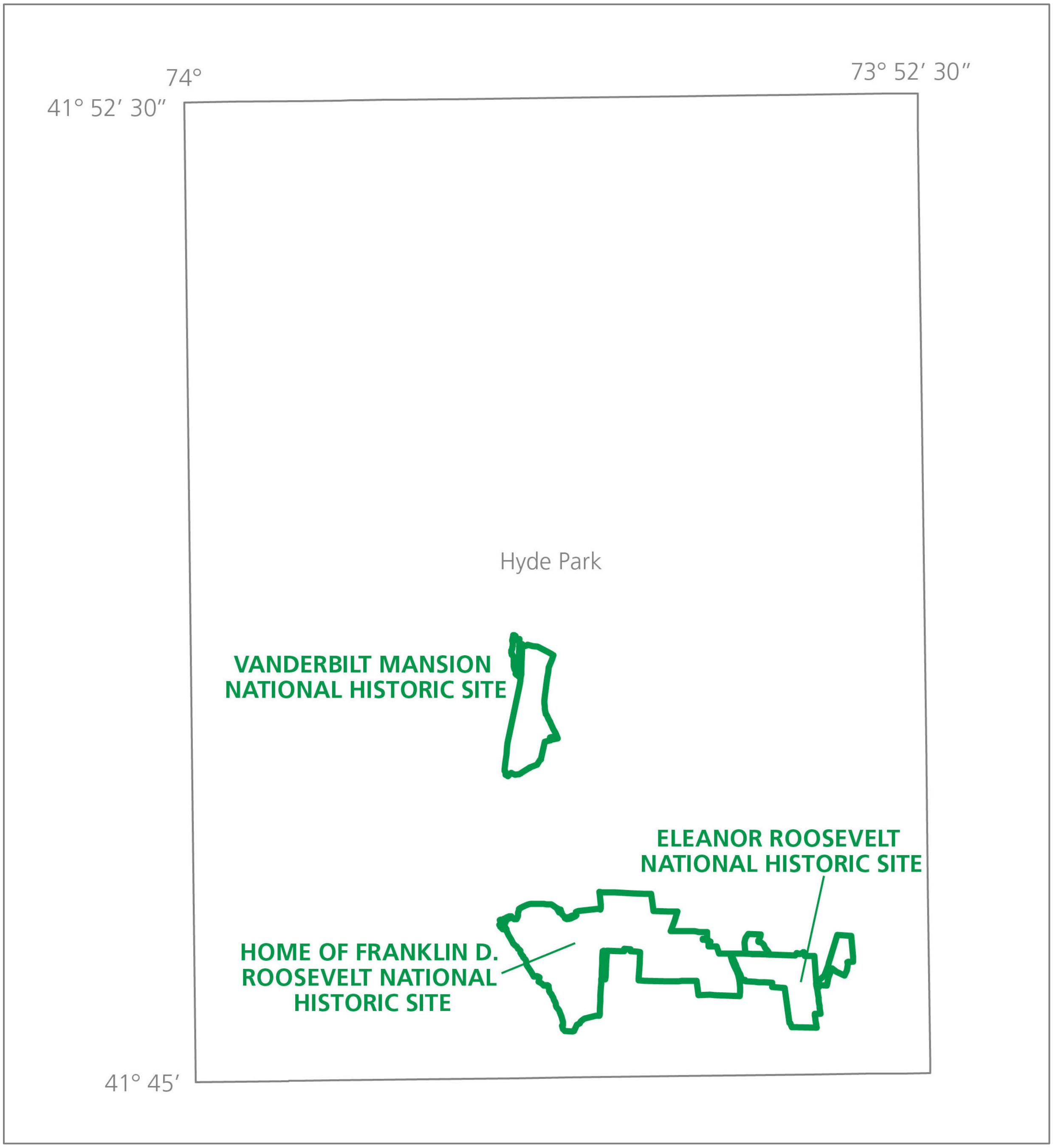

Figure 1. Index map of the GRI GIS data for the Roosevelt-Vanderbilt National Historic Sites. The map displays the extent of the Hyde Park 7.5' quadrangle (outlined in gray) which is also the extent of the GRI digital geologic-GIS map produced for the historic sites. The boundaries for the three national historic sites (as of April 2022) are outlined in green. GRI graphic by Kajsa Holland-Goon (Colorado State University).

More information about the GRI GIS data can be found in the files accompanying the data on the NPS DataStore. The “GIS readme file” explains the available file formats for the GRI GIS data, how to use the different file formats, and where to find more information about the GIS data model. The “ancillary map information document” lists the geologic maps or GIS data used to produce the GRI GIS data, the map units and map unit descriptions (including descriptions from all source maps), and additional information about the source maps.

The GRI GIS data for the historic sites was compiled from the following two source maps:

- Fisher, D. W. 1968. Draft Geologic Map of the Hyde Park New York 7.5’ Quadrangle: New York Geological Survey, Open File Report of-1gG745b (unpublished), scale 1:24,000.
- New York State Department of Transportation. 1973. Topographic Map of the Hyde Park Quadrangle, New York: New York State Department of Transportation, 7.5-Minute Series (2nd Edition), scale 1:24,000.

The source map of Fisher (1968) covers both the bedrock and surficial geology of the Hyde Park area, which encompasses the historic sites. The Hyde Park 7.5-Minute quadrangle extends from Hyde Park north to Staatsburg and crosses the Hudson River to include Ulster Park and West Park. The stratigraphy (geologic unit names, stratigraphic contacts) and symbology (faults, fossil localities, strike/dip measures) were completed by D. W. Fisher; map unit descriptions were provided by William Kelly (New York State Museum/Geological Survey). Although the original source map depicted the Poultney Formation along the southern part of the quadrangle, these deposits are now considered part of the Stuyvesant Falls Formation (**Osf**). Additionally, rocks interpreted by Fisher (1968) to be the Snake Hill Formation have now been grouped into the Austin Glen Formation (**Oag**) (National Park Service 2022). The GRI used the New York State Department of Transportation (1973) source map to capture mine and water/shoreline features.

GRI Poster
A poster of the GRI GIS data draped over a shaded relief image of the historic sites and surrounding area is the primary figure referenced throughout this GRI report. The poster is not a substitute for the GIS data but is supplied as a helpful tool for office and field use and for users without access to ArcGIS. Not all GIS feature classes are included on the poster (e.g., mine locations), and geographic information and selected park features have been added. Digital elevation data and added geographic information are not included in the GRI GIS data but are available online from a variety of sources.

GRI Report
On 1 February 2023, the GRI team hosted a follow-up meeting for historic site staff and interested geologic experts (see “Acknowledgements”). The call provided an opportunity to get back in touch with park staff, introduce “new” (since the 2007 scoping meeting) staff to the GRI process, and update the list of geologic features, processes, and resource management issues for inclusion in the final GRI report.

This report and the poster are the culmination of the GRI process. The report synthesizes discussions from the scoping meeting in 2007, the follow-up conference call in 2023, reviewers’ comments in

2023, and additional geologic research. The selection of geologic features discussed in the report was guided by the previously completed GRI GIS data and discussions during the scoping and follow-up meetings. Notably, the writing reflects the geologic interpretation provided by the authors of the source maps (see “GRI GIS Data”). Information from the individual historic site foundation documents (National Park Service 2017a, 2017b, 2017c) was also included as applicable to geologic resources and resource management. Another primary source of literature used to prepare the report content was the natural resource condition assessment report by Cole et al. (2012).

The GRI report links the GRI GIS data to the geologic features and processes discussed in the report using map unit symbols; for example, the Ordovician Austin Glen Formation mapped at all three historic sites has the map symbol **Oag**. Capital letters indicate age, and the following lowercase letters symbolize the unit name. “**O**” represents the Ordovician Period (approximately 485.0 million to 444.0 million years ago), and “**ag**” represents the Austin Glen Formation.

The primary audience of GRI reports is park resource managers, but the GRI team hopes that these reports will appeal to and be useful for other audiences, such as park interpreters and the general public. To that end, the reports try to avoid technical terms and keep the writing accessible to readers without a background in geology. Nevertheless, like most sciences, geology is a science that is full of jargon and based on complex concepts that have changed over time with more information and greater understanding. Thus, GRI reports use geologic terminology, but terms are defined at first instance, usually in parentheses following the term. Commonly, graphics are provided to illustrate unfamiliar concepts.

Geologic and geographic names used in this report reflect the formal nomenclature found in the US Geologic Names Lexicon (“Geolex”) and the spellings recorded in the Geographic Names Information System (GNIS), respectively. Geolex is a national compilation of names and descriptions of geologic units maintained by the USGS (see “Additional References, Resources, and Websites”). GNIS contains geographic terms that the US Board on Geographic Names has formally accepted. In 1947, the Secretary of the Interior was given joint authority with the US Board on Geographic Names and has final approval of the board’s actions. The online GNIS database is maintained by the USGS (see “Additional References, Resources, and Websites”).

Roosevelt-Vanderbilt National Historic Sites

Roosevelt-Vanderbilt National Historic Sites (referred to as the “historic sites” throughout this report) consist of three neighboring historic sites situated atop the scenic bluffs of the Hudson River in the town of Hyde Park, Dutchess County, New York: (1) Home of Franklin D. Roosevelt National Historic Site; (2) Eleanor Roosevelt National Historic Site; and (3) Vanderbilt Mansion National Historic Site. The three historic sites are cooperatively managed to preserve portions of the former Roosevelt and Vanderbilt estates. Wealthy families such as the Roosevelts and Vanderbilts were attracted to Hyde Park due to its proximity and railroad accessibility to New York City, the sprawling cultivated countryside, and the aesthetic Hudson River Valley views juxtaposed against the Catskill, Shawangunk, and Taconic Mountains (Nowak 2005).

Home of Franklin D. Roosevelt National Historic Site

Home of Franklin D. Roosevelt National Historic Site is located along the east bank of the Hudson River, approximately 4 km (2.5 mi) south of the Vanderbilt estate (Figure 2). The nearly 344-ha (850-ac) historic site was designated on 16 January 1944, and preserves the birthplace, home (Springwood), and personal retreat (Top Cottage) of the 32nd President of the United States, Franklin Delano Roosevelt ("FDR"). President Roosevelt led the nation through two national crises—the Great Depression and World War II—and is considered an iconic political figure. The Springwood home, Top Cottage, and surrounding rural landscape of the historic site are where FDR developed a passion for the natural world and crafted social and political policies that redefined the role of the federal government (National Park Service 2017b; Auwaerter 2022). The historic site is an homage to FDR's marriage and political partnership with First Lady Eleanor, as the estate is where they lived, raised their family, entertained political dignitaries, and are buried together in the Rose Garden. Although the FDR Presidential Library and Museum is located on a portion of the former Roosevelt estate, it is not within the historic site boundary and is managed by the US National Archives and Records Administration.

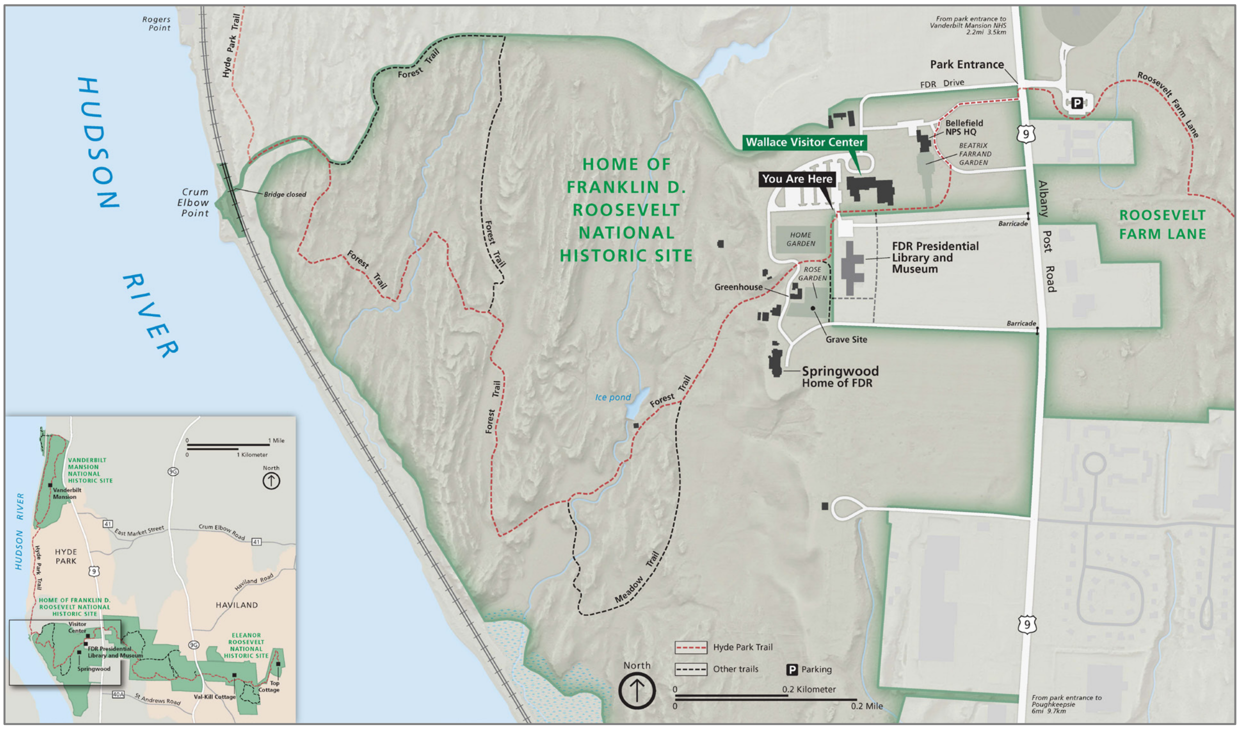

Figure 2. Map showing portions of the Springwood and Roosevelt Farm Lane units of Home of Franklin D. Roosevelt National Historic Site. The historic site consists of nearly 344 ha (850 ac) distributed amongst 4 separate parcels. The inset map shows the configuration of the historic site relative to Roosevelt-Vanderbilt National Historic Sites. The Springwood mansion, FDR Museum and Library, and Roosevelt Farm and Forest parcel are accessible along Albany Post Road (NY State Route 9) that continues north toward the Vanderbilt estate. Additional entry to the Roosevelt Farm and Forest unit is located along Violet Avenue (NY State Route 9G). NPS maps are available at https://www.nps.gov/subjects/gisandmapping/nps-maps.htm.

The Roosevelt estate is situated on the east bank of the Hudson River and provides scenic views of the Catskill Mountains and Shawangunk Mountains to the west. The landscape of the historic site consists of steep river bluffs, ravines, rocky spurs (elevated ridges), stream valleys, and rolling hills adorned with fields, forests, gardens, orchards, ponds, and wetlands (see Figure 2). Significant tracts of land were dedicated to tree farms established by FDR over several decades. Roosevelt's deep appreciation for forestry practices established a relationship with the New York State College of Forestry (now the SUNY College of Environmental Science and Forestry), and together they developed an extensive reforestation program that planted over 500,000 trees on the Roosevelt estate between 1912 and 1945 (Auwaerter and Curry 2009; Auwaerter 2022). The management and conservation of the family estate reflect FDR and Eleanor's environmental and social ideas that were later incorporated into some of the Roosevelt administration's New Deal programs (Auwaerter and Curry 2009).

Eleanor Roosevelt National Historic Site

Eleanor Roosevelt National Historic Site was authorized on 26 May 1977, and preserves Val-Kill, the retreat, office, and cherished home of First Lady Eleanor Roosevelt. The 73-ha (180-ac) property lies approximately 2.5 km (1.5 mi) east of the Hudson River on part of the Roosevelt estate between Roosevelt Farm and Forest and FDR's Top Cottage (Figure 3). According to its foundation document (National Park Service 2017a, p. 5), the historic site was established "to recognize the lifework of Eleanor Roosevelt, wife and political partner of Franklin D. Roosevelt ["FDR"] and preserve and interpret a place central to her emergence as a public figure, so that current and future generations can understand her life and legacy as a champion of democracy and pursue discussion about human rights issues." At Val-Kill, Eleanor published books and newspaper articles, hosted foreign dignitaries, served as the first US delegate to the newly formed United Nations, chaired the committee that drafted the Universal Declaration of Human Rights, and became one of the most influential social and political figures of her time (Nowak 2005; National Park Service 2017a).

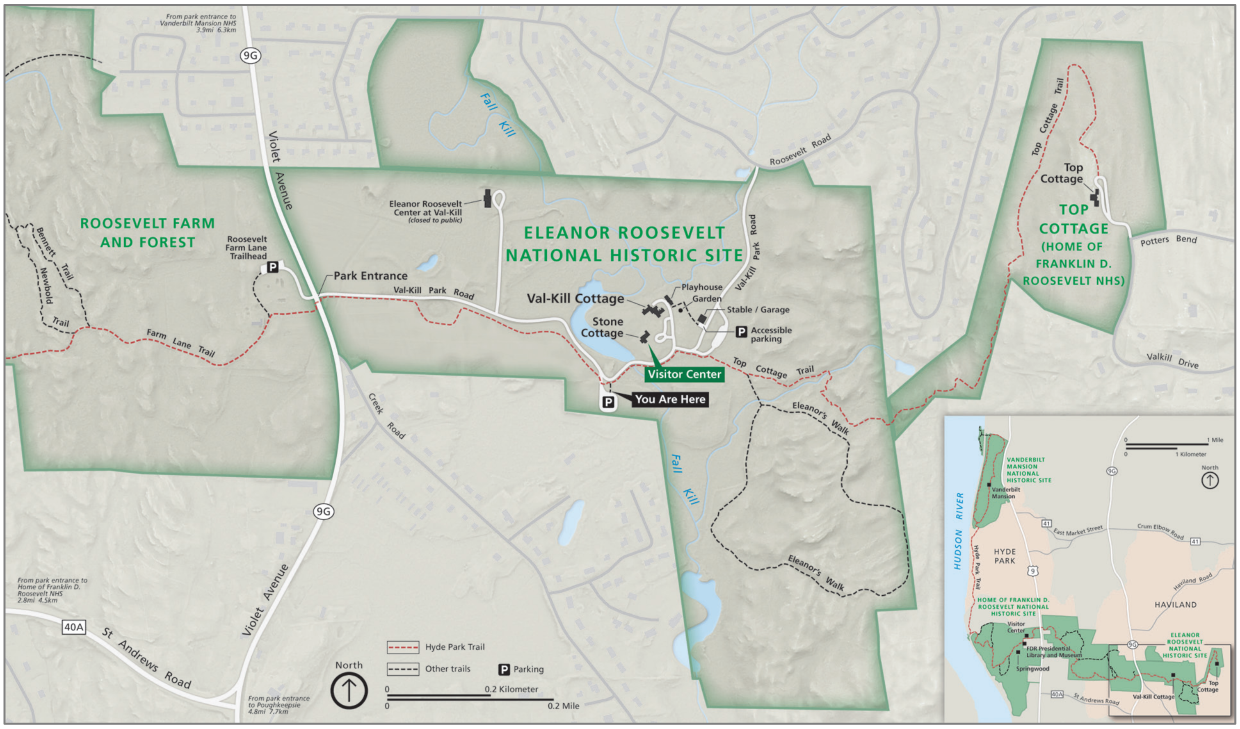

Figure 3. Map of Eleanor Roosevelt National Historic Site and surrounding units of Home of Franklin D. Roosevelt National Historic Site. Eleanor Roosevelt National Historic Site encompasses 73 ha (180 ac) of the Roosevelt estate, including historic structures such as Val-Kill Cottage, forests, trails, and wetland features. The inset map shows the configuration of the historic site relative to Roosevelt-Vanderbilt National Historic Sites. The main historic site entrance is located along Violet Avenue (New York State Route 9G). NPS maps are available at https://www.nps.gov/subjects/gisandmapping/nps-maps.htm.

The core of the historic site consists of Val-Kill Cottage, Stone Cottage, and other historic structures such as the stable-garage, doll house, playhouse, and swimming pool (see Figure 3). The Stone Cottage was built in 1924 by Eleanor and close friends Nancy Cook and Marion Dickerman as a year-round recreational retreat. After the Stone Cottage was completed, the three friends constructed and jointly managed a furniture factory named Val-Kill Industries until it closed in 1936 due to the economic downturn of the Great Depression (Nowak 2005). Eleanor converted the factory into Val-Kill Cottage in 1937 and, after the passing of FDR, made it her permanent residence in 1945.

Surrounding the main buildings are agricultural fields, gardens, ponds, wetlands, and FDR's tree farms. The landscape of the historic site features flat to gently sloping topography in the west that transitions into steeper, more heavily forested hills toward the east. The Fall Kill Creek traverses the central portion of the historic site and serves as an integral natural resource that is part of the cultural landscape; even the namesake "Val-Kill" is derived from a Dutch phrase meaning "valley stream." In the 1920s and 1930s, a small section of the Fall Kill was dammed and dredged (removal of sediments and debris from the bottom of a river, lake, or other water body) by the Roosevelts to form Val-Kill Pond immediately adjacent to the Stone Cottage and Val-Kill Cottage (Pandullo Quirk Associates 1979; Nowak 2005; National Park Service 2017a).

Vanderbilt Mansion National Historic Site

Vanderbilt Mansion National Historic Site is situated atop the eastern bluffs of the Hudson River, approximately 4 km (2.5 mi) north of the Roosevelt estate (Figure 4). The historic site was established on 18 December 1940, with fervent support from FDR. The 49-ha (120-ac) property preserves a small portion of the former estate of Frederick W. Vanderbilt, grandson of business tycoon Cornelius Vanderbilt. The centerpiece and namesake of the historic site is the Vanderbilt mansion, an elegant 50-room Beaux-Arts-style house of superior design that provides an intimate look into the life of an American aristocrat during the Gilded Age (National Park Service 2017c). Adjacent to the mansion is the Pavilion, a former guest house of the Vanderbilt family that now functions as the visitor center. The preserved estate also contains eight additional historic buildings as well as bridges, dams, garden structures, and trails.

The landscape surrounding the mansion features ornate formal gardens, forest plantations (forestry was a hobby Frederick Vanderbilt shared with FDR), steep Hudson River bluffs, rolling meadows, ponds, wetlands, and the lower stream valley of Crum Elbow Creek (see Figure 4). The ornately designed grounds of the estate are a product of five generations of ownership, representing nearly two centuries of development (Hammond 2009; National Park Service 2017c). The estate was of particular interest to FDR, who valued the Vanderbilt property for its historical integrity, scenic viewshed over the Hudson, and its aged collection of trees (Albee et al. 2008).

