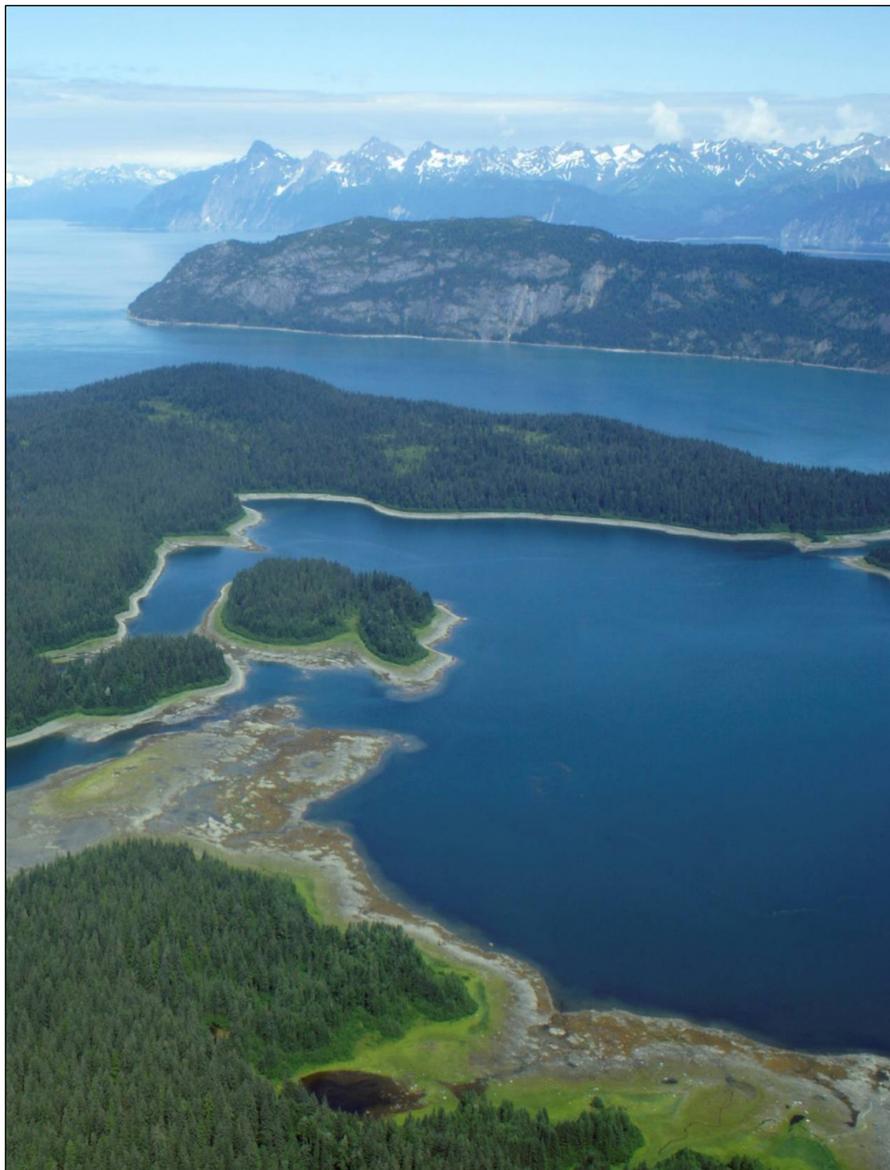




# National Park Service Geologic Type Section Inventory

## *Southeast Alaska Inventory & Monitoring Network*

Natural Resource Report NPS/SEAN/NRR—2021/2309



**ON THE COVER**

View looking northeast across Berg Bay toward Willoughby Island, type section location of the Willoughby Limestone, GLBA (NPS/BILL EICHENLAUB).