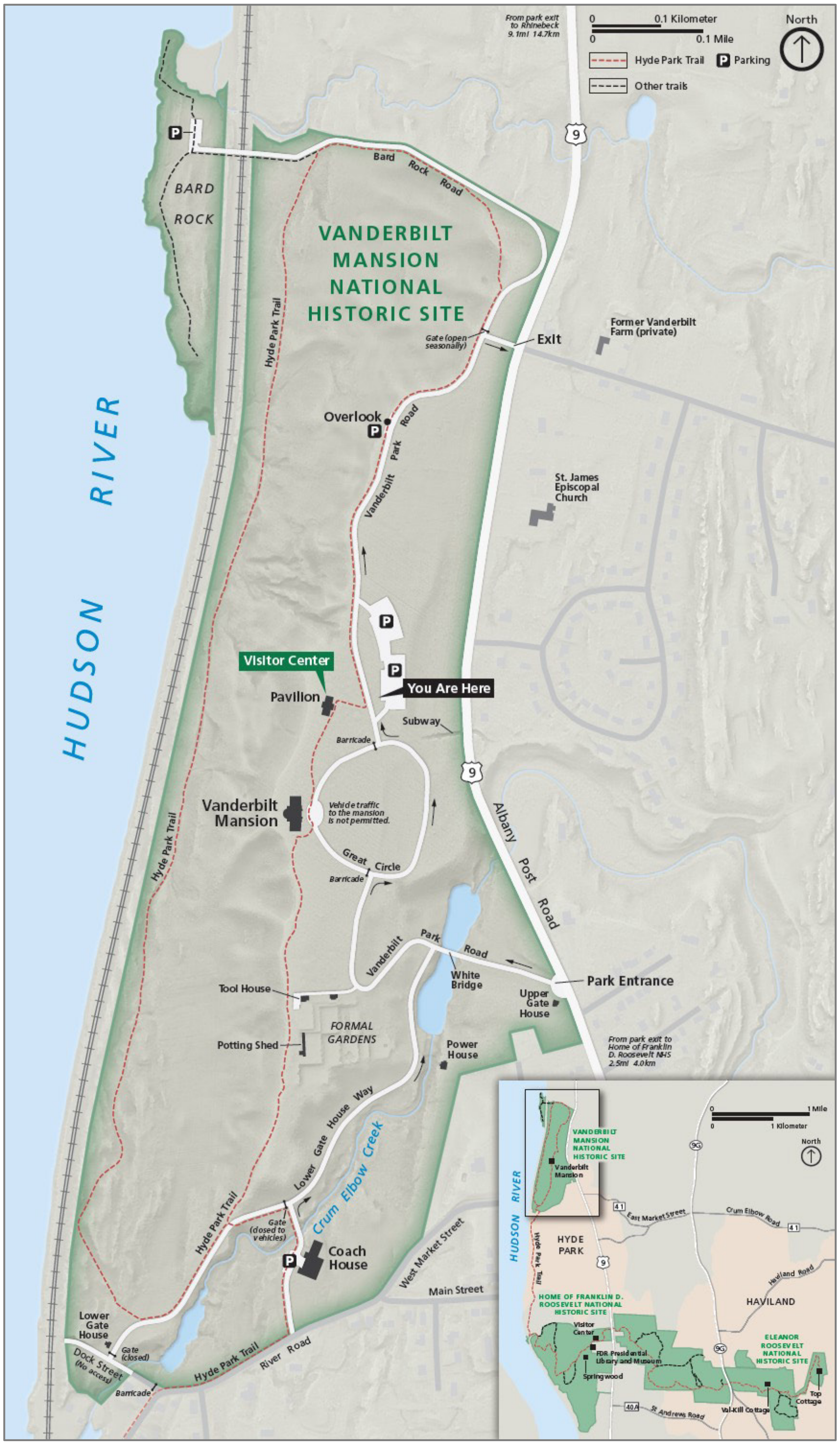

Figure 4. Map of Vanderbilt Mansion National Historic Site. Located along the scenic bluffs of the Hudson River, the historic site preserves 49 ha (120 ac) of the Vanderbilt estate, including the ornate mansion and formal gardens. Inset map shows the configuration of the historic site relative to Roosevelt-Vanderbilt National Historic Sites. The main visitor entrance is located along Albany Post Road (New York State Route 9) that continues south toward the Roosevelt estate. NPS maps are available at https://www.nps.gov/subjects/gisandmapping/nps-maps.htm.

Physiographic Setting

The landscape of the historic sites features steep hillslopes and ravines flanking the Hudson River, low-lying floodplains, rocky spurs (elevated ridges), rolling meadows, tidal wetlands, and tributary streams, in addition to historic structures, artificial ponds, roads, and trailways. Situated in the Hudson Lowlands of the Valley and Ridge physiographic province of southeastern New York, the geology of the historic sites is dominated by Paleozoic sedimentary rocks that are partially covered by younger Cenozoic deposits. The bedrock underlying the Roosevelt and Vanderbilt estates is composed of marine Ordovician strata that were compressed, faulted, and emplaced during an ancient mountain-building event called the Taconic orogeny. The surficial geology within and surrounding the historic sites consists of Quaternary glacial till (unconsolidated, poorly sorted material consisting of fine- to coarse-grained sediment), deltaic deposits (sands and gravels), lake sediments (clays and silts), and erratics (ice-transported boulders of various rock types) that were deposited during the recessional stages of the Laurentide Ice Sheet (the most recent continental glaciation of North America) approximately 17,000 years ago. During the Pleistocene Epoch, multiple glacial advances carved out the Paleozoic bedrock to widen and deepen the Hudson River Valley. As the glaciers melted and receded north, an immense amount of meltwater was created, which formed a series of glacial lakes. Today, remnant glacial deposits form the flat terrace topography of Hyde Park and underlie both the Springwood and Vanderbilt mansions.

The Hudson fluvial (river) system—including the Fall Kill, Maritje Kill, and Crum Elbow Creek tributaries—is the predominant landscape feature of the historic sites. The waterway is a dynamic and vital natural resource, as it drains the watershed, erodes and reworks the floodplain adjacent to the river channel, and carries nutrients that sustain ecosystems. However, the Hudson River and its tributaries present many management issues at the historic sites, especially in low-elevation regions (see “Geologic Resource Management Issues”).

Geologic Heritage

This chapter highlights the geologic features, landforms, landscapes, and stories of the historic sites valued for their geologic heritage. Geologic heritage exists at the overlap of geology and humanity and encompasses important aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific qualities. It also draws connections between geologic resources and other park resources and stories.

Geologic Heritage Sites and Conservation

Geologic heritage (also called "geoheritage") evokes the idea that the geology of a place is a part of its history and cultural identity. In 2015, in cooperation with the American Geosciences Institute (AGI), the GRD, which administers the GRI (see "Introduction to the Geologic Resources Inventory"), published *America's Geologic Heritage: An Invitation to Leadership* (National Park Service and American Geosciences Institute 2015). That booklet introduced the American experience of geologic heritage and outlined key principles and concepts, including the following five big ideas:

- America's geologic landscape is an integral part of its history and cultural identity, and Americans have a proud tradition of exploring and preserving geologic heritage.
- America's geologic heritage, as shaped by geologic processes over billions of years, is diverse and extensive.
- America's geologic heritage holds abundant values—aesthetic, artistic, cultural, ecological, economic, educational, recreational, and scientific—for all Americans.
- America's geologic heritage benefits from established conservation methods developed around the world and within the United States.
- America's geologic heritage engages many communities, and involvement by individuals will ensure its conservation for future generations.

Geoheritage sites are conserved so that their lessons and beauty will remain as a legacy for future generations. Such areas generally have great potential for scientific studies, use as outdoor classrooms, and enhancing public enjoyment. Geoheritage sites are fundamental to understanding dynamic Earth systems, the succession and diversity of life, climatic changes over time, the evolution of landforms, and the origin of mineral deposits. Currently, the United States does not have a comprehensive national registry of geoheritage sites. Though park units have not been established specifically for geoheritage values, any geologic component of a park's enabling legislation or planning and management documents can be considered a part of America's geoheritage.

Geologic Connections to Park Resources

The Taconic Orogeny

The bedrock beneath the historic sites is made up of marine sedimentary and metasedimentary (metamorphosed sedimentary) strata (layers) which were compressed, faulted, and thrust westward during an ancient mountain-building event called the Taconic orogeny. The name "Taconic" is derived from the Taconic Ranges in eastern New York and western New England, which rise to the east of the historic sites. The Taconic orogeny occurred during the Middle Ordovician to early Silurian Periods approximately 470 million to 440 million years ago and is interpreted as a collision between an ancient landmass known as Laurentia (ancestral North America) and a series of volcanic islands (Karabinos et al. 2003; Hurowitz and McLennan 2005; Jacobi and Mitchell 2018; Hildebrand and Whalen 2021). Today, the orogeny is represented by an extensive zone (called the Taconic orogenic zone) of deformed Paleozoic rock (Cambrian-Ordovician formations about 541 million to 444 million years old) that is approximately 100 km (60 mi) wide and more than 2,000 km (1,200 mi) long (Zen 1972; Landing 2007). Located in parts of both Canada and the United States, the Taconic orogenic zone encompasses northwestern Newfoundland, eastern Quebec, western Vermont, eastern New York, and north-central New Jersey to southeastern Pennsylvania (Zen 1972). It is believed that the Taconic orogeny is the first of three successive mountain-building episodes in the Appalachian Mountains.

The formation of the Taconic orogeny has a long history of study dating back to the early 19th century and was once a source of geologic debate involving criminal accusations, libel litigation, and resignations (Seward 2021). Geologists continue to debate specific structural and tectonic elements of the event, with different models involving the collision of one or multiple volcanic island arcs (chains of active volcanoes), the incorporation of one or multiple subduction zones (regions where one lithospheric plate descends beneath another), and differing subduction directions (Karabinos et al. 2003; Jacobi and Mitchell 2018; Hildebrand and Whalen 2021). One of the simplest models for the Taconic orogeny was proposed by Rowley and Kidd (1981) and involves an east-dipping subduction zone below a single volcanic island arc (Figure 5). According to their model, the subduction of Laurentia's distal oceanic crust beneath the volcanic island arc facilitated the closure of the ancient Iapetus Ocean (precursor to the modern Atlantic Ocean) and enabled melting in the mantle that fueled the volcanic origin of the islands (Rowley and Kidd 1981). At the subduction zone trench, sediments of the downgoing (sinking) oceanic slab were scraped off and incorporated into the overriding plate to form an accretionary wedge (steeply inclined, fault-bounded accumulations of rock material) in front of the advancing volcanic arc (Figure 5). The collision of Laurentia and the island arc terrane (a block of crust that is geologically unique from surrounding rocks) pushed deep marine sediments of the accretionary wedge and continental slope/rise to the west, where they now overlie shallow marine rocks of the Laurentian continental shelf (Rowley and Kidd 1981; Bosworth and Kidd 1985; Isachsen et al. 2000). Referred to as the Taconic allochthon, this sequence of thrusted rocks forms the bedrock underlying the historic sites and is widely mapped across eastern New York and the western portions of Vermont, Massachusetts, and Connecticut.

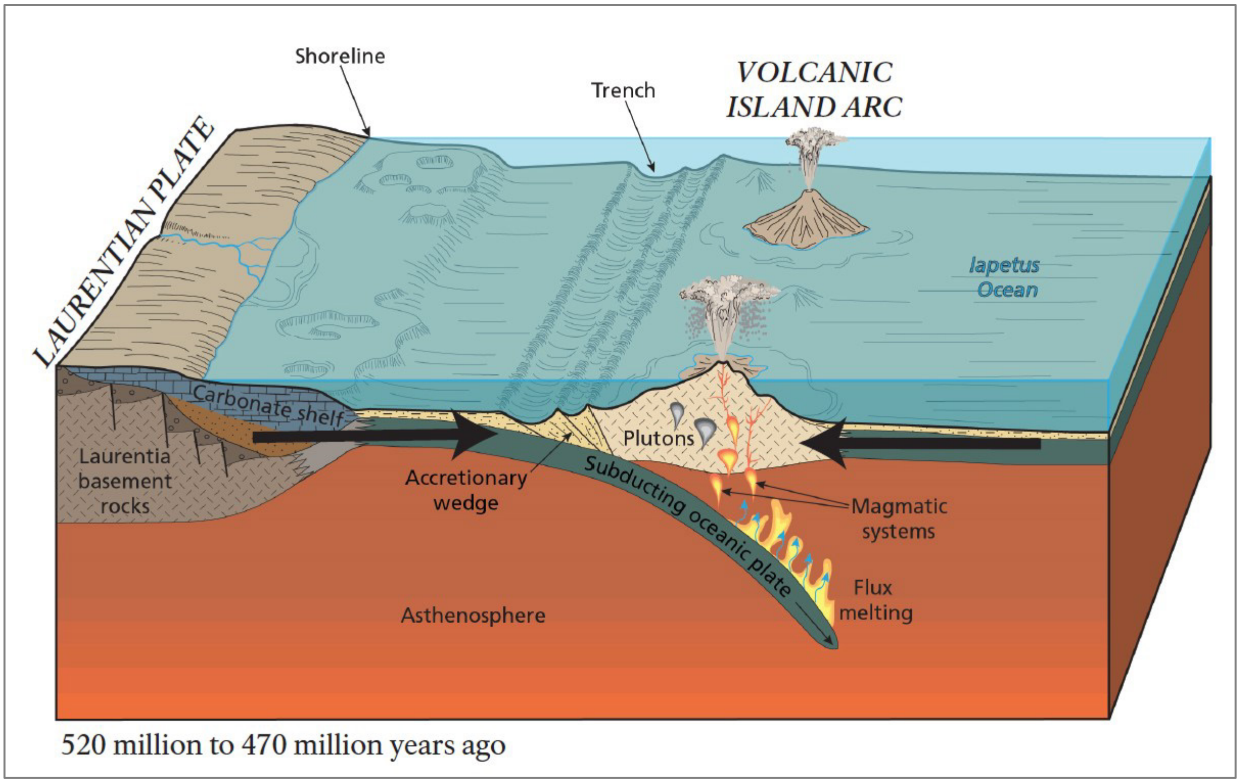

Figure 5. A simplified cross-sectional model prior to the Taconic orogeny. In this model, the Laurentian plate is converging with and subducting below volcanic island arc fragments about 520 million to 470 million years ago (Cambrian–Ordovician Periods). The bedrock underlying the historic sites was originally deposited as an accretionary wedge along the trench between the colliding land masses. As the orogeny progressed, marine sediments of the accretionary wedge and continental slope/rise were compressed, faulted, and thrust hundreds of kilometers west to their current position. Graphic created by Trista L. Thornberry-Ehrlich (Colorado State University).

The Taconic allochthon is a complex area of broken, folded, and sheared rocks that form a series of roughly northeast–southwest trending thrust faults and slices (Zen 1967; Rowley and Kidd 1981; Landing 1988, 2007; Vollmer and Walker 2009; Hildebrand and Whalen 2021). The terms "allochthon" or "allochthonous" are used to describe blocks of rock that have been compressed and transported from their original depositional setting along low angle thrust faults. Estimates of thrust displacement for the Taconic allochthon range from 200 km (120 mi) to nearly 1,000 km (620 mi) (Stanley and Ratcliffe 1985; Hurowitz and McLennan 2005). Ordovician rocks mapped within and immediately surrounding the historic sites are considered part of the lower thrust sheets along the western leading edge of the regional Taconic thrust belt (Kidd et al. 1995; Landing 2007; Vollmer and Walker 2009). Fisher (1968) mapped the older rocks of the Stuyvesant Falls Formation (**Osf**) in fault juxtaposition against younger strata of the Austin Glen Formation (**Oag**) in the eastern part of the Roosevelt estate near Val-Kill and Top Cottage (see poster). In Dutchess County, the underlying bedrock that comprises the allochthon displays a pattern of deformation and metamorphism that generally increases from the northwest to the southeast (Balk 1936; Vidale 1974; Donnelly 1998; Vollmer and Walker 2009). The westernmost thrust slices along the Taconic thrust belt include relatively undeformed sequences of strata that have been vital in deciphering the complicated structural and stratigraphic relationships associated with the Taconic orogeny (Rowley and Kidd 1981).

More information about the geologic units within the historic sites can be found in the "Geologic Features and Processes" section of this report.

Pleistocene Glacial History of the Hudson River Valley

The historic sites are marked by geologic features that record an interval in Earth's history in which thick, extensive ice sheets advanced and retreated across North America. The recent geologic history of the historic sites is defined by multiple Pleistocene glacial episodes ("Ice Ages") that sculpted the landscape of the Hudson Lowlands. Continental glaciers associated with the Laurentide Ice Sheet advanced south across Canada and the northern United States, beveling hills and other elevated features while transporting vast amounts of entrained sediment along the way. The direction of the ice flow paralleled the Hudson River Valley and scoured the underlying bedrock to widen and deepen the valley floor (Johnsen 1976). When the glacial ice melted and retreated north, enormous quantities of meltwater and unconsolidated sediment were released. Today, the surficial geology of the Hyde Park area consists of glacial debris that partially blankets older bedrock in the form of glacial drift or till (unconsolidated, poorly sorted material consisting of fine- to coarse-grained sediment; **PLt**), deltaic deposits (sands and gravels; **PLd**), lake sediments (clays and silts; **PLl**), and erratics (see poster).

Although glaciers have repeatedly covered the Hudson River Valley, evidence of previous glaciations has been widely destroyed or buried by subsequent glacial events (Cadwell et al. 2003). The region encompassing the historic sites contains physical evidence of the most recent glacial episode in North America, the Wisconsinan (or Wisconsin) glaciation. This glaciation began approximately 75,000 years ago, reached its maximum southern ice extent (the "Last Glacial Maximum") roughly 21,000 years ago, and ended about 11,000 years ago (Lewis and Stone 1991; Goldthwait 1992; Sirkin 1999; Gibbard and Cohen 2008). In the state of New York, the southernmost ice extended along Long Island and is recorded in extensive till and moraine (linear ridges of till that accumulate along glacial margins) deposits (see GRI report for Sagamore Hill National Historic Site by Henderson 2024). Glacial moraine features were deposited along the margins of the Laurentide Ice Sheet as it incrementally melted and retreated northward. In Dutchess County, these moraines resemble a ridge of hummocky hills that are traceable for 8–24 km (5–15 mi) from west to east and rise approximately 55 m (180 ft) above the surrounding landscape (Connally and Sirkin 1986; Budnik et al. 2010). One of these moraine features—the Hyde Park moraine—extends from Hyde Park east to the New York-Connecticut border (Connally and Sirkin 1986; Miller and Nester 2006). The western limit of the Hyde Park moraine is mapped adjacent to Top Cottage, near the eastern boundary of the Roosevelt estate.

As the Laurentide Ice Sheet receded north across New York, glacial meltwater was impounded between the moraines and the retreating ice front to form a series of ancient glacial lakes that inundated the lower Hudson River Valley (Glacial Lake Hudson), middle Hudson River Valley

(Glacial Lake Albany), Champlain Lowlands (Glacial Lake Vermont), and present-day Lake Ontario Basin (Glacial Lake Iroquois) (Johnsen 1976; Connally and Sirkin 1986; Cadwell et al. 2003; Donnelly et al. 2005). Glacial Lake Albany occupied the area of the historic sites for several thousand years and accumulated thick layers of lacustrine (lake) silt and clay (**PLl**) in the deep, quiet waters along the lake bottom (Donnelly et al. 2005). Although not depicted in the GRI GIS data, mapping by Cadwell (1989) and Cadwell et al. (1996) show lacustrine deltaic sand and gravel deposits underlying the Roosevelt and Vanderbilt mansions. These deltaic sediments are believed to have been deposited during the formation of the Hyde Park moraine as meltwater tributaries emptied into Glacial Lake Albany (Connally and Sirkin 1986; Titus and Titus 2012). Similar lake delta deposits (**PLd**) are located surrounding the historic sites (see poster).

Approximately 13,400 years ago, the ice dam impounding Glacial Lake Iroquois at Covey Hill (Quebec, Canada) failed, leading to a series of glacial outburst floods referred to as jökulhlaups (an Icelandic term meaning “glacial leap”) that flowed south through the Champlain Lowlands and Hudson River Valley (Figure 6; Donnelly et al. 2005; Pendleton 2021). The pulses of floodwater released during the jökulhlaups deeply incised and scoured the fine-grained lacustrine sediments (**PLl**) of Glacial Lake Albany that had accumulated within and surrounding the historic sites. Remnant lake deposits can still be found along the edges of the Hudson River in nearby Staatsburg (see poster). As the outburst floods continued south through the Hudson River Valley, they breached a glacial moraine dam at the Narrows (a tidal strait separating Staten Island and Brooklyn) in New York City and deposited large sediment lobes on the North Atlantic continental shelf (Figure 6; Donnelly et al. 2005). As Glacial Lake Albany drained following the Ice Age, lacustrine and deltaic sediments were left stranded high above the Hudson River Valley where they cap the bluffs of Hyde Park today. Both the Roosevelt and Vanderbilt families built their estates at the crest of these deposits.

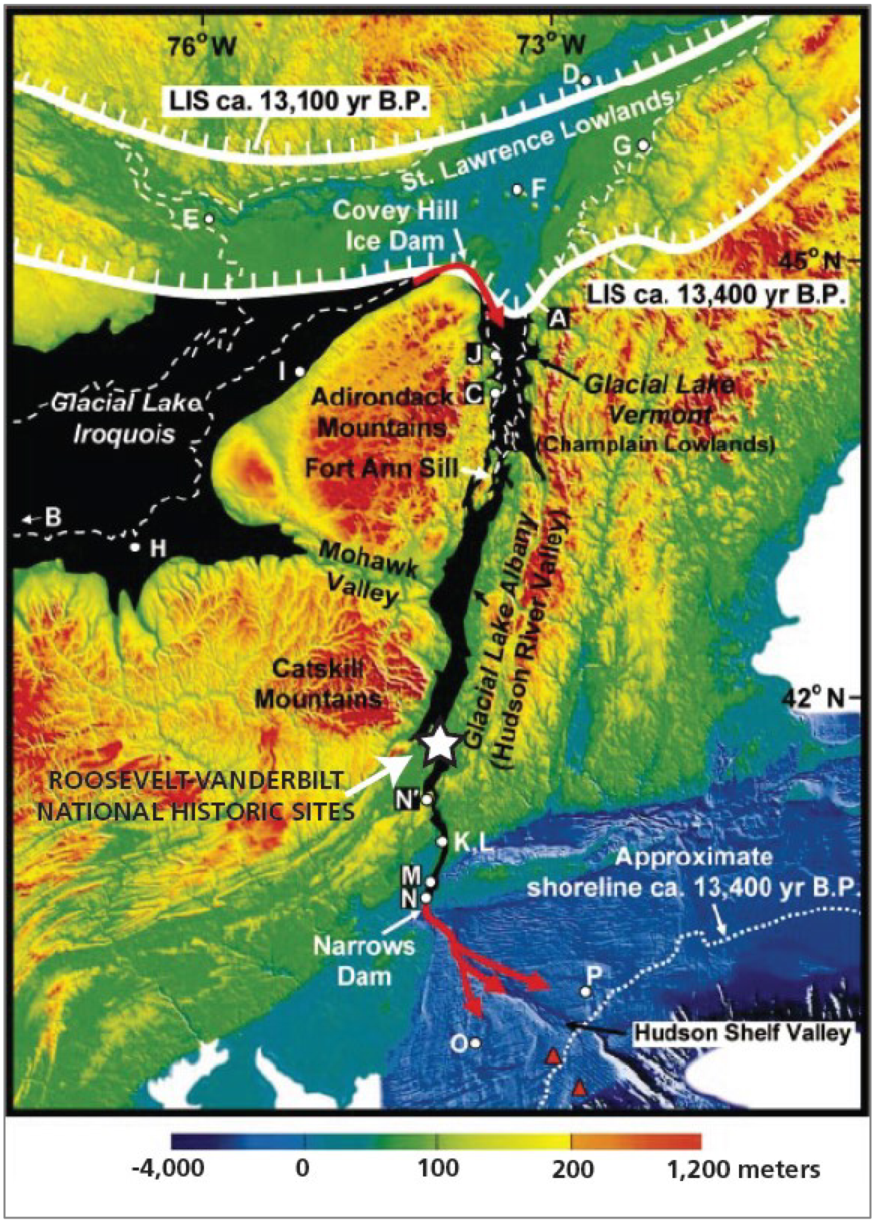

Figure 6. Relief and bathymetric map of the northeast US margin and southern Canada. The black shaded areas represent the approximate extent of Pleistocene glacial lake systems ca. 13,400 years ago. The approximate location of the historic sites is at the southern end of Glacial Lake Albany (denoted by the white star). Solid white lines mark the southern margin of the Laurentide Ice Sheet (LIS) ca. 13,400 and 13,100 years ago. Red arrows indicate the meltwater path following the Covey Hill Ice Dam failure at Glacial Lake Iroquois. Sediment lobes deposited by the massive meltwater surge are evident on the continental shelf area. Red triangles along the outer shelf are locations of large boulders inferred to have been transported by the surge event. The dotted white line represents the location of the Atlantic shoreline ca. 13,400 years ago. The dashed white line represents the approximate shoreline of Glacial Lake Candona following the demise of Glacial Lake Iroquois. White polygons along the coast represent areas that have no data. Locations A–P correspond to the radiocarbon and stratigraphic dated sites of Donnelly et al. (2005). Figure 1 from Donnelly et al. (2005), modified by Tim C. Henderson (Colorado State University), and copyrighted by the Geological Society of America. Used with permission.

The Hudson River and its Connections to Hyde Park

The Hudson River is the predominant landscape feature of the historic sites and has long been an important travel route for hunting, trade, settlement, and military campaigns. Flanking the river channel are fertile floodplains that were utilized for agricultural purposes by Indigenous cultures, early European-American settlers (including the Roosevelt and Vanderbilt families), and modern occupants of the Hyde Park area (Johnsen 1976). Since the end of the previous Ice Age, the Hudson River has weathered, eroded, and reworked the glaciated Hudson Lowlands to form the present fluvial landscape.

Situated adjacent to the Hudson River, the Roosevelt and Vanderbilt estates contain natural and man-made features that were previously used for transportation, recreation, and utilitarian purposes. In the northwest portion of Vanderbilt Mansion National Historic Site, Bard Rock is a small parcel along the riverbank that once functioned as a natural wharf for boats and ships until the late 19th century (Albee et al. 2008; Hammond 2009). Prior to acquisition by the Vanderbilt family, Bard Rock used to contain numerous buildings, including a boat captain’s cottage, pumphouse, and boat house. Although the Vanderbilts removed most of the buildings from the Bard Rock area, the boat house remained until it was demolished by the NPS in 1953 (Albee et al. 2008; Hammond 2009). Today, an iron hook set in exposed bedrock (“Bard Hook”) is the surviving remnant of two boat hooks that used to service small vessels docking at Bard Rock (Albee et al. 2008). Additionally, an iron eyelet affixed to the bedrock is another preserved historic docking feature (O’Donnell et al. 1992; Hammond 2009). Some of the most accessible bedrock exposures within the historic sites form the western shoreline of Bard Rock and consist of steeply dipping graywacke, sandstone, and interbedded shale of the Ordovician Austin Glen Formation (**Oag**) (see “Geologic Features and Processes” chapter).

In the Roosevelt family, boating was a passion shared by FDR and his father, James Roosevelt. At the Roosevelt estate, a historic boat house and boat landing at the northern end of Roosevelt Cove once provided access to the Hudson River until they were removed circa 1935 and 1945, respectively (Auwaerter and Curry 2009). James purchased the boat house in 1867, and upon its completion in 1868, the Roosevelt family often rowed or sailed to nearby river estates (Auwaerter 2022). During the winter months, the Roosevelt family competed in ice yachting, using specialized, lightweight boats that sailed on the frozen surface of the Hudson River. As a young boy, FDR was inspired by the sport of ice yacht racing, as his uncle John A. Roosevelt was one of the most competitive and successful captains in the local Hudson River Ice Yacht Club. In 1901, FDR was presented with his own ice yacht, dubbed “Hawk,” that he would sail and race along the Hudson River during his formative years as a student at Harvard; today, the yacht is part of the museum collection at Home of Franklin D. Roosevelt National Historic Site (see https://www.nps.gov/articles/000/ice-yachting-on-the-hudson.htm [accessed 17 January 2024]).

Maurice D. Hinchey Hudson River Valley National Heritage Area

The Maurice D. Hinchey Hudson River Valley National Heritage Area was designated by Congress in 1996 (originally the Hudson River Valley National Heritage Area) and renamed after New York Congressman Maurice D. Hinchey in 2019. In cooperation with the NPS, the national heritage area collaborates with residents, non-profit organizations, government institutions, and private partners to interpret, preserve, and celebrate the cultural, historic, natural, recreational, and scenic resources of the Hudson River Valley. Managed by the New York state-sponsored program Hudson River Valley Greenway, the national heritage area encourages public stewardship for these resources as well as promotes economic activity at the local and regional levels.

The Maurice D. Hinchey Hudson River Valley National Heritage Area encompasses the historic sites, in addition to Martin Van Buren National Historic Site, Saint Paul's Church National Historic Site, and Saratoga National Historical Park. The cultural history preserved within the national heritage area dates back thousands of years and includes Indigenous Native American societies, the early 17th century exploration of the Hudson River Valley by Henry Hudson, Dutch and subsequent English settlement, the American Revolutionary War, and the Gilded Age of the late 19th century. The aesthetic fluvial landscape of the Hudson River Valley inspired a group of 19th century artists—the Hudson River School of Painters—who drew creative vision from American scenery (Hudson River Valley National Heritage Area 2014). Many of the paintings produced by these artists depict the low-lying river valley and its scenic bluffs romantically juxtaposed against the towering Adirondack, Catskill, and Taconic Mountains (Figure 7; see also https://www.nps.gov/museum/exhibits/landscape_art/hudson_river_school.html [accessed 17 January 2024]).

Figure 7. Hyde Park, Hudson River, print by Nathaniel Currier and James Merritt Ives, c. 1838–1856. The painting romantically depicts the fluvial landscape of the Hudson River Valley from the Vanderbilt estate (formerly known as the “Hyde Park” estate) and is a representative piece by the 19th-century Hudson River School of Painters. NPS photo.

Geologic History

This chapter describes the geologic events that formed the present landscape. Events are discussed more-or-less in order of geologic age (oldest to youngest). A geologic map units table and geologic time scale show the chronology of geologic events (bottom to top) that led to the present-day landscape of the historic sites; this story covers more than 1 billion years and encompasses glacial events that occurred less than 20,000 years ago.

Geologic Time Scale

The following geologic map unit table (Table 1) and geologic time scale (Table 2) put the divisions of geologic time in stratigraphic order, with the oldest divisions at the bottom and the youngest at the top. Likewise, rocks and unconsolidated deposits are listed stratigraphically. The oldest (Ordovician) rocks form the bedrock within and immediately surrounding the historic sites. The youngest (Quaternary) rocks are surficial glacial units that partially cover underlying bedrock.

Table 1. Geologic units mapped within the historic sites. Colors correspond to USGS suggested colors for geologic maps. Letters in parentheses are abbreviations for geologic time units.

Geologic Time Unit	Age	Geologic Map Units	Geologic Events	Locations
Quaternary Period (Q): Pleistocene Epoch (PE)	2.6 million to 11,700 years ago	Till deposits (**PLt**)	Deposition of glacial till associated with the recessional stages of the Laurentide Ice Sheet during the late Wisconsinan glaciation, about 17,000 years ago (Connally and Sirkin 1986).	Till deposits are mapped across all three historic sites.
Ordovician Period (O)	485.4 million to 443.8 million years ago	Austin Glen Formation (**Oag**) Stuyvesant Falls Formation (**Osf**)	The Stuyvesant Falls Formation and Austin Glen Formation are lithified (turned into rock) deep marine sedimentary deposits of the continental rise and slope that were compressed, faulted, and thrust westward during the Taconic orogeny (Fisher and Warthin 1976; Rowley and Kidd 1981; Bock et al. 1998).	The Austin Glen Formation is mapped in all three historic sites and forms the predominant bedrock underlying Home of Franklin D. Roosevelt National Historic Site and Vanderbilt Mansion National Historic Site. Rocks of the Stuyvesant Falls Formation are limited to the Roosevelt estate underlying Val-Kill and Top Cottage.

Table 2. Geologic time scale. Colors correspond to USGS suggested colors for geologic maps. Letters in parentheses are abbreviations for geologic time units. Where no geologic time subdivision exists, “n/a” indicates not applicable.

Eon	Era(s)	Period(s)	Epoch(s)	MYA [A]
Phanerozoic	Cenozoic	Quaternary (Q)	Holocene (H)	0.0117–today
	Cenozoic	Quaternary (Q)	Pleistocene (PE)	2.6–0.0117
	Cenozoic	Neogene (N)	Pliocene (PL)	5.3–2.6
	Cenozoic	Neogene (N)	Miocene (MI)	23.0–5.3
	Cenozoic	Paleogene (PG)	Oligocene (OL)	33.9–23.0
	Cenozoic	Paleogene (PG)	Eocene (E)	56.0–33.9
	Cenozoic	Paleogene (PG)	Paleocene (EP)	66.0–56.0
	Mesozoic	Cretaceous (K)	Upper, Lower	145.0–66.0
	Mesozoic	Jurassic (J)	Upper, Middle, Lower	201.3–145.0
	Mesozoic	Triassic (TR)	Upper, Middle, Lower	251.9–201.3
	Paleozoic	Permian (P)	Lopingian, Guadalupian, Cisuralian	298.9–251.9
	Paleozoic	Pennsylvanian (PN)	Upper, Middle, Lower	323.2–298.9
	Paleozoic	Mississippian (M)	Upper, Middle, Lower	358.9–323.2
	Paleozoic	Devonian (D)	Upper, Middle, Lower	419.2–358.9
	Paleozoic	Silurian (S)	Pridoli, Ludlow, Wenlock, Llandovery	443.8–419.2
	Paleozoic	Ordovician (O)	Upper, Middle, Lower	485.4–443.8
	Paleozoic	Cambrian (C)	Furongian, Miaolingian, Series 2, Terreneuvian	538.8–485.4
Proterozoic	Neoproterozoic (Z)	Ediacaran, Cryogenian, Tonian	n/a	1,000–538.8
	Mesoproterozoic (Y)	Stenian, Ectasian, Calymmian	n/a	1,600–1,000
	Paleoproterozoic (X)	Statherian, Orosirian, Rhyacian, Siderian	n/a	2,500–1,600
Archean	Neo-, Meso-, Paleo-, Eo-archean	n/a	n/a	4,000–2,500
Hadean	n/a	n/a	n/a	4,600–4,000

[A] Boundary ages are millions of years ago (MYA) and follow the International Commission on Stratigraphy (2023).

Items in parentheses in the geologic time scale (Table 2) include GRI map abbreviations for geologic time units. For example, “**O**” in a map unit symbol means that a map unit was deposited during the Ordovician Period (approximately 485 million to 444 million years ago). The accompanying lowercase letters of a map unit symbol (see “Geologic Map Units” column in Table 1) indicate the name of a map unit, such as “sf” for Stuyvesant Falls Formation (**Osf**).

The names of map units used in this table and throughout the report reflect the formal nomenclature found in the USGS Geologic Names Lexicon (“Geolex”), which is a national compilation of names and descriptions of geologic units (see “Additional References, Resources, and Websites”). In geology, a formation is a formally recognized stratigraphic unit, meaning it is mappable (at a particular scale), lithologically distinct (with respect to rock type, texture, thickness, mineral composition, fossils, or age) from adjoining strata, and has a definable upper and lower boundary or contact (a surface where two different types or ages of rock meet). A formation can be divided into “members” or combined into a “group.” Map unit names that are formally recognized as formations are capitalized, for example, the Austin Glen Formation (**Oag**) or Mount Merino Formation (**Omm**). Table 1 notes the formal names found in Geolex. The table also has a column for “Age.” The various ages listed in the table follow the International Commission on Stratigraphy (2023).

Additionally, Table 1 has a column for “Geologic Events.” By reading the “Geologic Events” column from bottom to top, a geologic history is provided. Detailed descriptions of geologic events and associated geologic features are provided in sections of this chapter. The “Location” column of the table lists examples of where a geologic event is represented in the monument. Information about the geologic time scale, including the timing of geologic events, is primarily from Fisher and Warthin (1976), Rowley and Kidd (1981), Connally and Sirkin (1986), and Bock et al. (1998).

The historic sites are in the Hudson Lowlands of the Valley and Ridge physiographic province, a low-relief region of eastern New York defined by the glaciated Hudson River Valley (Figure 8). Situated atop the scenic bluffs overlooking the Hudson River, the historic sites are surrounded by the Catskill and Shawangunk Mountains to the west, the Taconic Mountains to the east, and the Hudson Highlands to the south. The geologic history of the Hudson Lowlands includes events that date back to the Proterozoic Eon, an interval of time over 541 million years ago (Isachsen et al. 2000). The bedrock underlying the region forms a series of faulted, northeast-southwest trending ridges and valleys predominantly composed of early Paleozoic sedimentary rocks (Vigil et al. 2000; Cadwell et al. 2003). The Ordovician strata that underlie the historic sites record several large-scale tectonic processes associated with the Taconic orogeny. The surficial geology is largely the result of more recent Pleistocene glaciations.

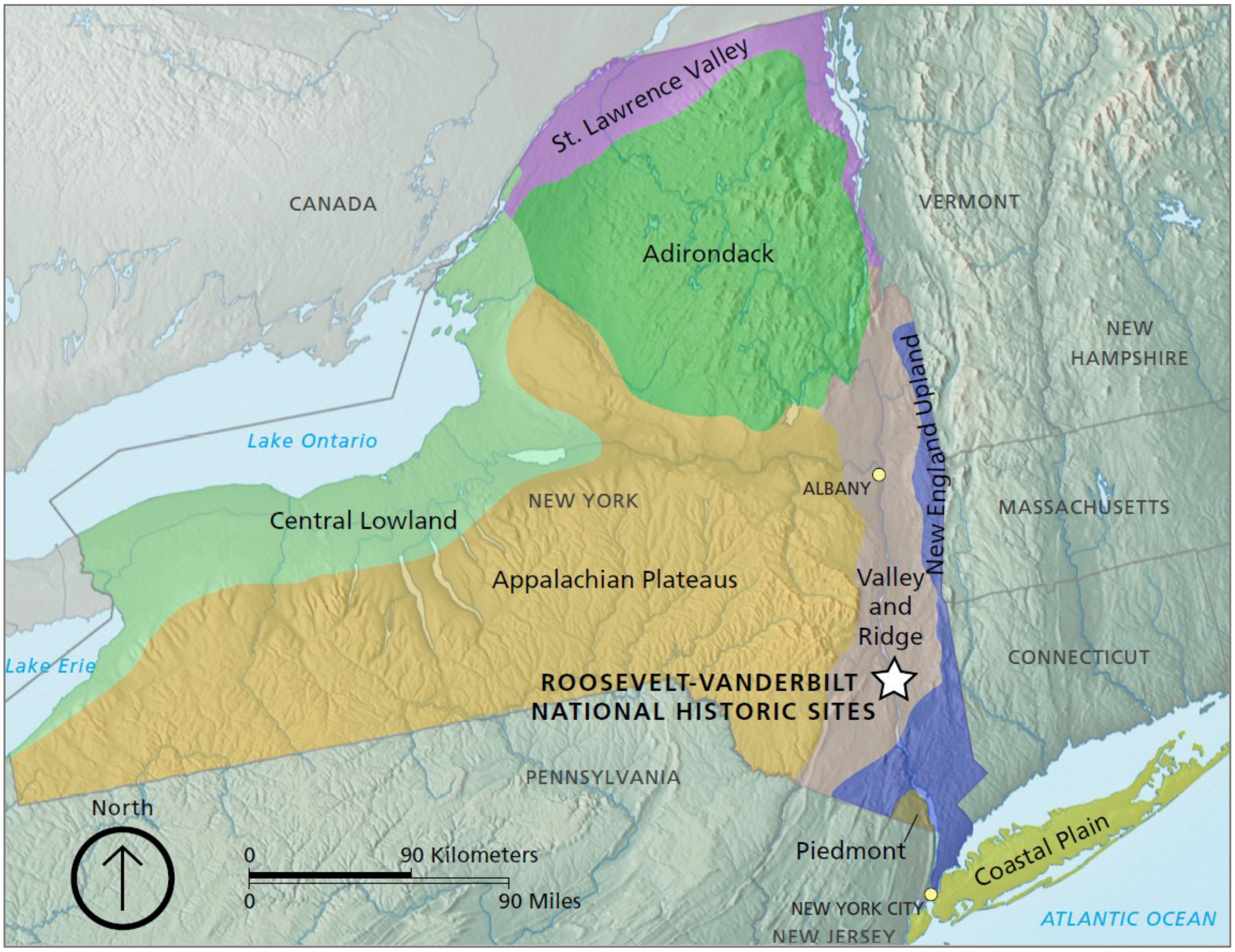

Figure 8. Physiographic province map of New York. The historic sites are situated in the Hudson Lowlands of the Valley and Ridge physiographic province, a low-relief region defined by the glaciated Hudson River Valley. The approximate location of the historic sites is denoted by the white star. Graphic created by Trista L. Thornberry-Ehrlich (Colorado State University) and modified from Fenneman and Johnson (1946).

Proterozoic Era

Beginning in the Proterozoic, the ancient continent of Laurentia (which would later become North America) existed in the southern hemisphere. The area of present-day New York was the setting of a tropical, shallow sea, and multi-celled organisms did not exist yet. Approximately 1.1 billion years ago, Laurentia collided with another continental landmass that resulted in a major mountain-building episode referred to as the Grenville orogeny (Fisher and Warthin 1976; Isachsen et al. 2000). Compressional forces associated with the Grenville orogeny produced a mountain chain similar in scale to the modern Himalayan Mountains and helped in the assembly of the ancient supercontinent Rodinia (Isachsen et al. 2000; Li et al. 2008). Today, the highly deformed metamorphic rocks and igneous intrusions that are records of the Grenville orogeny underlie the eastern seaboard of North America and form the Hudson Highlands, some of the oldest bedrock exposures in southeastern New York.

Continent-scale extension rifted the supercontinent Rodinia apart in the late Proterozoic, opening the Iapetus Ocean (precursor of the Atlantic Ocean) and creating a short-lived passive continental margin along eastern Laurentia (Figure 9a; Horowitz and McLennan 2005; Li et al. 2008). A passive margin is a tectonic plate boundary characterized by a lack of activity such as subduction, seismicity, volcanism, or collision; a present-day example is the Atlantic coast of North America. However, the Iapetus Ocean shoreline was located further inland and closer to the historic sites than the modern Atlantic coast.

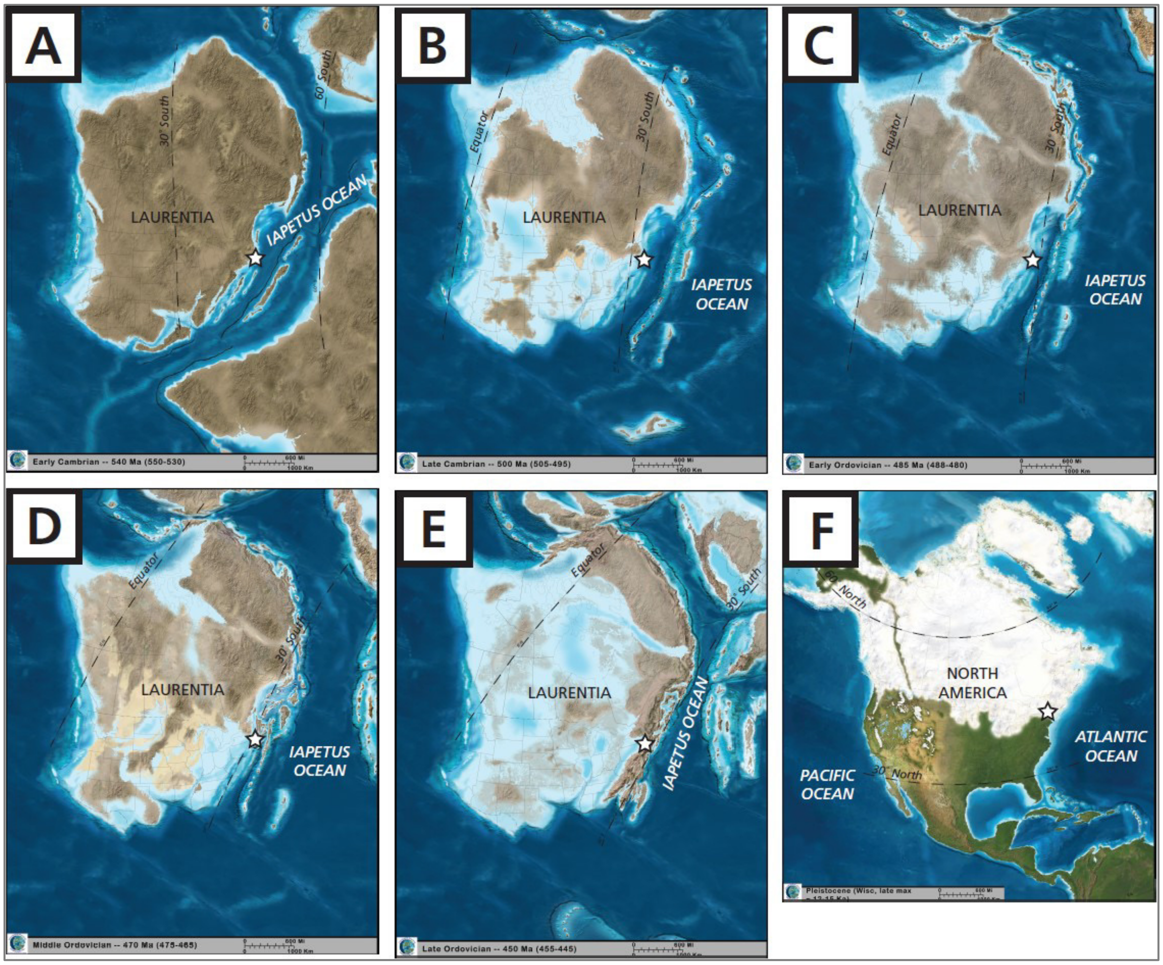

Figure 9. Paleogeographic reconstructions of North America, emphasizing the geologic events that shaped the historic sites. The approximate area of the historic sites is denoted by the white star. (A) Early Cambrian (540 million years ago) passive margin development and the formation of the Iapetus Ocean following the break-up of the supercontinent Rodinia; (B) Late Cambrian (500 million years ago) extensive shallow marine carbonate shelf deposition and active margin development associated with the initial closing stages of the Iapetus Ocean; (C) Early Ordovician (485 million years ago) continued closure of the Iapetus Ocean and growth of an extensive volcanic island arc complex; (D) Middle Ordovician (470 million years ago) early collisional stages of the Taconic orogeny; (E) Late Ordovician (450 million years ago) deformation and thrust emplacement of the Taconic allochthon; and (F) Pleistocene late Wisconsinan glaciation (15,000 to 12,000 years ago) that scoured the landscape of Canada and the northern United States. North American Key Time Slices © 2013 Colorado Plateau Geosystems Inc., modified by Tim C. Henderson (Colorado State University).

Paleozoic Era

Throughout the Cambrian and Early Ordovician (approximately 541 million to 470 million years ago), an active continental margin (a boundary characterized by abundant tectonic activity such as subduction, seismicity, volcanism, or collision) formed off the coast of Laurentia, which marked the initial closing stages of the Iapetus Ocean (see Figures 9b and 9c). During the early Paleozoic, carbonate deposition occurred across the shallow continental shelf of Laurentia, with coeval deep-water siliciclastic (sediments composed of rock fragments rich in silicate minerals) deposition further offshore on the continental rise (Fisher and Warthin 1976; Hurowitz and McLennan 2005). These shallow marine carbonates are referred to as the Wappinger Group, named after rock exposures south of the historic sites in nearby Wappinger Falls, New York (Mather 1838). The deep marine rocks deposited on the continental rise are composed of shale, siltstone, quartzite, chert, limestone, and conglomerate of the Stuyvesant Falls Formation, Quassaic Quartzite, and Germantown Formation (Fisher and Warthin 1976; Landing et al. 1992). Although the Germantown Formation (**Cg**) and Quassaic Quartzite (**Oq**) are mapped outside the boundary of the historic sites, strata of the Stuyvesant Falls Formation (**Osf**) form part of the bedrock underlying the Roosevelt estate at Val-Kill and Top Cottage (see poster).

By the Middle Ordovician, closure of the Iapetus Ocean led to the collision of Laurentia with a chain of volcanic islands, an event referred to as the Taconic orogeny (see “The Taconic Orogeny”; Rowley and Kidd 1981; Landing et al. 1992; Isachsen et al. 2000; Landing 2007). Offshore oceanic and volcanic sedimentation occurred in the collisional zone, depositing what are now the graywackes (dark, poorly sorted sandstone with angular grains), shales, cherts, and minor ash beds of the Austin Glen Formation (**Oag**), Mount Merino Formation (**Omm**), and Indian River Formation (of the Normanskill Group) (see Figure 9d; Rowling and Kidd 1981; Landing et al. 1992; Landing 2007). As collision progressed, marine strata that accumulated on the continental slope and rise of Laurentia were compressed, faulted, and thrust hundreds of kilometers west to their present location (see Figure 9e; Stanley and Ratcliffe 1985; Hurowitz and McLennan 2005). The bedrock underlying and surrounding the historic sites forms part of the westernmost frontal thrust sheets of the Taconic orogeny (Fisher and Warthin 1976; Vollmer and Walker 2009).

Pleistocene Epoch

During the Pleistocene, continental glaciers associated with the Laurentide Ice Sheet advanced south across North America and sculpted portions of Canada and the northern United States. In the area of New York, glaciers extended as far south as Long Island (see Figure 9f; Stone et al. 2005). These ice sheets weathered and eroded the landscape they covered, smoothing mountains and other topographic highs while widening and deepening the proto-Hudson River Valley. The surficial geology of the Hyde Park area consists entirely of glacially-derived sediment deposits that partially bury older Paleozoic bedrock. As the glaciers melted and retreated north out of New York, vast amounts of meltwater and glacial till (**PLt**) were released. The receding ice front created a series of glacial lakes that accumulated lacustrine deposits (**PLl**) of clay and silt, while tributary streams emptying into the lakes constructed deltas consisting predominantly of sand and gravel (**PLd**) (see poster). For more detailed information about the Pleistocene Ice Age history of the Hudson River, please refer to the section “Pleistocene Glacial History of the Hudson River Valley.”

Geologic Features and Processes

This chapter highlights geologic features and processes significant to the landscape and history of the historic sites. Selection of these features and processes was based on input from the scoping and follow-up meeting participants, analysis of the GRI GIS data, and research of the scientific literature and NPS reports. These features and processes are discussed more or less in order of geologic age (oldest to youngest).

At the beginning of each of the following sections, map units corresponding to the poster are listed; these indicate which map units are discussed in each section. Map units are referenced directly in the text as well. Some sections may not be directly related to a map unit on the poster, in which case no unit is listed at the start of the section. The map units can also be viewed in the GRI GIS data.

Bedrock Geology

Stuyvesant Falls Formation (map unit Osf)

The Early Ordovician Stuyvesant Falls Formation was first proposed by Fisher (1962) to describe a 122-m- (400-ft)-thick sequence of siltstone and shale exposed along Kinderhook Creek at Stuyvesant Falls, New York. In Hyde Park, the formation is the predominant bedrock unit underlying Eleanor Roosevelt National Historic Site and the adjacent Top Cottage unit of Home of Franklin D. Roosevelt National Historic Site (see poster). The Stuyvesant Falls Formation is characterized by light green shale with interbedded thin beds of dolostone, quartzite, and chert (Bence and McLelland 1976; Fisher and Warthin 1976). At the Roosevelt estate, the Stuyvesant Falls Formation is in fault contact with the Late Ordovician Austin Glen Formation (see poster). Although the historic sites have no known paleontological resources to date, the Stuyvesant Falls Formation contains graptolite fossils (an extinct, free-floating colonial animal useful for relative age dating) that are indicative of marine origin and limit its depositional age between approximately 479 million and 472 million years ago (Fisher and Warthin 1976; Tweet et al. 2010). The Stuyvesant Falls Formation is interpreted as a distal continental slope or continental rise deposit that was thrust westward during the emplacement of the Taconic allochthon (see "The Taconic Orogeny"; Vidale 1974; Bence and McLelland 1976; Fisher and Warthin 1976).

Due to the structural and stratigraphic complexity of the Taconic allochthon, rocks of the Stuyvesant Falls Formation are thought to be the same as those of the Poultney Slate, Deepkill (or Deep Kill) Formation, and Schaghticoke Shale (Fisher 1968; Bence and McLelland 1976; Landing 1988; Landing et al. 1992). To avoid any confusion with the GRI GIS data (source map by Fisher 1968), the name Stuyvesant Falls Formation is retained here.

Austin Glen Formation (map unit Oag)

The Late Ordovician Austin Glen Formation (of the Normanskill Group) was first named and described from folded, anticlinal (concave downward) rock exposures located approximately 48 km (30 mi) north of Hyde Park in the Austin Glen valley near the city of Catskill, New York (Ruedemann 1942). Marine sedimentary and metasedimentary rocks of the Austin Glen Formation are mapped within all three historic sites and form the predominant bedrock of Home of Franklin D.

Roosevelt National Historic Site and Vanderbilt Mansion National Historic Site (see poster). In Dutchess County, the lower division of the Austin Glen Formation predominantly consists of graywacke and more typical sandstone interbedded with bluish gray or black shale (Bence and McLelland 1976; Fisher and Warthin 1976). The upper part of the unit contains thicker, coarser intervals of graywacke, thin intervals of graywacke conglomerate, and relatively minor amounts of shale (Fisher and Warthin 1976). Sedimentary structures commonly occur in the upper interval and include load casts (depressions that form on bedding planes), ripple marks (straight or sinuous crests that develop under flow conditions), cross-bedding (angular layering), and graded bedding (sorted layering) (Fisher and Warthin 1976; Pratt 2009). Graptolite fossils from the Austin Glen Formation bracket the depositional age between approximately 462 million and 450 million years ago (Landing 1988; Bock et al. 1998; Tweet et al. 2010).

Based on lithology, sedimentary structures, and fossil evidence, the rocks comprising the Austin Glen Formation have been interpreted as turbidites (submarine gravity-flows consisting of alternating sandstone and shale intervals) that rapidly accumulated along an unstable continental slope (Rickard and Fisher 1973; Bence and McLelland 1976; Fisher and Warthin 1976). In the Hyde Park area, turbidite sequences of the Austin Glen Formation form the upper interval of the Taconic allochthon and are considered flysch deposits of the Taconic orogeny (see "The Taconic Orogeny"; Rowley and Kidd 1981; Landing et al. 1992; Bock et al. 1998; Vollmer and Walker 2009). The term "flysch" (a Swiss word meaning "to flow") is used to describe rock sequences that record the transition from deep to shallow marine sedimentation in a foreland basin prior to and during a mountain-building episode.

Regionally, the Austin Glen Formation thickens to the east and is known to contain devitrified glass (volcanic glass replaced with minerals) and detrital chromite (grains rich in chromium used to study rock origins). These elements indicate that the unit was derived from an easterly approaching offshore accretionary prism (a wedge-shaped body of deformed rock material scraped off oceanic crust as it descends at a subduction zone) and/or volcanic island arc (Fisher and Warthin 1976; Rowley and Kidd 1981; Stanley and Ratcliffe 1985; Landing 1988; Bock et al. 1994, 1998). According to Bock et al. (1998) and Vollmer and Walker (2009), the depositional setting of the Austin Glen Formation was in front of an advancing accretionary prism, where some of the flysch deposits were later incorporated and "recycled" into the thrust sheets of the Taconic allochthon. In Dutchess County, the Austin Glen Formation and similar flysch deposits form part of the lower thrust sheets along the western front of the allochthon (Vollmer and Walker 2009).

Within the region surrounding the historic sites, rocks of the Austin Glen Formation have been compressed, tilted, and exposed in beds that dip about 60–75° (measured from horizontal) toward the east (Fisher 1968). Excellent outcrops that demonstrate this distorted bedding inclination are located at Bard Rock along the Hudson River in the northwestern part of Vanderbilt Mansion National Historic Site (Figure 10; see https://www.nps.gov/media/video/view.htm?id=B020C3DD-FBD8-4B8A-BC91-7039EE5DE9AE [accessed 17 January 2024]). At Bard Rock, multiple turbidite sequences are exposed that become progressively younger upslope from the Hudson River. Within the Roosevelt estate, the Austin Glen Formation outcrops in a series of north-south trending spurs (elevated ridges of rock) west of the Springwood mansion (Figure 11; see poster). These smooth spurs trace parallel to and rise steeply above the perennial and non-perennial stream valleys flanking the Hudson River, including the unnamed creek that feeds into the Ice Pond (see Figure 4).

Strata of the Austin Glen Formation are considered equivalent to flysch deposits of the Pawlet Formation. The use of the name Austin Glen Formation is more common in the central and southern Taconic allochthon, while the Pawlet Formation is restricted to the northern Taconic region (Rowley and Kidd 1981; Landing 2007; Vollmer and Walker 2009).

Figure 10. Steeply inclined beds of the Late Ordovician Austin Glen Formation (Oag) at Bard Rock. View is looking north up the Hudson River Valley. Geologic exposures at Bard Rock are turbidites consisting of interbedded graywacke, sandstone, and shale that have been deformed and now dip approximately 60–75° (measured from horizontal) toward the east. NPS photograph modified by Tim C. Henderson (Colorado State University).

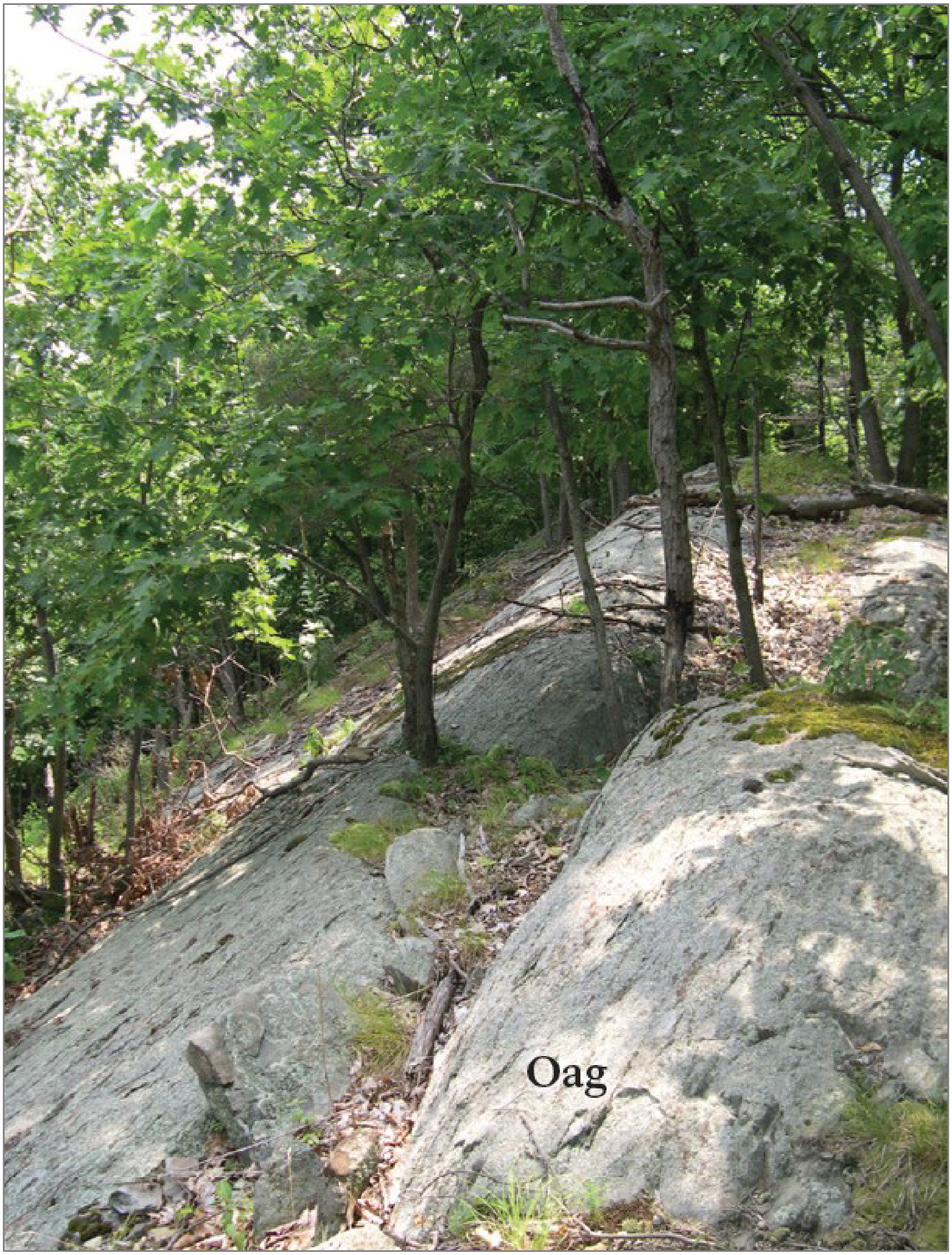

Figure 11. North-south trending spurs of the Austin Glen Formation (Oag) located on the Roosevelt estate. These steep-sided, smooth, linear ridges are aligned parallel to the Hudson River and local stream valleys located west of the Springwood mansion. According to Sechler et al. (2014), the vegetation community growing from the rocky spurs is a rare type called red cedar rocky summit. NPS / DAVID HAYES

Glacial Features and Processes

Till Deposits (map unit PLt)

According to the GRI GIS datasource map by Fisher (1968), the surficial geology consists entirely of Quaternary glacial till deposits that blanket portions of all three historic sites. Deposited by retreating ice sheets during the last glacial episode ("Ice Age") of the Pleistocene Epoch, these till deposits are composed of unconsolidated, poorly sorted sediment material of various clast sizes (boulders, cobbles, sand, silt, clay) that have a variable thickness ranging about 10–30 m (30–90 ft) (National Park Service 2022). An elongated deposit approximately 5.5 km (3.4 mi) long and 1 km (0.6 mi) wide is mapped along the Hudson River Valley at Hyde Park. The till extends along the eastern boundary of Vanderbilt Mansion National Historic Site and continues south into Home of Franklin D. Roosevelt National Historic Site, where it underlies FDR's Springwood home. These unconsolidated deposits form the ravines and steep slopes leading down to the Hudson River, and blanket portions of the underlying Austin Glen Formation (see poster). The unconsolidated nature of these glacial sediments, combined with their abrupt, steep topography, may make them susceptible to mass wasting events (downslope movements of earth material) if not properly managed (see "Geologic Resource Management Issues"). Although not depicted in the GRI GIS data, more recent mapping of the Hyde Park area by Cadwell (1989) and Cadwell et al. (1996) has interpreted these glacial till deposits as lake delta sediments associated with Glacial Lake Albany (see "Pleistocene Glacial History of the Hudson River Valley"). Additionally, the surficial map of Cadwell et al. (1996) has extended these deposits further west beneath the Vanderbilt mansion.

Further east of the Hudson River, additional glacial till deposits occur at Eleanor Roosevelt National Historic Site and the detached units of Home of Franklin D. Roosevelt National Historic Site, including the southernmost portion of Top Cottage. These till deposits overlie the Stuyvesant Falls Formation and are mapped in fault contact with the Austin Glen Formation (see poster).

Erratics and Striations

Additional glacial features not depicted as part of the GRI GIS data include erratics (large masses of ice-transported rock) and striations (linear grooves or scratches carved into bedrock by ice). Within the historic sites, erratics are located along the hill leading to Top Cottage in Home of Franklin D. Roosevelt National Historic Site. These large boulders were deposited during the previous Ice Age and represent masses of underlying bedrock that were plucked, transported, and deposited far away (sometimes thousands of miles) from their point of origin by the Laurentide Ice Sheet. As glaciers melted and receded north across New York, they released an immense amount of meltwater (comparable to the volume of Lake Huron) and unconsolidated rock debris ranging in size from fine sediments to boulders (Donnelly et al. 2005).

Bedrock exposures (**Oag**) located along the Hudson River at Bard Rock in Vanderbilt Mansion National Historic Site contain striations that record the incision of ice as continental glaciers flowed over the rock surface. Akin to frozen sandpaper, the advance and retreat of glaciers abraded, polished, and sculpted the ancestral Hudson River Valley. At Bard Rock, several narrow, linear scratches or grooves are preserved within interbedded graywacke and shale outcrops. During the Ice Age, entrained rock debris and ice located along the base of the Laurentide Ice Sheet scoured into the underlying bedrock, leaving striations that suggest the direction of flow (see https://www.nps.gov/media/video/view.htm%3Fid%3DF69AAE88-1DD8-B71B-0BABEAAA7C1CCF3C [accessed 17 January 2024]).

Fluvial Features and Processes

The Hudson River

The predominant natural feature of the historic sites' landscape is the Hudson River, an integral water resource that has long nurtured human settlement by providing sustenance, transportation, and a means for conducting trade (Johnsen 1976). From a geologic perspective, the Hudson River is the most dynamic geomorphologic feature of the historic sites, as it drains the landscape, transports sediments and vital nutrients, and slowly reshapes the region through erosion and deposition. The configuration of the modern Hudson fluvial system is a result of previous Pleistocene glaciations that scoured, widened, and deepened the river valley, combined with erosional processes that continue to carve steep slopes, terraces, and bluffs. The underlying geology in the Hudson Lowlands region of the historic sites determines the current course of the Hudson River, which typically flows along weak belts of shale located between the Catskill and Taconic Mountains (Johnsen 1976).

At Hyde Park, the Hudson River borders the Roosevelt and Vanderbilt estates to the west; in total, approximately 1.8 km (1.1 mi) of river front are shared amongst the historic sites (see poster; National Park Service 1997; Gawley and Dieffenbach 2016). Although most of the infrastructure and natural resources are located uphill from the Hudson River, floodplain regions adjacent to the historic site's river boundary are situated at the high-water mark and susceptible to periodic flooding events (see "Flooding"). Areas of low elevation along the river corridor also experience tidal processes, as the lowermost 240 km (150 mi) stretch of the Hudson River from Troy south to New York Harbor is a tidal estuary (body of water where freshwater and saltwater mix) that experiences daily fluctuations in relative water level (David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). At the historic sites, the average tidal fluctuation is about 1.2 m (4 ft) per day (Thornberry-Ehrlich 2008). Additionally, the Hudson River presents a considerable threat to historic site resources and staff due to polychlorinated biphenyls (PCBs) contamination, especially along floodplain and tidal wetland environments (see "Hudson River Contamination Issues").

The Roosevelt Estate – The Fall Kill and Maritje Kill

The Fall Kill is a tributary of the Hudson River that serves as a predominant natural resource and landscape feature of the Roosevelt estate, both historically and today. Eleanor Roosevelt National Historic Site and a small portion of Home of Franklin D. Roosevelt National Historic Site are situated in the floodplain of the Fall Kill, a perennial stream characterized by a slow-moving, low-gradient, shallow, and wide channel (see poster; Nowak 2005; David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). During the 1920s and 1930s, the Roosevelt family modified the Fall Kill for both land use and spatial organization purposes. Beginning in 1925, the Roosevelts constructed a 0.6 m (2 ft) tall dam across the creek, creating an extensive wetland that is now part of the Dutchess County Wetlands Complex (Thornberry-Ehrlich 2008; Cole et al. 2012; Sechler et al. 2014). Construction of the dam formed

Val-Kill Pond, a 2.8-ha (7-acre) man-made pond that became the architectural focal point of the historic Val-Kill structures (Nowak 2005). The pond was used by the Roosevelt family for a variety of recreational activities, including swimming, fishing, and boating (Klemens et al. 1992). Historically, Val-Kill Pond was periodically dredged to enlarge and deepen the body of water, as well as remove accumulated silt material from along the bottom of the pond (see "Guidance for Resource Managers"; Klemens et al. 1992).

Originating about 11 km (7 mi) north of the Roosevelt estate, the Fall Kill flows south across Home of Franklin D. Roosevelt National Historic Site and Eleanor Roosevelt National Historic Site before emptying into the Hudson River (Cole et al. 2012). The Fall Kill feeds into Val-Kill Pond, exits at the dam located south of the Stone Cottage, and continues along the southwestern boundary of the historic site. As the stream flows through the center of Val-Kill, it divides the historic site into two regions consisting of flat lands to the west and rocky uplands to the east (Nowak 2005). In the southwestern region of Eleanor Roosevelt National Historic Site, the edge of the Fall Kill channel is poorly defined, allowing water to sometimes spill over into adjacent shallow wetlands (Nowak 2005). A second dam located along the southwestern boundary dates to the 1950s and has created a small, serpentine-shaped pond that abuts several private residences.

The Maritje Kill is another tributary of the Hudson River that flows south through the Roosevelt Farm and Forest unit of Home of Franklin D. Roosevelt National Historic Site (see poster). As the Maritje Kill passes through the historic site, it crosses irregular forested terrain along the Newbold Trail and Farm Lane Trail before leaving the southern boundary. In 1923, FDR constructed a concrete bridge across the Maritje Kill in an effort to build additional roadways connecting various portions of the Roosevelt estate (Auwaerter 2022). As the creek leaves the Roosevelt estate, it changes course, flowing west along the southern historic site boundary before emptying into the Hudson River.

In addition to the Fall Kill and Maritje Kill, there are several perennial and non-perennial streams, ponds, and vernal pools located throughout the Roosevelt estate. West of the Springwood mansion are several small stream valleys, one of which feeds into the Ice Pond and drains south into a freshwater tidal marsh at Roosevelt Cove (see poster). During FDR's tenure, the Roosevelt family constructed a 4 m (13 ft) high dam to impound the Ice Pond, which was historically used for ice production and swimming (Cole et al. 2012). Notable water bodies at Eleanor Roosevelt National Historic Site include small tributaries of the Fall Kill, ponds, and vernal pools. Ponds and vernal pool features are sustained by underground springs or exist only during the wet months of the year (see poster; Klemens et al. 1992; Nowak 2005).

The Vanderbilt Estate – Crum Elbow Creek and Bard Rock Creek

The major fluvial feature of Vanderbilt Mansion National Historic Site is Crum Elbow Creek, which enters the historic site along its eastern boundary and traverses the southern part of the Vanderbilt estate before draining into the Hudson River. The Vanderbilt family built several small dams along lower Crum Elbow Creek, creating two small artificial ponds (see poster; Cole et al. 2012). The first dam is located near the main entrance of the historic site and underlies the White Bridge. A second, smaller pond is situated along the southern boundary of the Vanderbilt estate, adjacent to the Coach House. Low-elevation regions of the historic site near the mouth of Crum Elbow Creek are susceptible to periodic flooding events (see "Flooding").

In the northern portion of the estate, a small perennial stream informally referred to as "Bard Rock Creek" flows through part of the historic site along the northern Bard Rock parcel (Cole et al. 2012). The lower segment of the creek flows west along Bard Rock Road until it empties into the Hudson River (see poster). In addition to Crum Elbow Creek and Bard Rock Creek, a small, intermittent stream drains below the visitor center (Cole et al. 2012).

Tidal Marsh and Wetland Features

Although not depicted in the GRI GIS data, the historic sites contain a combined 24 ha (59 ac) of tidal marsh and/or wetland features (Cole et al. 2012). Together, these vital aquatic habitats provide refuge for a diverse variety of wildlife, including 71 confirmed breeding bird species, 20 fish species, 16 amphibian species, and 30 reptile species—including the endangered Blanding's Turtle (Klemens et al. 1992; Cole et al. 2012).

The Roosevelt family dammed the Fall Kill Creek at Val-Kill in the 1920s and 1930s, resulting in an extensive wetland complex that accounts for nearly 25% of the land cover in Eleanor Roosevelt National Historic Site (Klemens et al. 1992; Sechler et al. 2014). The Fall Kill wetland complex is the largest wetland feature amongst the three historic sites, supporting several shrub swamps and wet meadows surrounding the historic core of Val-Kill and Val-Kill Pond (see poster; Klemens et al. 1992). At Home of Franklin D. Roosevelt National Historic Site, a small 1.8 ha (4.4 ac) freshwater tidal marsh is located at Roosevelt Cove and in the ledges above Roosevelt Cove along the southwestern boundary bordering the Hudson River (see poster). The tidal marsh supports critical vegetation communities and bird habitats, but the sediments of the marsh need to be investigated regarding possible PCB contamination (see "Guidance for Resource Management"; Cole et al. 2012). Vanderbilt Mansion National Historic Site contains non-tidal wetlands totaling about 0.4 ha (1 ac) that occur east of the Formal Gardens and Crum Elbow Creek (Klemens et al. 1992; Cole et al. 2012). Extending along the east bank of the Hudson River is a freshwater tidal wetland that parallels the entire western boundary of the Vanderbilt estate (Cole et al. 2012).

Unnamed Thrust Faults

According to the GRI GIS data (source map by Fisher 1968), a series of unnamed, roughly north-south trending thrust faults occur throughout Hyde Park and across the Hudson River in West Park. One thrust fault is mapped underlying Eleanor Roosevelt National Historic Site and the adjacent easternmost detached units of Home of Franklin D. Roosevelt National Historic Site, including Top Cottage. Along this thrust, rocks of the Austin Glen Formation have been compressed, uplifted, and juxtaposed against older strata of the Stuyvesant Falls Formation (see poster). The thrust faults mapped within and immediately surrounding the historic sites are attributable to the Taconic orogeny, as the bedrock forms part of the lower thrust sheets along the western frontal edge of the Taconic allochthon (see "The Taconic Orogeny"; Vollmer and Walker 2009).

Paleontological Resources

Paleontological resources (fossils) are any evidence of life preserved in a geologic context (Santucci et al. 2009). They may be body fossils (any remains of the actual organism such as bones, teeth, shells, or leaves) or trace fossils (evidence of an organism's activity such as nests, burrows, tracks, or coprolites [fossil feces]). All fossils are nonrenewable resources. Fossils in NPS areas occur in situ in rocks or unconsolidated sediment deposits, in museum collections, and in cultural contexts such as building stones or archeological resources. As of January 2024, 286 NPS areas had documented paleontological resources in at least one of these contexts (Justin Tweet, GRD paleontologist, personal communication January 2024).

According to the NPS paleontological resources inventory by Tweet et al. (2010), the fossils of the historic sites are limited to isolated, undescribed shell imprints in rocks of unknown origin (David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication October 2009). The historic sites currently have no paleontological material in their collections.

The Hyde Park Mastodon

Surficial Pleistocene glacial deposits in the Hyde Park area are known to contain fossilized remains of extinct, large Ice Age megafauna such as mastodons. A notable fossil found immediately outside the historic sites is the Hyde Park mastodon. The mastodon was discovered in 1999 when excavators were deepening a kettle pond (a topographic depression of glacial origin that is filled with water) on a private residence located approximately 1.5 km (0.6 mi) north of the Roosevelt estate (Menking et al. 2001; Fisher and Sherpa 2003). The mastodon is a well-preserved, essentially complete (84–91%) adult male specimen with an estimated age of about 29 to 39 years old at the time of death (Fisher and Sherpa 2003; Miller and Nester 2006). Radiocarbon dating of the preserved mammoth yielded an age of 11,480 yr ± 50 14C years before present (between approximately 13,465 and 13,240 calendar years before present) (Menking et al. 2001; Fisher and Sherpa 2003; Miller and Nester 2006; Tweet et al. 2010). It is important to acknowledge that radiocarbon dates are not equivalent to calendar dates and that radiocarbon years require calibration to yield calendar years. Radiocarbon dates for the Hyde Park mastodon were calibrated to calendar years by the investigators using Calib 8.2 (Justin Tweet, GRD paleontologist, personal communication November 2023). Today, the Hyde Park mastodon is on display at the Paleontological Research Institution Museum of the Earth in Ithaca, New York (Figure 12). Along with the mastodon specimen, the Hyde Park mastodon site also preserved other Ice Age species including beetles, bivalves (aquatic organisms with shells composed of two distinct, hinged parts), gastropods (slugs or snails), ostracodes (small aquatic crustaceans), and a rich variety of plant material including cones, leaves, needles, peat, pollen, seeds, and twigs (Nelson et al. 2002; Miller and Nester 2006).

Figure 12. The Hyde Park mastodon. The Hyde Park mastodon exhibit is on display at the Paleontological Research Institution Museum of the Earth in Ithaca, New York. The exceptionally preserved mastodon specimen is approximately 84–91% complete and was discovered in 1999 just north of the Roosevelt estate on private property. Photograph courtesy of the Paleontological Research Institution/Jonathan Hendricks.

In addition to Hyde Park, several other mastodon discoveries have been made just south of the historic sites in the town of Poughkeepsie (Tweet et al. 2010). Mammoth or mastodon remains were also reportedly found in proximity to the Vanderbilt estate, according to a vaguely detailed article in the New York Herald dated 20 November 1899:

> *Portions of a mastodon have been found in Dutchess county[sic], in a swamp on the old Macpherson place, in the Hyde Park road, near the country homes of Frederick W. Vanderbilt and other prominent New York persons. Workman digging a drain found several fragments of heavy bone 15 feet [4.5 m] below the surface, and some feet deeper part of a mammoth tusk (Hartnagel and Bishop 1921, p. 24; Tweet et al. 2010, p. 138).*

Archeological Resources

The preservation and protection of archeological resources should be a priority as these items represent an irreplaceable and unique record of the past. According to NPS Management Policies

(2006), archeological resources should remain in situ whenever possible and protected from looting, vandalism, erosion, and destruction.

Indigenous Resources

Indigenous sites scattered across the banks, ridges, and terraces along the Hudson River Valley record a cultural history dating back several thousand years (Parker 1920; Funk 1976; Cook 1987; Nowak 2005). The Dutchess County region was inhabited by the Algonquian Wappinger tribe, whose people occupied large tracts of land along the Hudson and Delaware river valleys (Nowak 2005; Cole et al. 2012; Auwaerter 2022). Although previous archeological resource studies by Hsu (1973) and Rhodes (1986) revealed no traces of Indigenous occupation within the historic sites, the Roosevelt family is known to have discovered projectile points within the boundaries of their estate (Auwaerter 2022). According to the book Franklin D. Roosevelt and Hyde Park: Personal Recollections of Eleanor Roosevelt (Roosevelt 1949), Eleanor quotes FDR:

> *…the fields in front of my house and Mrs. James R. Roosevelt's house prove that an Indian encampment existed here before the white man came. The old oak tree in front of the Library and on the lot south of the Avenue must, of course, have grown up under field conditions and this existed only where Indians had cleared the land and cultivated it. About 1920 one of these trees got so old I had to take it down. And the rings at the base proved that it dated from about 1690. Furthermore a good many arrowheads have been found in plowing. Probably this Indian cultivation is not true of the east side of the Post Road because I can remember no similar very old trees* (Roosevelt 1949, p. 2).

The FDR Presidential Library and Museum collections contain at least one item of Indigenous origin that was discovered within or near Home of Franklin D. Roosevelt National Historic Site. A small piece of carved deer bone was collected by President Roosevelt and preserved in a Tiffany & Co. cardboard box bearing a note from FDR, dated 20 April 1942, which stated: "This piece of bone from a deer was found on the avenue at Hyde Park when it was being rebuilt in 1934. Evidently, the Indians were trying to fashion it into an arrowhead or a needle" (Figure 13).

Figure 13. A small piece of carved deer bone collected by FDR. Found in 1934, the bone was found within or near Home of Franklin D. Roosevelt National Historic Site. According to FDR, the bone was sculpted by Indigenous Peoples who once occupied the area of Hyde Park. The specimen measures 0.3 cm × 5.1 cm × 1.3 cm (0.125 in × 2 in × 0.5 in) and is part of the FDR Presidential Library and Museum collection (MO: 1942.259). Image courtesy of Michelle Frauenberger and the Franklin D. Roosevelt Presidential Library and Museum.

Euro-American Resources

The historic sites contain valuable resources associated with the Roosevelt and Vanderbilt families, but also include materials that date back to some of the earliest Euro-American occupants of Hyde Park. In 2017, contractors excavating in front of the eastern steps to the Vanderbilt mansion unintentionally discovered historic foundation structures and artifacts associated with the estates of Dr. Samuel Bard (George Washington's family physician), Dr. David Hosack, and Walter Langdon Sr. and Jr. (Figure 14; Nyman 2017). The Bard family built the first house on the site in 1799 that is now Vanderbilt Mansion National Historic Site; the estate was acquired and occupied by the Hosack family (circa 1821–1840) and subsequently the Langdon family (circa 1840–1895). The Langdon's lived in the Bard/Hosack mansion until a fire destroyed the structure in 1845 and a new mansion was constructed in 1847 (Hammond 2009; Nyman 2017). The 2017 excavation unearthed foundation stones associated with the Bard/Hosack mansion, including building materials (brick, wood, and wrought iron nails) scorched black by the 1845 fire (Nyman 2017). Two archeological features, a partial cistern (well) and drain box, were identified as dating to the Langdon mansion. During the excavation, remnants of late 18th/early 19th century household items were also found, including pottery sherds, some iron hardware, and glass bottle fragments (Nyman 2017).

Figure 14. A 2017 archeological excavation in front of the Vanderbilt mansion. The investigation discovered historic foundational structures and artifacts adjacent to the eastern steps of the building. These archeological resources date back to the late 18th and early 19th century families that constructed mansions in the same location as the Vanderbilt family. Some of the foundation stones and materials are scorched black from an 1845 fire that destroyed one of the historic mansion structures. NPS / VANDERBILT MANSION NATIONAL HISTORIC SITE

In addition to materials related to the Bard, Hosack, and Langdon estates, the historic sites contain historical dump sites dating back to the 19th- and 20th-century tenure of the Roosevelt and Vanderbilt families (Hsu 1973; National Park Service 1990; National Park Service 2017a, 2017c). Numerous additional archeological sites identified within the historic sites have the potential to yield significant insight into the lives of the Roosevelt and Vanderbilt families, in addition to other early occupants of Hyde Park (Hammond 2009; National Park Service 2017a, 2017b, 2017c; Auwaerter 2022).

One personal item of historical (and geological) interest is a rock specimen that FDR kept on the desk of his private study. Discovered in the woods of the Roosevelt estate circa 1905, the crystalline, quartz-rich rock was presumably used by FDR as a paperweight (Figure 15). Not known to be an avid geologist, FDR's hobbies typically involved forestry, sailing, and his collections of birds, naval books/prints, and stamps (Elmore Design Collaborative Inc. and John G. Waite Associates Architects 2002). As part of the FDR Presidential Library and Museum archive collection, the rock specimen had a paper note pasted on the bottom that had the following message in the handwriting of FDR's mother, Sara Delano Roosevelt: "Rock in our woods. A piece blasted in 1905. SDR." Today, the item is part of the permanent exhibit of FDR's private study, where it is displayed on his desk (FDR Presidential Library and Museum website: https://fdr.artifacts.archives.gov/objects/3525 [accessed 17 January 2024]).

Figure 15. The rock paperweight that FDR collected from the woods of his estate in 1905. Although not an avid geologist, FDR kept the crystalline rock on the desk of his private study. The specimen measures 8.6 cm × 10.2 cm × 8.3 cm (3.375 in × 4 in × 3.25 in) and is part of the FDR Presidential Library and Museum collection (MO: 1947.93.33; https://fdr.artifacts.archives.gov/objects/3525). Image courtesy of Michelle Frauenberger and the Franklin D. Roosevelt Presidential Library and Museum.

Geologic Resource Management Issues

This chapter highlights issues (geologic features, geologic processes, and human activities affecting or affected by geology) that may require management for human safety, protection of infrastructure, or preservation of natural and cultural resources. The issues are categorized based on whether geology poses the hazard ("Geologic Hazards" section) or the geologic feature or process requires resource protection ("Geologic Resource Monitoring and Protection" section). Within each section, the issues are ordered with respect to management priority. The GRD provides technical and policy assistance for these issues (see "Guidance for Resource Management" chapter).

Geologic Hazards

Park resources are not only visitor attractions but may also be potentially hazardous. The dynamic landscapes preserved at many national park units present a variety of natural hazards that threaten NPS facilities, staff, and visitors. Many of these natural hazards are geologic. Geologic hazards are naturally occurring, dynamic geologic processes that have the potential to cause damage, loss of property, injury, and loss of life. Schaller et al. (2014) summarized and categorized the geologic hazards of the National Park System (Appendix A is a table of hazards at each of the 83 parks in the study). Geologic hazard categories include avalanches, cave and karst incidents, coastal and shoreline hazards, flooding, geothermal risks, glacial activity, mass wasting events, rockfalls, seismic activity, and volcanic hazards. The primary geologic hazards of the historic sites are flood-related impacts associated with the Hudson River and its tributaries, particularly the Fall Kill. Furthermore, floodplain and wetland environments along the Hudson River have likely been exposed to PCB contamination during previous flooding events or due to daily tidal fluctuations within the river channel. Additional potential geologic hazards include mass wasting events, seismicity, and impacts from climate change. Table 3 summarizes the geologic hazards at the historic sites.

Table 3. Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2015 and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the historic sites.

Hazard	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Sea level change	Potential Hazard	• Inundation • Enhanced erosion • Destruction of infrastructure, e.g., through saturation • Water quality effects • Water supply diminished	DOI SHIRA (Strategic Hazard Identification and Risk Assessment) risk mapper (Department of the Interior 2023)
Coastal storm surge	Potential Hazard	Flooding from increased sea level coupled with tidal amplification	• Orton et al. (2020) • Tabak et al. (2016) • Weiss (2017)
Coastal erosion	Not applicable; not in coastal zone	Not applicable	Not applicable
Flash flood	Known Hazard	• Sudden rising water (e.g., Val-Kill Pond and surrounding wetlands) • Destruction of infrastructure	Roosevelt-Vanderbilt National Historic Sites scoping summary (Thornberry-Ehrlich 2008)
Riverine flood	Known Hazard	• Flooding (e.g., snowmelt, rainfall, storm activity, tidal fluctuations) • Destruction of infrastructure • Stream channel migration • Stream bank erosion • Floodplain and wetland contamination with polychlorinated biphenyls (PCBs)	• DOI SHIRA risk mapper (Department of the Interior 2023) • Federal Emergency Management Agency (FEMA) Map Service Center • Natural resource condition assessment report (Cole et al. 2012) • Roosevelt-Vanderbilt National Historic Sites scoping summary (Thornberry-Ehrlich 2008) • US Environmental Protection Agency (2002) Hudson River PCBs Site Record of Decision • US Environmental Protection Agency (2019, 2023) Hudson River PCBs Superfund site fact sheets

Table 3 (continued). Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2015 and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the historic sites.

Hazard	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Lake, pond, and/or reservoir level change	Known Hazard	• Flash flooding (e.g., Val-Kill Pond and surrounding wetlands) • Destruction of infrastructure	Roosevelt-Vanderbilt National Historic Sites scoping summary (Thornberry-Ehrlich 2008)
Earthquake	Potential Hazard (very low)	• Falling objects • Collapsing structures • Inoperability of major building systems (e.g., power, sewer, water) • Liquefaction; loss of strength to foundations, silt deposition, standing water • Trigger to other hazards (e.g., landslides, debris flows)	• DOI SHIRA risk mapper (Department of the Interior 2023) • The New York City Area Consortium for Earthquake Loss Mitigation report (Tantala et al. 2005) • USGS Earthquake Hazards Program, Information by Region – New York • USGS National Seismic Hazard Model • Wheeler et al. (2000)
Slope movements (landslide/avalanche)	Known Hazard – susceptible to landslides and slumps	• Rockfall • Slides or flows onto structures • Slides or flows from under structures • Damage or destruction of park infrastructure, including roads, trails, and buildings • Damage to or loss of natural or cultural resource sites or features • Tree mortality due to infestation is a known problem in the historic sites. Loss of stabilizing vegetation can increase susceptibility to mass wasting events. • Human injury or casualty	• DOI SHIRA risk mapper (Department of the Interior 2023) • FEMA National Risk Index – Landslide • Roosevelt-Vanderbilt National Historic Sites scoping summary (Thornberry-Ehrlich 2008) • Titus and Titus (2012) • Cole et al. (2012) • Denny Capps, NPS GRD, personal communication 29 January 2024
Permafrost	Not applicable; not present at the historic sites	Not applicable	Not applicable

Table 3 (continued). Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2015 and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the historic sites.

Hazard	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Cave/karst	Not applicable; no known sinkhole susceptibility	Not applicable	Not applicable
Shrink/swell soils	Potential Hazard (low) – Linear extensibility ratings are “low” (below 3%) for all the soils mapped within the historic sites	• Damage or destruction of park infrastructure • “Heaving” of ground beneath infrastructure • Increase susceptibility to mass wasting events	Web Soil Survey, Dutchess County, NRCS Soil Survey Area NY027
Tsunami	Not applicable; not near coastal zone	Not applicable	Not applicable
Volcanic eruption	Not applicable; not present in or near the historic sites	Not applicable	Not applicable
Hydrothermal activity	Not applicable; not present in or near the historic sites	Not applicable	Not applicable
Radon	Known Hazard (EPA zone 1 [high])	Health hazard	• DOI SHIRA risk mapper (Department of the Interior 2023) • EPA Map of Radon Zones • New York State Department of Health Radon Result Tracker website: Dutchess County

Table 3 (continued). Geologic hazards checklist. This summary table is a synthesis of existing GRI-compiled map data and information, as well as published USGS or state geological survey information. It is appropriate for use at park-scale discussions and assessments. It is not a substitute for site-specific investigations or National Environmental Policy Act (NEPA) analysis. Ground-disturbing activities should neither be approved nor denied based upon the information here. This table is modeled after the Natural Hazard Checklist (see NPS 2015 and Jarvis 2015). It is meant to provide general information to identify the full range of natural hazard-based risks for the historic sites.

Hazard	Best Professional Judgement	Risk or Secondary Hazard	Sources of Geohazard Information
Fluvial contamination (Hudson River)	Known Hazard	Health hazard	• Natural resource condition assessment report (Cole et al. 2012) • Roosevelt-Vanderbilt National Historic Sites scoping summary (Thornberry-Ehrlich 2008) • US Environmental Protection Agency (2002) Hudson River PCBs Site Record of Decision • US Environmental Protection Agency (2019, 2023) Hudson River PCBs Superfund site fact sheets • US Environmental Protection Agency Hudson River PCBs Superfund website: https://www.epa.gov/hudsonriverpcbs (accessed 17 January 2024)

According to NPS Management Policies (2006), although the magnitude and timing of future geologic hazards are difficult to forecast, the NPS strives to understand hazards and, subsequently, minimize their potential impact on visitors, staff, and developed areas. NPS Policy Memorandum 15-01 (Jarvis 2015) directs NPS managers and their teams to proactively identify and document facility vulnerabilities to climate change and other natural hazards. The saving of human life will take precedence over all other management actions.

In the context of naturally occurring hazards and risk assessment, it is important to understand the distinction between "hazard" and "risk." The terms "hazard" or "geologic hazard" refer to dangerous natural processes, substances, or conditions that may result in loss of life, injury, property damage, economic disruption, or environmental change (Holmes et al. 2013). "Risk" refers to the likelihood that a hazard will cause harm and is a function of both hazard probability and the value of assets in harm's way (Holmes et al. 2013). Identifying geologic hazards, assessing the likelihood of their occurrence, and defining potential risks to infrastructure or people can assist the NPS with the management of these hazards (Schaller et al. 2014, p.1). Activities to mitigate risks associated with geologic hazards are carried out within the constraints of the 1916 Organic Act, primarily that discretionary activities may not impair park resources and values and must be consistent with management policies. The NPS cannot totally control these risks; therefore, park visitors must assume a substantial degree of risk and responsibility for their own safety when visiting areas that are managed and maintained as natural, cultural, or recreational environments (National Park Service 2006).

Management policies (National Park Service 2006) do not impose specific visitor safety instructions. This GRI report presents recommendations for reducing risks related to geologic hazards; however, it is up to the discretion of decision-makers at the park level on whether, how, and when to implement these recommendations, and they will be subject to the availability of funding and staffing as well as legal and policy considerations.

It is recommended that the historic sites' management and staff consider avoiding the placement of new visitor and other facilities in geologically hazardous areas such as low-lying floodplains and areas prone to flash flooding associated with the Fall Kill, Maritje Kill, Crum Elbow Creek, and the Hudson River. The exposure to PCB-contaminated floodwaters and floodplain sediments along the Hudson River presents a potential health hazard. Historic site managers should examine the feasibility of phasing out, relocating, or providing alternative facilities for park developments subject to hazardous processes. In areas where dynamic natural processes cannot be avoided, such as floodplains, developed facilities should be sustainably designed (e.g., removable in advance of hazardous storms or other conditions). When it is determined that facilities must be located in such areas, their design and siting will be based on a thorough understanding of the nature of the physical processes and on avoiding or mitigating (1) the risks to human life and property and (2) the effect of the facility on natural physical processes and the ecosystem.

Although the steep hillslopes and ravines that border the Roosevelt and Vanderbilt mansions along the Hudson River are vegetated and appear stable, minor mass wasting events have occurred and present a considerable hazard. Any development, maintenance, or rehabilitation projects that disturb the ground or remove vegetation in these areas should be avoided until the potential destabilization impact has been evaluated. Additionally, any stormwater management projects that redirect drainage, runoff, or precipitation should avoid the embankment leading down to the river, as high degrees of ground saturation can trigger mass wasting events. If the historic sites intend to make significant drainage or runoff changes, it is strongly recommended that additional investigations of the substrate be conducted to further mitigate the likelihood of mass wasting events (Denny Capps, NPS GRD, personal communication 29 January 2024).

Flooding

One of the priority management concerns for Eleanor Roosevelt National Historic Site and Home of Franklin D. Roosevelt National Historic Site is flooding associated with the Fall Kill tributary system. The Fall Kill is characterized as a shallow, wide, low-gradient creek, and it poses a known flood hazard during large storms or hurricanes due to its sluggish discharge. Both historic sites are situated within the 100-year floodplain of the Fall Kill, a designation that predicts the area will experience one major flood event every century (or a 1% annual chance). Historically, large storm events have negatively impacted the low-lying Fall Kill floodplain, including historic site resources and surrounding residential properties. In 2011, heavy rains associated with Hurricane Irene caused a significant amount of flooding that created debris obstructions along the Fall Kill. Within the Roosevelt estate, NPS staff were able to clear blockages along the Fall Kill to help restore drainage and prevent additional overflow along upstream segments of the creek. Flooding events along the Fall Kill also introduce large sediment loads that become trapped by artificial impoundments such as Val-Kill Pond and impact the cultural landscape (see "Geologic Resource Protection"). Park management should monitor the drainage network of the Fall Kill to help minimize flooding impacts caused by natural events (e.g., storms, hurricanes, beaver dams) and surrounding development projects.

The Hudson River presents a minor, albeit present, hazard along the low-lying portions of the Roosevelt and Vanderbilt estates. Along the river corridor, the boundary of the historic sites is located near the high-water mark, and areas of low elevation frequently experience flooding associated with storm activity coupled with tidal fluctuations (Thornberry-Ehrlich 2008). Despite its name, the lower stretch of the Hudson River is technically a tidally influenced estuary from its mouth at New York Harbor north to the Federal Dam in Troy, New York; the daily tidal range at the historic sites is about 1.2 m (4 ft) per day (David Hayes, NPS Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 16 March 2023). At the Roosevelt estate, elevated river levels pose a potential threat to freshwater tidal wetlands located south of the Springwood mansion at Roosevelt Cove.

At the Vanderbilt estate, minor flooding has occurred along the southern boundary of the historic site near the mouth of Crum Elbow Creek. The confluence of Crum Elbow Creek and the Hudson River is a low-lying floodplain prone to flooding events and daily tidal fluctuations. In the past, rising water levels along the creek outlet have flooded neighboring businesses and residential properties adjacent to the historic site (Figure 16).

Figure 16. Flooding near the southern boundary of Vanderbilt Mansion National Historic Site in April 2007. The confluence of Crum Elbow Creek and the Hudson River is a low-elevation floodplain region susceptible to flood events and daily tidal fluctuations. NPS / DAVID HAYES

Park management should be aware of the threats of climate change that may introduce more frequent, intense, and prolonged storm events. The increased occurrence and strength of these storms have the potential to enhance flooding impacts at all three historic sites. Additionally, rising sea levels not only impact coastal regions of New York but also have negative influences inland up the Hudson River Valley (see "Climate Change"). Managers and staff who are interested in learning more about fluvial systems monitoring are encouraged to read Lord et al. (2009), which provides an overview of river and stream dynamics and contains helpful guidelines and methodology descriptions.

Hudson River Contamination Issues

Although water resource issues are beyond the scope of this GRI report, a discussion of river contamination is included because of the potential disruption it may cause to the geologic features, processes, and resources of the historic sites. Park managers are directed to the NPS Water Resources Division (see "Additional References, Resources, and Websites") to address water resources planning.

According to the Natural Resource Condition Assessment by Cole et al. (2012), the historic sites are situated adjacent to or near three federally designated Superfund sites (uncontrolled or controlled sites containing hazardous waste): Jones Sanitation, the Haviland Complex, and the Hudson River. The Hudson River Superfund site poses the highest threat, as the river corridor bordering both the Roosevelt and Vanderbilt estates has been contaminated by industrial chemical pollutants and can directly impact the natural resources of the historic sites. From the 1940s through the 1970s, manufacturing plants discharged an estimated 1.3 million pounds of PCBs into the Hudson River, contaminating the lower 322 km (200 mi) stretch extending from Hudson Falls to the Battery in New York City (Cole et al. 2012). The US Environmental Protection Agency (EPA) has banned the production of PCBs because these substances accumulate inside living things, gradually increasing in concentration as they move up the food chain. Although PCBs originated upriver, these pollutants contaminated the water and adhered to mobile river sediments that negatively impacted downstream aquatic ecosystems. Several New York fisheries were closed, and public advisory notifications were issued when certain species of fish tested above the acceptable level of PCBs for human consumption (US Environmental Protection Agency 2002; Cole et al. 2012).

Contamination along the Hudson River Superfund site is not confined to the river channel itself, as floodplains and other low-lying regions have been exposed to PCBs due to tidal fluctuations or flooding events. The contamination of floodplain sediments serves as a pathway to introduce pollutants into the terrestrial food chain. Thus, it is possible that natural resources and wildlife communities within Home of Franklin D. Roosevelt National Historic Site and Vanderbilt Mansion National Historic Site have been exposed to PCB contamination over the past several decades (Cole et al. 2012). As part of the remediation process, the EPA coordinated a multi-year sediment removal project north of the historic sites near the sources of PCB contamination. Initial restoration efforts began in 2009 when the EPA required GE to dredge PCB-contaminated river sediment "hot spots" along a 64 km (40 mi) interval of the Upper Hudson from Fort Edward to Troy, New York (US Environmental Protection Agency 2002, 2023). Continued dredging and habitat restoration activities were completed over an additional 6-year period; in all, approximately 2.75 million cubic yards of PBC-contaminated sediment were removed from the Hudson River bottom (US Environmental Protection Agency 2019). Future investigations and monitoring of the lower Hudson River from the Federal Dam to New York Harbor are ongoing (US Environmental Protection Agency 2019, 2023). Beginning in the spring of 2023, the EPA began sampling water, fish, and sediment of this lower portion of the river to test for PCBs and other contaminants to help inform additional investigations through the year 2025 (US Environmental Protection Agency 2023). According to the GRI scoping summary (Thornberry-Ehrlich 2008), there are currently no plans to remove potential contaminated floodplain sediments bordering the Roosevelt and Vanderbilt estates.

Facilities Maintenance and Erosion

Modifications to the steep hillslopes adjacent to the Hudson River, such as road and trail construction or expansion, have the potential to destabilize the ground and trigger mass wasting events such as slope creep (downslope movement of loose, weathered rock material) and slumping (downslope movement of a coherent mass of rock material) (see "Mass Wasting along the Hudson River"). Any project involving the loss of vegetation weakens the ground by eliminating cohesive root structures, thereby increasing erosion and mass wasting susceptibility. Accelerations in erosion or runoff—especially along the Hudson River, Crum Elbow Creek, Fall Kill, and Maritje Kill—can increase the sediment load and impact downstream channel and pond morphology (Thornberry-Ehrlich 2008).

The soils and surficial geologic units underlying the historic sites are unconsolidated deposits that are highly susceptible to natural and artificially induced erosion and mass wasting events. According to the US Department of Agriculture (USDA) Natural Resources Conversation Service (NRCS) Web Soil Survey, all the soils mapped within the historic sites present a "low" shrink/swell hazard, as measured by a <3% linear extensibility rating. However, the soils within the historic site are not favorable for the design, construction, and performance of stormwater management infrastructure. Over 90% of the historic sites' acreage contains soils that are rated "most limited," meaning that soils possess one or more characteristics (i.e., permeability, slope, depth to bedrock) that are not favorable for runoff mitigation practices (NRCS Web Soil Survey). Soils with "most limited" ratings have constraints on stormwater infiltration that cannot be easily remediated without the implementation of specially designed construction projects or a major soil reclamation (NRCS Web Soil Survey). Since 2010, stormwater management projects designed to redirect drainage at the Vanderbilt estate have failed, resulting in multiple pipe ruptures that rapidly incised the hillslopes flanking the Hudson River (Figure 17; see "Mass Wasting along the Hudson River"). Some of the erosion extended up to the base of the Vanderbilt mansion, illustrating the poorly consolidated nature of the underlying soil and surficial geology (Figure 18). At the Roosevelt estate, a storm drain that originated from the FDR Presidential Library and Museum created an erosional swale (a shallow drainage channel with gently sloping sides) through part of a historic tree farm within Home of Franklin D. Roosevelt National Historic Site. To rehabilitate the site damage, a 2005 project installed a new catch basin and attempted to stabilize the slopes (Figure 19).

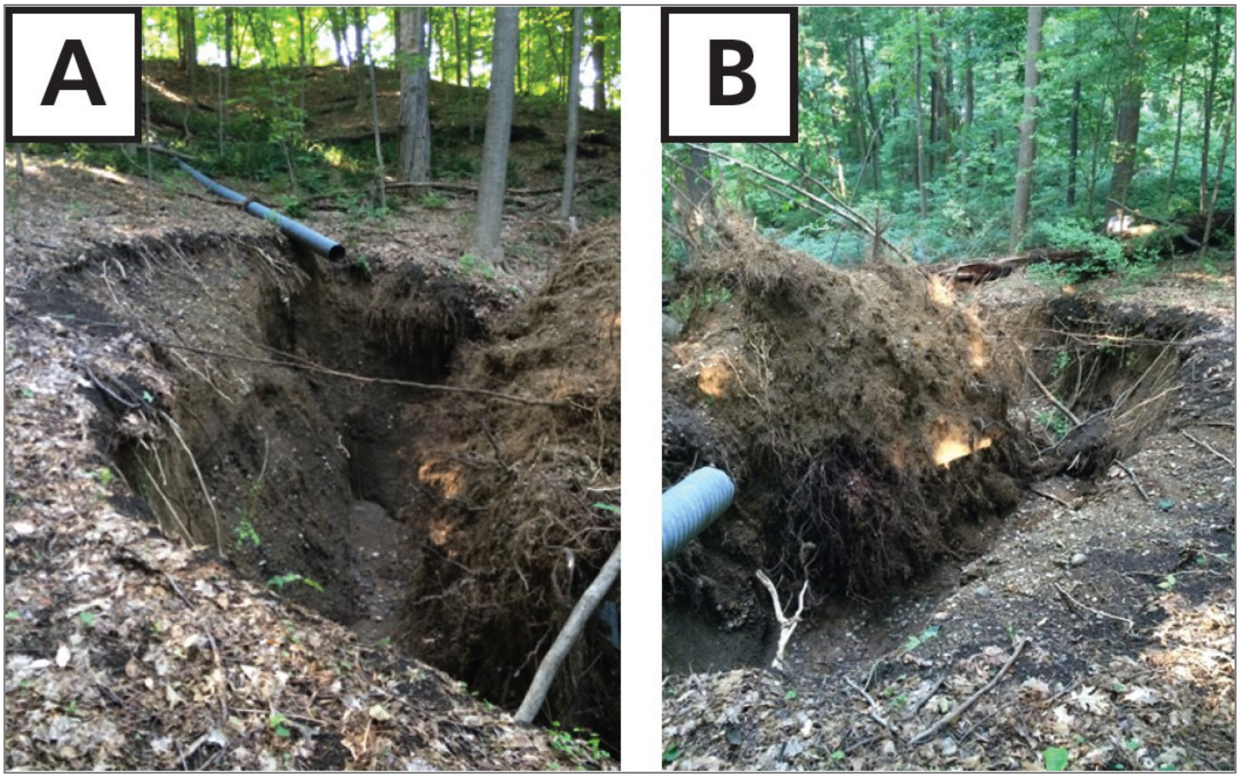

Figure 17. Erosional incision along the Hudson River hillslopes in Vanderbilt Mansion National Historic Site. The incision occurred rapidly following the failure of a drainage pipe that extends from the historic site parking lot down to the river. A) Photograph of an erosional gully looking upslope toward the historic site, while B) shows the same feature viewing downslope. For scale, the drainage pipe is approximately 30 cm (1 ft) in diameter. NPS / DAVID HAYES

Figure 18. Erosional gully feature created by drainage pipe failure adjacent to the Vanderbilt mansion. Drainage projects engineered to divert precipitation and runoff down the steep slopes next to the Hudson River have caused multiple incidents of erosion and mass wasting. For scale, the drainage pipe at the bottom of the gully is approximately 30 cm (1 ft) in diameter. NPS / DAVID HAYES

Figure 19. Slope rehabilitation efforts at Home of Franklin D. Roosevelt. Storm drainage adjacent to the FDR Library and Museum has created an erosional swale through part of a historic tree plantation. The 2005 project installed a new catch basin and attempted to stabilize the swale slopes within the damaged site. Indicators of slope instability include leaning and J-shaped trees, such as the ones to the right of the photograph (yellow arrows). NPS / DAVID HAYES

Historically, there have been several construction projects that have altered the landscape of the Roosevelt estate. The mid-19th century completion of the New York Central & Hudson Railroad (now the CSX Railroad) inadvertently established a freshwater tidal wetland along the Hudson River at Roosevelt Cove. Since the railway was built, a culvert pipe has been installed that regulates the flow of water in and out of the wetland area. Rising water levels along the wetland have impacted part of the road system, including the old historic road (River Road) that carried FDR’s casket to his resting place at Springwood (Auwaerter and Curry 2009; David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). The low-lying historic road is impassable today, mostly due to increased water levels attributable to beaver activity along the edges of the wetland. According to Auwaerter and Curry (2009), consideration should be given to reconstructing the lost portion of River Road along the north side of Roosevelt Cove, as it would allow visitors to view historic sites such as the Roosevelt boat house (removed circa 1935), boat landing (removed after 1945), and railroad platform (removed after 1945) where FDR’s casket was transported to Hyde Park. The Val-Kill Pond represents an artificial sediment and nutrient trap along the Fall Kill that hasn't been dredged in decades. Over the years, the open water portion of the pond has decreased as rising nutrient levels have allowed vegetative growth to thrive (see "Flooding").

A fundamental characteristic of the historic sites is the scenic viewshed of the Hudson River Valley admired from atop the river bluffs. However, over many decades, the integrity of the historic landscape along the Hudson River has slowly deteriorated as vegetative growth now obscures portions of the river corridor and beyond. The restoration of the viewshed presents a significant compliance issue, as the necessary removal of trees would likely introduce problems related to erosion, invasive species, runoff, and slope stability if not performed properly (David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). To further preserve the aesthetic views and cultural landscape that the Roosevelt and Vanderbilt families cherished, the historic sites have partnered with Scenic Hudson, one of the Hudson River Valley's largest environmental organizations. In addition to protecting land now owned by the NPS, Scenic Hudson has purchased approximately 77 ha (190 ac) of property across the river from Springwood and preserves the land on behalf of the historic site (see https://www.scenichudson.org/explore-the-valley/our-parks/ [accessed 17 January 2024]).

Mass Wasting along the Hudson River

The term "mass wasting" is used to describe downhill movements of rock or soil and includes events such as landslides, slumping, and slope creep. Mass wasting events are driven by natural processes such as erosion, precipitation, flooding, and seismicity (earthquakes) but can also be artificially induced by construction, mining, undercutting, vegetative clearing, and other projects that destabilize the ground. At the historic sites, the Hudson River fluvial system is a significant and dynamic landscape component that incises bluffs, terraces, and ravines while simultaneously modifying hillslope stability conditions. As rocks are weathered and eroded, unstable material is transported downgradient by water, wind, and gravity, where it accumulates as unconsolidated alluvium or alluvial fan deposits along the basal slopes and lowlands of the Hudson River Valley.

According to the NPS scoping summary (Thornberry-Ehrlich 2008), landslides, slumping, and slope creep are all prevalent issues or potential concerns within the historic sites, especially surrounding the steep Hudson River slopes bordering the Springwood and Vanderbilt mansions. Although most of the slopes and ravines along the river corridor are vegetated and appear stable, minor slumping events provide clear evidence of their vulnerability to mass wasting. Slumping and slope creep pose a considerable risk, as the roads and historic structures in the area are all at risk of being damaged or destroyed (Thornberry-Ehrlich 2008; Titus and Titus 2012). According to the GRI GIS data, the Springwood and Vanderbilt mansions are both underlain by unconsolidated Quaternary glacial sediments (**PLt**). However, several publications (Connally and Sirkin 1986; Cadwell 1989; Cadwell et al. 1996; Titus and Titus 2012) have proposed that the Hyde Park area encompassing the ornate mansions is underlain by the Hyde Park delta, an Ice Age landform created by tributary streams that emptied into Glacial Lake Albany about 17,000 years ago (see "Pleistocene Glacial History of the Hudson River Valley"). As Glacial Lake Albany drained following the Ice Age, these deltaic sediments were left standing high above the Hudson River Valley, where they cap the bluffs today.

Both the Roosevelt and Vanderbilt families are believed to have built their homes at the crest of these deltaic deposits, and the steep slopes west of the properties are thought to represent foresets (inclined surfaces that dip in the direction of sediment transport) along the front edge of the delta (Titus and Titus 2012).

Many cities and towns located along the Hudson River—Catskill, Germantown, Hyde Park, New Baltimore, Poughkeepsie, Rensselaer, Rhinebeck, and Staatsburg, to name a few—are built on top of unconsolidated gravels, sands, silts, and clays associated with glacial retreat and Glacial Lake Albany (Titus and Titus 2012). The Hudson River Valley has a history of mass wasting events such as landslides and slumping, especially along steep river embankments where surficial units contain high amounts of clay (Newland 1909, 1916; Dunn and Banino 1977; Jäger and Wieczorek 1994). The threat of mass wasting is exacerbated when these steeply inclined deposits become saturated with water and develop subsurface fractures or failure planes along which the ground will slide, slip, or migrate downslope (Coates 1977, 1985). Although fractures or failure planes may develop, these features can remain relatively stable for long periods of time until heavy rain or snowmelt cause the ground to become waterlogged (saturated and heavy with water) and increased pore-water pressures (pressure exerted by groundwater in pore spaces) trigger the fracture surface to move (Coates 1985; Jäger and Wieczorek 1994; Titus and Titus 2012; Coe 2016). However, mass wasting events can also be artificially induced by mining, road and trail construction, undercutting (removal of base material along a slope or cliff), vegetative clearing, and other development projects that destabilize the ground. Such was the case with the historic 1906 Haverstraw landslide. Located along the Hudson River about 64 km (40 mi) south of Hyde Park, the town of Haverstraw is sited atop a thick accumulation of clay-rich, glacial lacustrine deposits that were historically mined for brick manufacturing. As the clay deposits were stripped back from the Hudson River, the local brickyards oversteepened (modification or steepening of hillslopes beyond the angle of repose) the mined hillslopes below the town, causing six city blocks to collapse downslope, resulting in 19 deaths (Figure 20; Coates 1977, 1985). Resource management and staff should remain mindful of any hillslope modifications performed along the Hudson River that may lead to slope failure or destabilization.

Figure 20. Before (A) and after (B) photographs of the 1906 Haverstraw landslide. Local brick yards overexcavated and oversteepened the mined hillslopes leading to a series of landslide events that swallowed 6 city blocks (including 5 streets and 21 buildings) and claimed the lives of 19 people. Photographs were taken from different vantage points before and after the landslide. A) A pre-landslide photograph taken in 1902 that shows visual evidence of how clay mining was encroaching upon buildings and undermining the riverbank at Haverstraw. Finely layered, clay-rich deposits form the steep embankment directly below the buildings. Photograph from the Archives of the Haverstraw Brick Museum, Danielle DeNoyelles Collection. B) Post-landslide image taken in 1906. Photograph from the Archives of the Haverstraw Brick Museum, Thomas Sullivan Collection.

The landscape surrounding the Roosevelt and Vanderbilt estates presents evidence of several rotational slump features along the steep embankment of the Hudson River, some of which are close to the mansions themselves (Titus and Titus 2012). These slumps are characterized by a curved failure surface where slope movements display both downward and backward rotational motion. According to Titus and Titus (2012), these rotational slumps resemble semi-circular, scallop-shaped hillslopes that contain wrinkled earth flows (downslope flow of saturated, fine-grained material) at or near the base; earth flows are sometimes referred to as the slump "foot." These older slump features have left visible scars on the landscape that are now largely vegetated and considered stable (Figure 21; Thornberry-Ehrlich 2008; Cole et al. 2012).

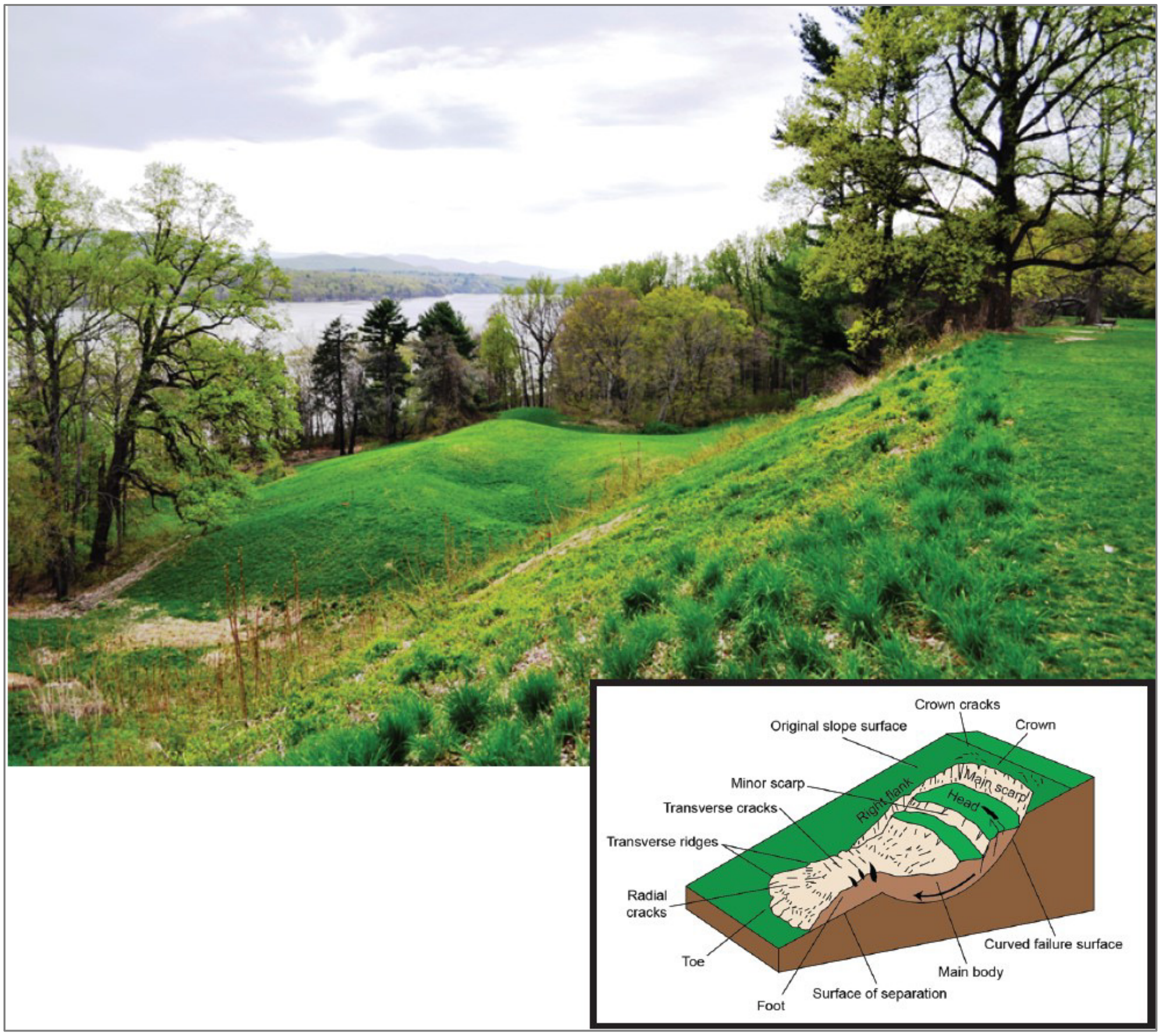

Figure 21. Interpreted slump features near the Overlook at Vanderbilt Mansion National Historic Site. Unconsolidated glacial deposits that form the steep Hudson River hillslopes and ravines are susceptible to erosion and pose a slumping hazard commonly triggered by excessive exposure to water in the form of rainfall, snowmelt, or diverted drainage. Located north of the Vanderbilt mansion, these older slumps are vegetated and appear stable today. Photograph courtesy of Dr. Robert Titus (Hartwick College, retired). Inset image shows a simplified, cross-sectional block model of a rotational slump feature that has failed and formed an earthflow. Inset block model from Highland and Bobrowski (2008) and modified by Tim C. Henderson (Colorado State University).

At the Vanderbilt estate, several instances of slumping and erosion have negatively impacted resources within the historic site. The construction and subsequent modification of the parking lot in the 1950s and 1960s installed a large, 0.3 m (1 ft) diameter drainage pipe that extends down the western slopes toward the Hudson River. Since 2010, the pipe has failed at least twice, resulting in drainage issues, rapid erosional incision, and associated incidents of slumping (see Figures 17 and 18; see also "Facilities Maintenance and Erosion"; David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). Additional slumping has occurred along the entrance road to the historic site, necessitating the need for road repairs (Thornberry-Ehrlich 2008). To help mitigate the threat of mass wasting, the long-term remediation plan is to remove the drainage pipe and redirect runoff beyond the historic site boundary using a combination of in-ground infiltration and rain gardens. Although in-ground infiltration is good at minimizing erosion, it may potentially aggravate areas where landslides are a substantial concern (Denny Capps, GRD geologist, personal communication December 2023). Another project at the Vanderbilt estate estimated for fiscal year 2026–2027 involves converting all stormwater management to an on-site location, further eliminating the need for drainage systems that redirect water down the Hudson River slopes.

At the Roosevelt estate, similar incidents of erosion and mass wasting have occurred in association with drainage projects, and the landscape surrounding Springwood suggests an extensive history of slumping (Titus and Titus 2012). At Home of Franklin D. Roosevelt National Historic Site, a storm drain that diverted water away from the FDR Presidential Library and Museum had slowly formed an erosional swale, which destabilized the slopes, leading to slope creep and J-shaped trees (see Figure 19; David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). Sometimes referred to as a "drunken forest," J-shaped trees develop as unstable soils or slope materials slowly move under gravity. As trees have a natural tendency to grow in an upright vertical position, the progressive downward and lateral migration of the substrate distorts the tree's morphology as it "corrects" to maintain vertical growth. In addition to slope creep, it has been speculated that steep slump slopes surround the Springwood mansion on three sides, although some degree of post-glacial fluvial erosion cannot be ruled out (Titus and Titus 2012).

The GRD employs three slope management strategies: (1) an Unstable Slope Management Program (USMP) for transportation corridor risk reduction; (2) quantitative risk estimation for specific landslide hazards; and (3) monitoring of potential mass wasting areas. Park managers can contact the GRD to discuss these options and determine if submitting a technical request is appropriate. Further information about slope movements is provided in the "Guidance for Resource Management" section. The National Landslide Preparedness Act was signed into law on 5 January 2021. The act authorized the establishment of the National Landslide Hazards Reduction Program and requires the USGS and other federal agencies to identify, map, assess, and research landslide hazards.

Radon

Radon is a naturally occurring gas created by the radioactive decay of the element radium. Although radon is usually ubiquitous (present in small amounts) in soil and rocks, some types of rock (i.e., volcanic rocks, granites, dark shales, phosphate-rich rocks, and metamorphic rocks) have the potential to produce above average amounts of radon gas that can pose a known health risk (Otton 1992). According to the US Environmental Protection Agency (EPA) map of radon zones, Dutchess County is identified as a zone of high potential (zone 1) for elevated indoor radon levels.

Seismic Activity

The eastern continental margin of the United States is considered passive, meaning that it lacks high levels of earthquake, volcanic, or mountain-building activity associated with tectonic plate motion. However, seismic events still occur along the eastern seaboard as geologic structures (e.g., faults and fractures) accommodate stress within the subsurface of the Earth's crust. In the Hyde Park area, several roughly N-S-trending faults are mapped along both sides of the Hudson River, including a couple that transect portions of the Roosevelt estate (see poster). However, these fault structures are not considered active and were established several hundred million years ago during the Taconic orogeny (see "The Taconic Orogeny").

Historically, there have been only six earthquake events registering greater than a magnitude 5.0 on the Richter scale within New York (Wheeler et al. 2000; Tantala et al. 2005). Although earthquake events larger than magnitude 5.0 are rare, there is still plenty of evidence to show the region is seismically active. Data from the USGS Earthquake Hazards Program shows approximately 500 recorded lower magnitude seismic events in New York since 1900, with many additional earthquakes that have occurred along the Connecticut-New Jersey-New York boundary (Figure 22; see https://www.usgs.gov/programs/earthquake-hazards/science/information-region-new-york [accessed 17 January 2024]). Although these records show that earthquakes are a common occurrence, these low magnitude events pose a very low potential hazard risk to the historic sites.

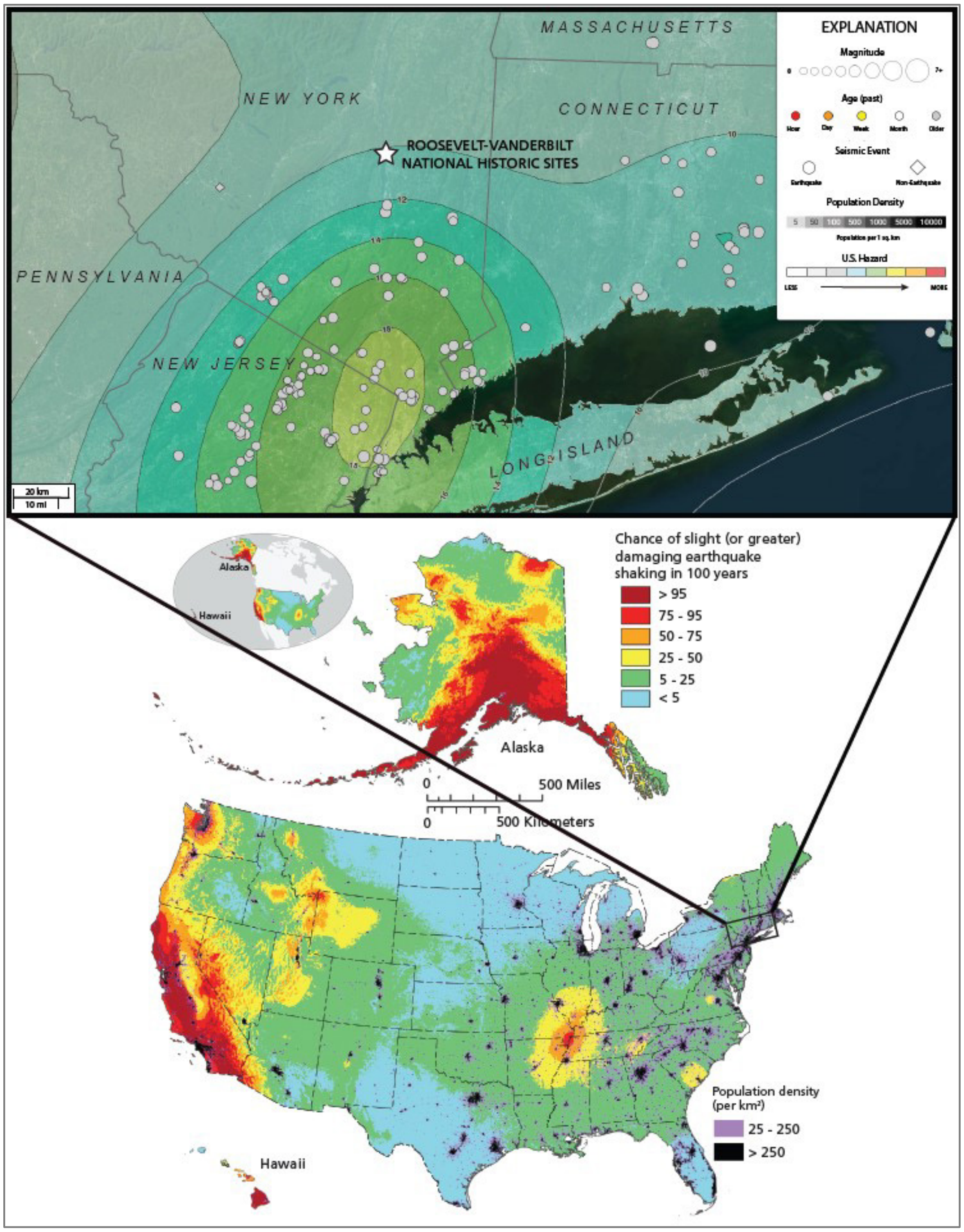

Figure 22. National seismic hazard map of the United States, with detailed map of the southeastern New York area. The national map shows predicted earthquake hazards across the United States for the next 100 years based on National Seismic Hazard Models (US 50-state National Seismic Hazard Model by Petersen et al. 2023). The New York seismic map depicts historic earthquake activity since 1900. Numerous, low magnitude earthquakes have been recorded surrounding the historic sites, but these events only pose a very low potential seismic hazard. Contour labels in the detailed New York seismic map represent the expected number of damaging earthquake occurrences per 10,000 years. Based on both maps, the historic sites are situated in an area of medium seismic hazard relative to the rest of the country. The white star denotes the approximate location of the historic sites. USGS map modified by Tim C. Henderson (Colorado State University) using data from the USGS Earthquake Hazards Program (https://www.usgs.gov/programs/earthquake-hazards/science/information-region-new-york; accessed 17 January 2024).

Climate Change

Although climate change planning is beyond the scope of this GRI report, a discussion of climate change is included because of the potential disruption it may cause to the geologic features, processes, and resources of the historic sites. Additionally, NPS Policy Memorandum 15-01 (Jarvis 2015) directs NPS managers and their teams to proactively identify and document facility vulnerabilities to climate change and other natural hazards. Park managers are directed to the NPS Climate Change Response Program (see “Additional References, Resources, and Websites”) to address climate change planning. This program helps park managers develop plausible science-based scenarios that can be used to guide strategies and management activities that can help reduce the effects of climate change or adapt to them.

Climate change manifestations that may intensify geologic hazards within the historic sites include the following:

- More frequent and intense storm events
- Rising sea levels coupled with tidal amplification
- More frequent and intense flooding
- Increased erosion
- Increased threat of mass wasting events

According to the NPS foundation documents for the historic sites (National Park Service 2017a, 2017b, 2017c), projected climate change may adversely affect the landscape and viewshed by increasing the threat of erosion, increasing invasive species, shifting species phenology (cyclical and seasonal biotic cycles), and driving northward shifts in species ranges. Additionally, factors such as soil stability, vegetation, species composition, vernal pools, forest types, wetland migration and resilience, and habitat diversity may be impacted by projected increases in sea level, temperature, overall precipitation, frequency, and intensity of storms associated with climate change (Tabak et al. 2016; National Park Service 2017a, 2017b, 2017c).

Rising global temperatures present a clear and present risk now and in the coming decades as they facilitate increases in sea level, storm frequency and intensity, wave effects, coastal flooding, river flows, and rainfall (Sweet et al. 2022). In the past century, the northeast region of the United States has experienced a sea level rise of more than 0.3 m (1 ft), a phenomenon that has enhanced storm activity and flooding in not only coastal regions of New York but also inland waterways such as the Hudson River (Weiss 2017). Since the Hudson River is a tidally influenced estuary south of the Federal Dam in Troy, New York, increases in sea level are coupled with enhanced tidal amplification and inundation (Holleman and Stacey 2014). Any projected increases in sea level are highly likely to impact the low-gradient portions of the Hudson River Valley, including those at the historic sites (Orton et al. 2020). Both Home of Franklin D. Roosevelt National Historic Site and Vanderbilt Mansion National Historic Site are vulnerable to predicted rises in sea level. While Home of Franklin D. Roosevelt National Historic Site is considered susceptible to a 1.5 m (5.0 ft) rise in sea level, Vanderbilt Mansion National Historic Site is susceptible to a smaller rise of 0.3 m (1.0 ft)

(Department of the Interior 2023). Currently, low-elevation regions of the Roosevelt and Vanderbilt estates adjacent to the Hudson River already experience flood activity resulting from precipitation, meltwater, storm activity, and tidal fluctuations (see "Flooding"). Additionally, cities such as Catskill and Kingston that are located upstream of the historic sites are considered highly vulnerable to riverine and storm surge flooding (Weiss 2017). Continued projections of future sea level rise are only expected to exacerbate flood risks along the Hudson River Valley.

Increased storm frequency and intensity can bring extreme costs through loss of visitor access, impacts to neighboring communities and local economies, investments in recovery, irrevocable damage to unique resources, and permanent loss of land space (Caffrey et al. 2018; Sweet et al. 2022). At the historic sites, the combination of enhanced rainfall and storm activity has the potential to affect the Hudson River, Crum Elbow Creek, the Fall Kill, and Maritje Kill, increasing the threat and vulnerability posed by flooding hazards. The low-lying floodplain of the Fall Kill at Eleanor Roosevelt National Historic Site is particularly susceptible due to the sluggish drainage of the Fall Kill combined with its low water holding capacity. High flood stages already threaten local structures, roads, and bridges within the historic site; projected increases in precipitation will only exacerbate the issue (Thornberry-Ehrlich 2008). Although most of the infrastructure and natural resources along the flanks of the Hudson River have not been negatively impacted by flooding, portions of Vanderbilt Mansion National Historic Site at Bard Rock and along the mouth of Crum Elbow Creek have already experienced rising water levels (David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). Additional flooding has occurred along the freshwater tidal wetland near Roosevelt Cove along the southern boundary of Home of Franklin D. Roosevelt National Historic Site (see "Flooding").

In addition to enhanced flooding and tidal amplification, projected increases in temperature, precipitation, and storm activity have both direct and indirect consequences for slope stability and erosion. Excessive amounts of rainfall or snowfall will contribute to the threat of mass wasting events, as additional water will increase ground mass and subsurface pore-water pressures, leading to slope destabilization and failure (Coates 1985; Jäger and Wieczorek 1994). The steep hillslopes and ravines flanking the Hudson River are, in places, underlain by unconsolidated sediments that are already susceptible to erosion, slope creep, and slumping (see "Mass Wasting along the Hudson River"). Although these slopes are heavily forested and appear stable today, rising global temperatures may shift tree species tolerance while introducing invasive biota. According to the DOI SHIRA Risk Mapper hazard exposure summary report, the hazard level of tree mortality due to infestation is considered high at both Home of Franklin D. Roosevelt National Historic Site and Eleanor Roosevelt National Historic Site. Additionally, hemlock and ash trees are already in peril at the historic sites and throughout the northeast region due to the hemlock woolly adelgid and emerald ash borer, respectively (McCarty and Addesso 2019; David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). The potential loss of slope vegetation will only encourage soil instability, erosion, and mass wasting.

Geologic Resource Monitoring and Protection

Val-Kill Pond

Situated in the floodplain of the Fall Kill, Val-Kill Pond is an artificial water impoundment feature created by the Roosevelt family when they dammed the creek during the 1920s and 1930s. The construction of the dam and pond has altered the natural drainage of the Fall Kill, and fine-grained sediment is accumulating along the bottom of the pond. Historically, the Roosevelts dredged the creek and surrounding wetland to enlarge, deepen, and better define the Val-Kill Pond shoreline. Periodic dredging was also routinely performed into the 1950s as maintenance for rapid, unwanted sediment accumulation (Klemens et al. 1992). However, the Val-Kill Pond has not been dredged in recent decades. Since its last known dredging, up to 4.2 m (14 ft) of silt has accumulated on the bottom of the pond (Klemens et al. 1992). According to a 2004 evaluation by Geo Environmental, Inc., the sediment thickness was measured to be between 1.8 and 2.4 m (6 and 8 ft) (Cole et al. 2012). Although further dredging has been proposed, the assessed cost of such a project was higher than originally estimated (David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). Any future dredging projects should consider the methods outlined in Klemens et al. (1992) that acknowledge the potential adverse ecological effects, especially on endangered species such as the Blanding’s Turtle.

The Fall Kill tributary system transports nutrients into Val-Kill Pond that sustain a variety of native and invasive aquatic plants. However, over the years, the open water portion of Val-Kill Pond has gotten significantly smaller as nutrient levels have increased and aquatic plant growth has thrived (Klemens et al. 1992; Cole et al. 2012; David Hayes, Chief of Resource Management at Home of Franklin D. Roosevelt NHS, personal communication 1 February 2023). Park management should consider how these impacts are altering the character of the historic landscape.

Future Paleontological Potential

Although there are currently no paleontological resources reported from the historic sites (Tweet et al. 2010), it is possible that future fossil discoveries could be made from the underlying bedrock and surficial geology. Both bedrock units that underlie the historic sites—the Early Ordovician Stuyvesant Falls Formation (**Osf**) and Late Ordovician Austin Glen Formation (**Oag**)—have been reported to contain rare graptolites and radiolarians (tiny marine pelagic organisms characterized by a silica-rich skeleton) in Dutchess County (Fisher and Warthin 1976). Additionally, it is plausible that Cenozoic fossils could be contained in the Quaternary glacial tills (**PLt**) that comprise the surficial geology of the historic sites. Glacial deposits of similar age that surround the historic sites have already yielded spectacular Ice Age flora and fauna, including those of the Hyde Park mastodon site (see “Paleontological Resources”).

Guidance for Resource Management

This chapter provides information to assist resource managers in addressing geologic resource management issues and applying NPS policy. The compilation and use of natural resource information by park managers is called for in the 1998 National Parks Omnibus Management Act (§ 204), NPS 2006 Management Policies, and the Natural Resources Inventory and Monitoring Guideline (NPS-75).

Access to GRI Products

- GRI products (scoping summaries, GIS data, posters, and reports): http://go.nps.gov/gripubs
- GRI products are also available through the NPS DataStore: https://irma.nps.gov/DataStore/Search/Quick. Enter "GRI" as the search text and select a park from the unit list.
- GRI GIS data model: http://go.nps.gov/gridatamodel
- Additional information regarding the GRI, including contact information: https://www.nps.gov/subjects/geology/gri.htm

Three Ways to Receive Geologic Resource Management Assistance

- Contact the GRD (https://www.nps.gov/orgs/1088/contactus.htm). GRD staff members provide coordination, support, and guidance for geologic resource management issues in three emphasis areas: (1) geologic heritage, (2) active processes and hazards, and (3) energy and minerals management. GRD staff can provide technical assistance with resource inventories, assessments, and monitoring; impact mitigation, restoration, and adaptation; hazards risk management; laws, regulations, and compliance; resource management planning; and data and information management.
- Formally request assistance at the Solution for Technical Assistance Requests (STAR) webpage: https://irma.nps.gov/Star/ (available on the Department of the Interior [DOI] network only). NPS employees (from a park, region, or any other office outside of the Natural Resource Stewardship and Science [NRSS] Directorate) can submit a request for technical assistance from NRSS divisions and programs.
- Submit a proposal to receive geologic expertise through the Scientists in Parks program (SIP; see https://www.nps.gov/subjects/science/scientists-in-parks.htm). Formerly the Geoscientists-in-the-Parks program, the SIP program places scientists (typically undergraduate students) in parks to complete science-related projects that may address resource management issues. Proposals may be for assistance with research, interpretation and public education, inventory, and/or monitoring. The GRD can provide guidance and assistance with submitting a proposal. The Geological Society of America and Environmental Stewards are partners of the SIP program. Visit the internal SIP website to submit a proposal at https://doimspp.sharepoint.com/sites/nps-scientistsinparks (only available on DOI network computers).

Geological Monitoring

Geological Monitoring (Young and Norby 2009) provides guidance for monitoring vital signs (measurable parameters of the overall condition of natural resources). Each chapter covers a different geologic resource and includes detailed recommendations for resource managers, suggested methods of monitoring, and case studies. Chapters are available online at https://www.nps.gov/subjects/geology/geological-monitoring.htm.

Park-Specific Documents

Primary sources of information for resource management within the historic sites include the individual historic site foundation documents (National Park Service 2017a, 2017b, 2017c), the natural resource condition assessment report (Cole et al. 2012), and the GRI scoping summary report (Thornberry-Ehrlich 2008). These documents guided the writing of this GRI report.

NPS Natural Resource Management Guidance and Documents

- National Parks Omnibus Management Act of 1998: https://www.congress.gov/bill/105th-congress/senate-bill/1693
- NPS-75: Natural Resources Inventory and Monitoring guideline: https://irma.nps.gov/DataStore/Reference/Profile/622933
- NPS Management Policies 2006 (Chapter 4: Natural Resource Management): https://www.nps.gov/subjects/policy/management-policies.htm
- NPS Natural Resource Management Reference Manual #77: https://irma.nps.gov/DataStore/Reference/Profile/572379
- Resist-Accept-Direct (RAD)—A Framework for the 21st-century Natural Resource Manager: https://irma.nps.gov/DataStore/Reference/Profile/2283597

Identified Data and Resource Management Needs

Assistance with River Pollution-Related Issues

Contamination of the Hudson River corridor introduces additional management considerations that are beyond the scope of this report. Agencies such as the EPA are best equipped to handle issues related to fluvial contamination or pollution. For issues related to the PCB contamination of the Hudson River, the reader is directed to the EPA Hudson River PCBs Superfund Site (https://www.epa.gov/hudsonriverpcbs). The EPA website contains fact sheets, remediation project documents, remediation updates, in addition to long-term river monitoring operations. Additionally, park managers are directed to the NPS Water Resources Division (see “Additional References, Resources, and Websites”) for more information regarding water resources guidance and planning.

Geologic Resource Laws, Regulations, and Policies

The following sections, which were developed by the GRD, summarize laws, regulations, and policies that specifically apply to NPS geologic resources, processes, and energy and minerals. The first section summarizes law and policy for geoheritage resources, which includes caves, paleontological resources, and geothermal resources. The energy and minerals section includes abandoned mineral lands, mining, rock and mineral collection, and oil and gas operations. Active processes include geologic hazards (e.g., landslides), coastal processes, soils, and upland and fluvial processes (e.g., erosion). Laws of general application (e.g., Endangered Species Act, Clean Water Act, Wilderness Act, NEPA, or the National Historic Preservation Act) are not included, but the NPS Organic Act is listed when it serves as the main authority for protection of a particular resource or when other, more specific laws are not available.

Geoheritage Resource Laws, Regulations, and Policies

Caves and Karst Systems

Resource-specific laws:

- **Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309** requires Interior/Agriculture to identify "significant caves" on Federal lands, regulate/restrict use of those caves as appropriate, and include significant caves in land management planning efforts. Imposes civil and criminal penalties for harming a cave or cave resources. Authorizes Secretaries to withhold information about specific location of a significant cave from a Freedom of Information Act (FOIA) requester.
- **National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of cave and karst resources.
- **Lechuguilla Cave Protection Act of 1993, Public Law 103-169** created a cave protection zone (CPZ) around Lechuguilla Cave in Carlsbad Caverns National Park. Within the CPZ, access and the removal of cave resources may be limited or prohibited; existing leases may be cancelled with appropriate compensation; and lands are withdrawn from mineral entry.

Resource-specific regulations:

- **36 CFR § 2.1** prohibits possessing/destroying/disturbing…cave resources…in park units.
- **43 CFR Part 37** states that all NPS caves are "significant" and sets forth procedures for determining/releasing confidential information about specific cave locations to a FOIA requester.

NPS Management Policies 2006:

- **Section 4.8.1.2** requires NPS to maintain karst integrity, minimize impacts.
- **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.
- **Section 4.8.2.2** requires NPS to protect caves, allow new development in or on caves if it will not impact the cave environment, and to remove existing developments if they impair caves.
- **Section 6.3.11.2** explains how to manage caves in/adjacent to wilderness.

Geothermal

Resource-specific laws:

- **Geothermal Steam Act of 1970, 30 USC. § 1001** et seq. as amended in 1988, states:

    - No geothermal leasing is allowed in parks.
    - "Significant" thermal features exist in 16 park units (the features listed by the NPS at 52 Fed. Reg. 28793-28800 (August 3, 1987), plus the thermal features in Crater Lake, Big Bend, and Lake Mead).
    - NPS is required to monitor those features.
    - Based on scientific evidence, Secretary of Interior must protect significant NPS thermal features from leasing effects.
- **Geothermal Steam Act Amendments of 1988, Public Law 100--443** prohibits geothermal leasing in the Island Park known geothermal resource area near Yellowstone and outside 16 designated NPS units if subsequent geothermal development would significantly adversely affect identified thermal features.

Resource-specific regulations:

- **43 CFR Part 3200** requires BLM to include stipulations when issuing, extending, renewing, or modifying leases or permits to protect significant thermal features in NPS-administered areas (see 43 CFR §3201.10), prohibit the bureau from issuing leases in areas where geothermal operations are reasonably likely to result in significant adverse effects on significant thermal features in NPS-administered areas (see 43 CFR §3201.11 and §3206.11), and prohibit BLM from issuing leases in park units.

NPS Management Policies 2006:

- **Section 4.8.2.3** requires NPS to:
    - Preserve/maintain integrity of all thermal resources in parks.
    - Work closely with outside agencies.
    - Monitor significant thermal features.

Paleontological Resources

Resource-specific laws:

- **Archaeological Resources Protection Act of 1979, 16 USC §§ 470aa – mm Section 3 (1)** Archaeological Resource—nonfossilized and fossilized paleontological specimens, or any portion or piece thereof, shall not be considered archaeological resources, under the regulations of this paragraph, unless found in an archaeological context. Therefore, fossils in an archaeological context are covered under this law.
- **Federal Cave Resources Protection Act of 1988, 16 USC §§ 4301 – 4309 Section 3 (5)** Cave Resource—the term "cave resource" includes any material or substance occurring naturally in caves on Federal lands, such as animal life, plant life, paleontological deposits, sediments, minerals, speleogens, and speleothems. Therefore, every reference to cave resource in the law applies to paleontological resources.

- **National Parks Omnibus Management Act of 1998, 54 USC § 100701** protects the confidentiality of the nature and specific location of paleontological resources and objects.
- **Paleontological Resources Preservation Act of 2009, 16 USC § 470aaa** et seq. provides for the management and protection of paleontological resources on federal lands.

Resource-specific regulations:

- **36 CFR § 2.1(a)(1)(iii)** prohibits destroying, injuring, defacing, removing, digging or disturbing paleontological specimens or parts thereof.
- **Prohibition in 36 CFR § 13.35** applies even in Alaska parks, where the surface collection of other geologic resources is permitted.
- **43 CFR Part 49** contains the DOI regulations implementing the Paleontological Resources Preservation Act, which apply to the NPS.

NPS Management Policies 2006:

- **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.
- **Section 4.8.2.1** emphasizes Inventory and Monitoring, encourages scientific research, directs parks to maintain confidentiality of paleontological information, and allows parks to buy fossils only in accordance with certain criteria.

Energy and Minerals Laws, Regulations, and Policies

Abandoned Mineral Lands and Orphaned Oil and Gas Wells

Resource-specific laws:

- **The Bipartisan Infrastructure Law**, **Inflation Reduction Act**, and **NPS Line Item Construction** program all provide funding for the reclamation of abandoned mineral lands and the plugging of orphaned oil and gas wells.

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- None applicable.

Coal

Resource-specific laws:

- **Surface Mining Control and Reclamation Act (SMCRA) of 1977, 30 USC § 1201** et. seq. prohibits surface coal mining operations on any lands within the boundaries of a NPS unit, subject to valid existing rights.

Resource-specific regulations:

- **SMCRA Regulations at 30 CFR Chapter VII** govern surface mining operations on Federal lands and Indian lands by requiring permits, bonding, insurance, reclamation, and employee protection. Part 7 of the regulations states that National Park System lands are unsuitable for surface mining.

NPS Management Policies 2006:

- None applicable.

<u>Common Variety Mineral Materials (Sand, Gravel, Pumice, etc.)</u>

Resource-specific laws:

- **Materials Act of 1947, 30 USC § 601** does not authorize the NPS to dispose of mineral materials outside of park units.
- **Reclamation Act of 1939, 43 USC §387**, authorizes removal of common variety mineral materials from federal lands in federal reclamation projects. This act is cited in the enabling statutes for Glen Canyon and Whiskeytown National Recreation Areas, which provide that the Secretary of the Interior may permit the removal of federally owned nonleasable minerals such as sand, gravel, and building materials from the NRAs under appropriate regulations. Because regulations have not yet been promulgated, the National Park Service may not permit removal of these materials from these National Recreation Areas.
- **16 USC §90c-1(b)** authorizes sand, rock and gravel to be available for sale to the residents of Stehekin from the non-wilderness portion of Lake Chelan National Recreation Area for local use as long as the sale and disposal does not have significant adverse effects on the administration of the national recreation area.

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- **Section 9.1.3.3** clarifies that only the NPS or its agent can extract park-owned common variety minerals (e.g., sand and gravel), and:
    - Only for park administrative uses;
    - After compliance with NEPA and other federal, state, and local laws, and a finding of non-impairment;
    - After finding the use is the park's most reasonable alternative based on environment and economics;
    - Parks should use existing pits and create new pits only in accordance with park-wide borrow management plan;
    - Spoil areas must comply with Part 6 standards; and
    - NPS must evaluate use of external quarries.

- Any deviation from this policy requires a written waiver from the Secretary, Assistant Secretary, or Director.

Federal Mineral Leasing (Oil, Gas, and Solid Minerals)

Resource-specific laws:

- **The Mineral Leasing Act, 30 USC § 181** et seq., and the Mineral Leasing Act for Acquired Lands, 30 USC § 351 et seq. do not authorize the BLM to lease federally owned minerals in NPS units.
- **Combined Hydrocarbon Leasing Act, 30 USC §181**, allowed owners of oil and gas leases or placer oil claims in Special Tar Sand Areas (STSA) to convert those leases or claims to combined hydrocarbon leases, and allowed for competitive tar sands leasing. This act did not modify the general prohibition on leasing in park units but did allow for lease conversion in Glen Canyon National Recreation Area, which is the only park unit that contains a STSA.
- **Exceptions:** Glen Canyon National Recreation Area (NRA) (16 USC § 460dd et seq.), Lake Mead NRA (16 USC § 460n et seq.), and Whiskeytown-Shasta-Trinity NRA (16 USC § 460q et seq.) authorizes the BLM to issue federal mineral leases in these units provided that the BLM obtains NPS consent. Such consent must be predicated on an NPS finding of no significant adverse effect on park resources and/or administration.
- **American Indian Lands** Within NPS Boundaries Under the Indian Allottee Leasing Act of 1909, 25 USC §396, and the Indian Leasing Act of 1938, 25 USC §396a, §398 and §399, and Indian Mineral Development Act of 1982, 25 USCS §§2101-2108, all minerals on American Indian trust lands within NPS units are subject to leasing.
- **Federal Coal Leasing Amendments Act of 1975, 30 USC § 201** prohibits coal leasing in National Park System units.

Resource-specific regulations:

- **36 CFR § 5.14** states prospecting, mining, and…leasing under the mineral leasing laws [is] prohibited in park areas except as authorized by law.
- **BLM regulations at 43 CFR Parts 3100, 3400, and 3500** govern Federal mineral leasing.
- Regulations re: Native American Lands within NPS Units:
    - **25 CFR Part 211** governs leasing of tribal lands for mineral development.
    - **25 CFR Part 212** governs leasing of allotted lands for mineral development.
    - **25 CFR Part 216** governs surface exploration, mining, and reclamation of lands during mineral development.
    - **25 CFR Part 224** governs tribal energy resource agreements.
    - **25 CFR Part 225** governs mineral agreements for the development of Indian-owned minerals entered into pursuant to the Indian Mineral Development Act of 1982, Pub. L. No. 97-382, 96 Stat. 1938 (codified at 25 USC §§ 2101-2108).

  - **30 CFR §§ 1202.100-1202.101** governs royalties on oil produced from Indian leases.
  - **30 CFR §§ 1202.550-1202.558** governs royalties on gas production from Indian leases.
  - **30 CFR §§ 1206.50-1206.62 and §§ 1206.170-1206.176** governs product valuation for mineral resources produced from Indian oil and gas leases.
  - **30 CFR § 1206.450** governs the valuation of coal from Indian Tribal and Allotted leases.
  - **43 CFR Part 3160** governs onshore oil and gas operations, which are overseen by the BLM.

NPS Management Policies 2006:

- **Section 8.7.2** states that all NPS units are closed to new federal mineral leasing except Glen Canyon, Lake Mead and Whiskeytown-Shasta-Trinity NRAs.

Mining Claims (Locatable Minerals)

Resource-specific laws:

- **Mining in the Parks Act of 1976, 54 USC § 100731** et seq. authorizes NPS to regulate all activities resulting from exercise of mineral rights, on patented and unpatented mining claims in all areas of the System, in order to preserve and manage those areas.
- **General Mining Law of 1872, 30 USC § 21** et seq. allows US citizens to locate mining claims on Federal lands. Imposes administrative and economic validity requirements for "unpatented" claims (the right to extract Federally-owned locatable minerals). Imposes additional requirements for the processing of "patenting" claims (claimant owns surface and subsurface). Use of patented mining claims may be limited in Wild and Scenic Rivers and OLYM, GLBA, CORO, ORPI, and DEVA.
- **Surface Uses Resources Act of 1955, 30 USC § 612** restricts surface use of unpatented mining claims to mineral activities.

Resource-specific regulations:

- **36 CFR § 5.14** prohibits prospecting, mining, and the location of mining claims under the general mining laws in park areas except as authorized by law.
- **36 CFR Part 6** regulates solid waste disposal sites in park units.
- **36 CFR Part 9**, Subpart A requires the owners/operators of mining claims to demonstrate bona fide title to mining claim; submit a plan of operations to NPS describing where, when, and how; prepare/submit a reclamation plan; and submit a bond to cover reclamation and potential liability.
- **43 CFR Part 36** governs access to mining claims located in, or adjacent to, National Park System units in Alaska.

NPS Management Policies 2006:

- **Section 6.4.9** requires NPS to seek to remove or extinguish valid mining claims in wilderness through authorized processes, including purchasing valid rights. Where rights are left outstanding, NPS policy is to manage mineral-related activities in NPS wilderness in accordance with the regulations at 36 CFR Parts 6 and 9A.
- **Section 8.7.1** prohibits location of new mining claims in parks; requires validity examination prior to operations on unpatented claims; and confines operations to claim boundaries.

Nonfederal Minerals other than Oil and Gas

Resource-specific laws:

- NPS Organic Act, 54 USC §§ 100101 and 100751

Resource-specific regulations:

- **NPS regulations at 36 CFR Parts 1, 5, and 6** require the owners/operators of other types of mineral rights to obtain a special use permit from the NPS as a business operation (§ 5.3) or for construction of buildings or other facilities (§ 5.7), and to comply with the solid waste regulations at Part 6.

NPS Management Policies 2006:

- **Section 8.7.3** states that operators exercising rights in a park unit must comply with 36 CFR Parts 1 and 5.

Nonfederal Oil and Gas

Resource-specific laws:

- **NPS Organic Act, 54 USC § 100751** et seq. authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights).
- Individual Park Enabling Statutes:
    - 16 USC § 230a (Jean Lafitte NHP & Pres.)
    - 16 USC §450kk (Fort Union NM)
    - 16 USC § 459d-3 (Padre Island NS)
    - 16 USC § 459h-3 (Gulf Islands NS)
    - 16 USC § 460ee (Big South Fork NRRA)
    - 16 USC § 460cc-2(i) (Gateway NRA)
    - 16 USC § 460m (Ozark NSR)
    - 16 USC§698c (Big Thicket N Pres.)
    - 16 USC §698f (Big Cypress N Pres.)

Resource-specific regulations:

- **36 CFR Part 6** regulates solid waste disposal sites in park units.
- **36 CFR Part 9, Subpart B** requires the owners/operators of nonfederally owned oil and gas rights in parks outside of Alaska to:
    - Demonstrate valid right to develop mineral rights;
    - Submit an Operations Permit Application to NPS describing where, when, and how they intend to conduct operations;
    - Prepare/submit a reclamation plan; and
    - Submit financial assurance to cover reclamation and potential liability.
- **43 CFR Part 36** governs access to nonfederal oil and gas rights located in, or adjacent to, National Park System units in Alaska.

NPS Management Policies 2006:

- **Section 8.7.3** requires operators to comply with 9B regulations.

Recreational Collection of Rocks and Minerals

Resource-specific laws:

- **NPS Organic Act, 54 USC. § 100101** et seq. directs the NPS to conserve all resources in parks (which includes rock and mineral resources) unless otherwise authorized by law.
- **Exception: 16 USC. § 445c (c)** – Pipestone National Monument enabling statute. Authorizes American Indian collection of catlinite (red pipestone).

Resource-specific regulations:

- **36 C.F.R. § 2.1** prohibits possessing, destroying, disturbing mineral resources…in park units.
- **Exception: 36 C.F.R. § 7.91** allows limited gold panning in Whiskeytown.
- **Exception: 36 C.F.R. § 13.35** allows some surface collection of rocks and minerals in some Alaska parks (not Klondike Gold Rush, Sitka, Denali, Glacier Bay, and Katmai) by non-disturbing methods (e.g., no pickaxes), which can be stopped by superintendent if collection causes significant adverse effects on park resources and visitor enjoyment.

NPS Management Policies 2006:

- **Section 4.8.2** requires NPS to protect geologic features from adverse effects of human activity.

Transpark Petroleum Product Pipelines

Resource-specific laws:

- The **Mineral Leasing Act, 30 USC § 181** et seq., and the **Mineral Leasing Act for Acquired Lands, 30 USC § 351** et seq. authorize new rights of way across some federal lands for pipelines, excluding NPS areas.

- The only parks with the legal authority to grant new rights of way for petroleum product pipelines are:
    - Natchez Trace Parkway (16 USC §460a)
    - Blue Ridge Parkway (16 USC §460a-8)
    - Great Smoky Mountains National Park (P.L. 107-223 – 16 U.S.C. §403 notes)
    - Klondike Gold Rush National Historical Park (16 USC §410bb(c) (limited authority for the White Pass Trail unit)
    - Gulf Islands National Seashore — enabling act authorizes rights-of-way for pipelines for oil and gas transported across the seashore from outside the unit (16 USC §459h-3)
    - Gateway National Recreation Area — enabling act authorizes rights-of-way for gas pipelines in connection with the development of methane gas owned by the City of New York within the unit (16 USC §460cc-2(i))
    - Denali National Park — 2013 legislation allows for issuance of right-of-way permits for a natural gas pipeline within, along, or near the approximately 7-mile segment of the George Parks Highway that runs through the park (Public Law 113–33)

Resource-specific regulations:
- NPS regulations at **36 CFR Part 14 Rights of Way**

NPS Management Policies 2006:
- **Section 8.6.4** states that new rights of way through, under, and across NPS units may be issued only if there is specific statutory authority and there is no practicable alternative.

Uranium

Resource-specific laws:
- **Atomic Energy Act of 1954** allows Secretary of Energy to issue leases or permits for uranium on BLM lands; may issue leases or permits in NPS areas only if president declares a national emergency.

Resource-specific regulations:
- None applicable.

NPS Management Policies 2006:
- None applicable.

Active Processes and Geohazards Laws, Regulations, and Policies

Coastal Features and Processes

Resource-specific laws:

- **NPS Organic Act, 54 USC § 100751** et. seq. authorizes the NPS to promulgate regulations to protect park resources and values (from, for example, the exercise of mining and mineral rights).
- **Coastal Zone Management Act, 16 USC § 1451** et. seq. requires Federal agencies to prepare a consistency determination for every Federal agency activity in or outside of the coastal zone that affects land or water use of the coastal zone.
- **Clean Water Act, 33 USC § 1342/Rivers and Harbors Act, 33 USC 403** require that dredge and fill actions comply with a Corps of Engineers Section 404 permit.
- **Executive Order 13089** (coral reefs) (1998) calls for reduction of impacts to coral reefs.
- **Executive Order 13158** (marine protected areas) (2000) requires every federal agency, to the extent permitted by law and the maximum extent practicable, to avoid harming marine protected areas.

Resource-specific regulations:

- **36 CFR § 1.2(a)(3)** applies NPS regulations to activities occurring within waters subject to the jurisdiction of the US located within the boundaries of a unit, including navigable water and areas within their ordinary reach, below the mean high water mark (or OHW line) without regard to ownership of submerged lands, tidelands, or lowlands.
- **36 CFR § 5.7** requires NPS authorization prior to constructing a building or other structure (including boat docks) upon, across, over, through, or under any park area.

NPS Management Policies 2006:

- **Section 4.1.5** directs the NPS to re-establish natural functions and processes in human-disturbed components of natural systems in parks unless directed otherwise by Congress.
- **Section 4.4.2.4** directs the NPS to allow natural recovery of landscapes disturbed by natural phenomena, unless manipulation of the landscape is necessary to protect park development or human safety.
- **Section 4.8.1** requires NPS to allow natural geologic processes to proceed unimpeded. NPS can intervene in these processes only when required by Congress, when necessary for saving human lives, or when there is no other feasible way to protect other natural resources/park facilities/historic properties.
- **Section 4.8.1.1** requires NPS to:
    - Allow natural processes to continue without interference,
    - Investigate alternatives for mitigating the effects of human alterations of natural processes and restoring natural conditions,
    - Study impacts of cultural resource protection proposals on natural resources,
    - Use the most effective and natural-looking erosion control methods available, and

  - Avoid putting new developments in areas subject to natural shoreline processes unless certain factors are present.

Geologic Hazards

Resource-specific laws:

- **National Landslide Preparedness Act, 43 USC §§ 3101–3104** strengthens the mandate to identify landslide hazards and reduce losses from landslides. Established the National Landslide Hazards Reduction Program. "…the United States Geological Survey and other Federal agencies, shall – identify, map, assess, and research landslide hazards;" Reduce landslide losses, respond to landslide events

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- **Section 4.8.1.3**, Geologic Hazards
- **Section 9.1.1.5**, Siting Facilities to Avoid Natural Hazards
- **Section 8.2.5.1**, Visitor Safety
- **Policy Memo 15-01** (Climate Change and Natural Hazards for Facilities) (2015) provides guidance on the design of facilities to incorporate impacts of climate change adaptation and natural hazards when making decisions in national parks.

Soils

Resource-specific laws:

- **Soil and Water Resources Conservation Act, 16 USC §§ 2011–2009** provides for the collection and analysis of soil and related resource data and the appraisal of the status, condition, and trends for these resources.
- **Farmland Protection Policy Act, 7 USC § 4201** et. seq. requires NPS to identify and take into account the adverse effects of Federal programs on the preservation of farmland; consider alternative actions, and assure that such Federal programs are compatible with State, unit of local government, and private programs and policies to protect farmland. NPS actions are subject to the FPPA if they may irreversibly convert farmland (directly or indirectly) to nonagricultural use and are completed by a Federal agency or with assistance from a Federal agency. Applicable projects require coordination with the Department of Agriculture's Natural Resources Conservation Service (NRCS).

Resource-specific regulations:

- **7 CFR Parts 610 and 611** are the US Department of Agriculture regulations for the Natural Resources Conservation Service. Part 610 governs the NRCS technical assistance program, soil erosion predictions, and the conservation of private grazing land. Part 611 governs soil surveys and cartographic operations. The NRCS works with the NPS through cooperative arrangements.

NPS Management Policies 2006:

- **Section 4.8.2.4** requires NPS to (1) prevent unnatural erosion, removal, and contamination; (2) conduct soil surveys; (3) minimize unavoidable excavation; and (4) develop/follow written prescriptions (instructions).

Upland and Fluvial Processes

Resource-specific laws:

- **Rivers and Harbors Appropriation Act of 1899, 33 USC § 403** prohibits the construction of any obstruction on the waters of the United States not authorized by congress or approved by the USACE.
- **Clean Water Act 33 USC § 1342** requires a permit from the USACE prior to any discharge of dredged or fill material into navigable waters (waters of the US [including streams]).
- **Executive Order 11988** requires federal agencies to avoid adverse impacts to floodplains. (see also **D.O. 77-2**).
- **Executive Order 11990** requires plans for potentially affected wetlands (including riparian wetlands). (see also **D.O. 77-1**).

Resource-specific regulations:

- None applicable.

NPS Management Policies 2006:

- **Section 4.1** requires NPS to manage natural resources to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities; maintain all components and processes of naturally evolving park ecosystems.
- **Section 4.1.5** directs the NPS to re-establish natural functions and processes in human-disturbed components of natural systems in parks, unless directed otherwise by Congress.
- **Section 4.4.2.4** directs the NPS to allow natural recovery of landscapes disturbed by natural phenomena, unless manipulation of the landscape is necessary to protect park development or human safety.
- **Section 4.6.4** directs the NPS to (1) manage for the preservation of floodplain values; [and] (2) minimize potentially hazardous conditions associated with flooding.
- **Section 4.6.6** directs the NPS to manage watersheds as complete hydrologic systems and minimize human-caused disturbance to the natural upland processes that deliver water, sediment, and woody debris to streams.
- **Section 4.8.1** directs the NPS to allow natural geologic processes to proceed unimpeded. Geologic processes…include…erosion and sedimentation…processes.

- **Section 4.8.2** directs the NPS to protect geologic features from the unacceptable impacts of human activity while allowing natural processes to continue.

Additional References, Resources, and Websites

Climate Change Resources

- Intergovernmental Panel on Climate Change: http://www.ipcc.ch/
- *Global and regional sea level rise scenarios for the Unites States* (Sweet et al. 2022): https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html
- NPS Climate Change Response Strategy (2023 Update): https://www.nps.gov/subjects/climatechange/response-strategy.htm
- NPS Green Parks Plan: https://www.nps.gov/subjects/sustainability/green-parks.htm
- NPS National Climate Change Interpretation and Education Strategy: https://www.nps.gov/subjects/climatechange/nccies.htm
- NPS Policy Memorandum 12-02—Applying NPS Management Policies in the Context of Climate Change: https://npspolicy.nps.gov/PolMemos/policymemoranda.htm
- NPS Policy Memorandum 15-01—Addressing Climate Change and Natural Hazards for Facilities: https://npspolicy.nps.gov/PolMemos/policymemoranda.htm
- NPS Sea Level Change website: https://www.nps.gov/subjects/climatechange/sealevelchange.htm/index.htm
- *Sea level rise and storm surge projections for the National Park Service* (Caffrey et al. 2018): https://irma.nps.gov/DataStore/Reference/Profile/2253283
- U.S. Global Change Research Program: http://www.globalchange.gov/home

Days to Celebrate Geology

- Geologist Day—the first Sunday in April (marks the end of the winter and beginning of preparation for summer field work; formally celebrated in Ukraine, Kazakhstan, Belarus, Kyrgyzstan, and Russia)
- National Cave and Karst Day—6 June, also known as International Day of Caves and Subterranean World
- International Geodiversity Day—6 October: https://www.geodiversityday.org/
- Earth Science Week—typically the second full week of October: https://www.earthsciweek.org/
- National Fossil Day—the Wednesday of Earth Science Week: https://www.nps.gov/subjects/fossilday/index.htm

Disturbed Lands Restoration

- Geoconservation—Disturbed Lands Restoration: https://www.nps.gov/articles/geoconservation-disturbed-land-restoration.htm

Earthquakes

- ShakeAlert: An Earthquake Early Warning System for the West Coast of the United States (USGS sponsored): https://www.shakealert.org/
- USGS Did You Feel It? reporting system: https://earthquake.usgs.gov/data/dyfi/
- USGS Earthquake Hazards Program unified hazard tool: https://earthquake.usgs.gov/hazards/interactive/
- USGS Earthquake Hazards Program, Information by Region – New York (https://www.usgs.gov/programs/earthquake-hazards/science/information-region-new-york)
- USGS National Seismic Hazard Model: https://www.usgs.gov/programs/earthquake-hazards/science/national-seismic-hazard-model
- USGS ShakeMap: https://earthquake.usgs.gov/data/shakemap/

Flooding

- FEMA National Flood Hazard Layer: https://www.fema.gov/flood-maps/national-flood-hazard-layer

Geologic Heritage

- NPS America's Geologic Heritage: https://www.nps.gov/subjects/geology/americas-geoheritage.htm
- NPS Geoheritage Sites — Examples on Public Lands, Natural Landmarks, Heritage Areas, and The National Register of Historic Places: https://www.nps.gov/subjects/geology/geoheritage-sites-listing-element.htm
- NPS Museum Collection (searchable online database): https://museum.nps.gov/ParkPList.aspx
- NPS National Natural Landmarks Program: https://www.nps.gov/subjects/nnlandmarks/index.htm
- NPS National Register of Historic Places: https://www.nps.gov/subjects/nationalregister/index.htm
- NPS Stratotype Inventory: https://www.nps.gov/subjects/geology/nps-stratotype-inventory.htm
- UNESCO Global Geoparks: https://en.unesco.org/global-geoparks

Geologic Maps

- American Geosciences Institute (provides information about geologic maps and their uses): http://www.americangeosciences.org/environment/publications/mapping
- *General Standards for Geologic Maps* (Evans 2016)
- USGS MapView by National Geologic Map Database: https://ngmdb.usgs.gov/mapview

- USGS National Geologic Map Database: https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html

Geological Surveys and Societies

- American Geophysical Union: http://sites.agu.org/
- American Geosciences Institute: http://www.americangeosciences.org/
- Association of American State Geologists: http://www.stategeologists.org/
- Geological Society of America: http://www.geosociety.org/
- US Geological Survey: http://www.usgs.gov/

Hudson River PCBs

- NPS Water Resources Division: https://www.nps.gov/orgs/1439/index.htm
- US Environmental Protection Agency Hudson River PCBs Superfund Site: https://www.epa.gov/hudsonriverpcbs

Landslides and Slope Movements

- FEMA National Risk Index – Landslide: https://hazards.fema.gov/nri/landslide
- *Geological Monitoring* chapter about slope movements (Wieczorek and Snyder 2009): http://go.nps.gov/geomonitoring
- *The Landslide Handbook—A Guide to Understanding Landslides* (Highland and Bobrowsky 2008): http://pubs.usgs.gov/circ/1325/
- Unstable Slope Management Program for transportation corridor risk reduction: https://usmp.info/client/credits.php
- USGS Landslide Inventory: https://www.usgs.gov/tools/us-landslide-inventory

New York State Geology

- *Geology of New York: A Simplified Account (2nd Edition)* (Isachsen et al. 2000): http://www.nysm.nysed.gov/publications/education-leaflets
- New York State Department of Health Radon Tracker: https://www.health.ny.gov/environmental/radon/
- New York State Geological Association – Field Guidebooks: https://www.nysga-online.org/guidebooks/
- New York State Museum/Geological Survey – Archaeology: http://www.nysm.nysed.gov/research-collections/archaeology
- New York State Museum/Geological Survey – Geology: http://www.nysm.nysed.gov/research-collections/geology
- New York State Museum/Geological Survey – GIS Data: http://www.nysm.nysed.gov/research-collections/geology/gis

- New York State Museum/Geological Survey – Map and Chart Series: https://www.nysm.nysed.gov/publications/map-chart-series
- New York State Museum/Geological Survey – Paleontology: http://www.nysm.nysed.gov/research-collections/paleontology
- New York State Museum/Geological Survey – Publications: http://www.nysm.nysed.gov/publications

NPS Geology

- NPS America's Geologic Legacy: http://go.nps.gov/geology. This primary site for information about NPS geology includes a geologic tour, news, and other information about geology in the NPS, and resources for educators and park interpreters.
- NPS Geodiversity Atlas: https://www.nps.gov/articles/geodiversity-atlas-map.htm. The NPS Geodiversity Atlas is a collection of park-specific webpages containing information about the park's geology and links to additional resources.
- NPS Geologic Resources Inventory: http://go.nps.gov/gri

NPS Reference Tools

- NPS Technical Information Center (TIC; repository for technical documents and means to receive interlibrary loans): https://www.nps.gov/orgs/1804/dsctic.htm
- GeoRef. The GRI team collaborates with TIC to maintain an NPS subscription to GeoRef (the premier online geologic citation database) via the Denver Service Center Library interagency agreement with the Library of Congress. Multiple portals are available for NPS staff to access these records. Park staff can contact the GRI team or GRD for access.
- NPS DataStore: https://irma.nps.gov/DataStore/Search/Quick. *Note*: The GRI team uploads scoping summaries, maps, and reports to DataStore. Enter "GRI" as the search text and select a park from the unit list.

Relevancy, Diversity, and Inclusion

- NPS Office of Relevancy, Diversity, and Inclusion: https://www.nps.gov/orgs/1244/index.htm
- Changing the narrative in science & conservation: an interview with Sergio Avila (Sierra Club, Outdoor Program coordinator). Science Moab radio show/podcast: https://sciencemoab.org/changing-the-narrative/

Soils

- Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS): https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- Using Web Soil Survey - The Four Steps (PDF/guide for how to use WSS): https://irma.nps.gov/DataStore/Reference/Profile/2305342

USGS Reference Tools

- Geographic Names Information System (GNIS; official listing of place names and geographic features): http://gnis.usgs.gov/
- Geologic Names Lexicon (Geolex; geologic unit nomenclature and summary): http://ngmdb.usgs.gov/Geolex
- National Geologic Map Database (NGMDB): http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
- NGMDB Geochron Downloader: https://ngmdb.usgs.gov/geochron/
- Publications Warehouse: http://pubs.er.usgs.gov
- A Tapestry of Time and Terrain (descriptions of physiographic regions; Vigil et al. 2000): http://pubs.usgs.gov/imap/i2720/
- USGS Store (find maps by location or by purpose): http://store.usgs.gov

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Fort Collins, CO 80525

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