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Fort Collins, Colorado

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# Contents

	Page
Figures.....	v
Tables.....	vii
Photographs.....	vii
Executive Summary .....	ix
Acknowledgments.....	xi
Dedication .....	xiii
Introduction.....	1
Geology and Stratigraphy of the SEAN I&M Network Parks.....	3
Precambrian.....	5
Paleozoic .....	5
Mesozoic .....	5
Cenozoic.....	5
National Park Service Geologic Resource Inventory .....	7
GRI Products .....	7
Geologic Map Data.....	7
Geologic Maps.....	8
Source Maps .....	8
GRI GIS Data .....	8
GRI Map Posters .....	9
Use Constraints.....	9
Methods.....	11
Methodology.....	11
Definitions .....	16
Glacier Bay National Park and Preserve (GLBA).....	17
Klondike Gold Rush National Historical Park (KLGO).....	31
Sitka National Historical Park (SITK).....	35

## Contents (continued)

	Page
Recommendations.....	39
Literature Cited .....	41
Appendix A: Source Information for GRI Maps of SEAN Parks.....	45
Appendix B: Geologic Time Scale .....	47

# Figures

	Page
<b>Figure 1.</b> Map of Southeast Alaska I&M Network parks, including Glacier Bay National Park and Preserve (GLBA), Klondike Gold Rush National Historical Park (KLG0), and Sitka National Historical Park (SITK) (NPS).....	4
<b>Figure 2.</b> Screenshot of digital bedrock geologic map of Glacier Bay National Park and Preserve showing mapped units.....	12
<b>Figure 3.</b> GEOLEX search result for the Cenotaph Volcanics unit. ....	13
<b>Figure 4.</b> Stratotype inventory spreadsheet of SEAN displaying attributes appropriate for geolocation assessment. ....	15
<b>Figure 5.</b> Park map of GLBA, Alaska (NPS).....	18
<b>Figure 6.</b> Geologic map of GLBA, Alaska (see Figure 7 for legend).....	19
<b>Figure 7.</b> Geologic map legend of GLBA, Alaska.....	20
<b>Figure 8.</b> Modified geologic map of GLBA showing stratotype locations.....	21
<b>Figure 9.</b> View looking northeast across Berg Bay toward Willoughby Island, type section location of the Willoughby Limestone. ....	23
<b>Figure 10.</b> Outcrop of lagoonal limestone of the Willoughby Limestone with abundant <i>Pycinodesma</i> bivalve shells. ....	24
<b>Figure 11.</b> Exposures of the Tidal Formation consisting of sandy siltstone with a large proportion of argillaceous material, GLBA. ....	25
<b>Figure 12.</b> Limestone conglomerate and breccia representing debris blocks derived from upslope failure in the coeval Willoughby Limestone, and which have transported downslope into the Tidal Formation along Tidal Inlet, GLBA.....	26
<b>Figure 13.</b> View looking northeast across Rendu Inlet towards Carroll Glacier, GLBA. ....	27
<b>Figure 14.</b> Intricately folded sequence of the Rendu Formation composed of limestone and argillaceous limestone layers, GLBA.....	28
<b>Figure 15.</b> North-facing view across Tidal Inlet toward Black Cap Mountain, type section location for the Black Cap Limestone, GLBA. ....	29
<b>Figure 16.</b> View looking northeast at Lituya Bay and Cenotaph Island, type locality of the Cenotaph Volcanics, GLBA.....	30
<b>Figure 17.</b> Cenotaph Island, type locality of the Cenotaph Volcanics in Lituya Bay, GLBA.....	30

## Figures (continued)

	Page
<b>Figure 18.</b> Park map of KLGO, Alaska (NPS).....	32
<b>Figure 19.</b> Geologic map of KLGO, Alaska. ....	33
<b>Figure 20.</b> Park map of SITK, Alaska (NPS).....	36
<b>Figure 21.</b> Geologic map of SITK, Alaska. ....	37

## Tables

	Page
<b>Table 1.</b> List of GLBA stratotype units sorted by age with associated reference publications and locations.....	22

## Photographs

	Page
Lewis Sharman, retired NPS–GLBA.....	xiii



## Executive Summary

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

There are several different categories of geologic or stratigraphic units (supergroup, group, formation, member, bed) that represent a hierarchical system of classification. The mapping of stratigraphic units involves the evaluation of lithologies, bedding properties, thickness, geographic distribution, and other factors. Mappable geologic units may be described and named through a rigorously defined process that is standardized and codified by the professional geologic community (North American Commission on Stratigraphic Nomenclature 2005). In most instances when a new geologic unit such as a formation is described and named in the scientific literature, a specific and well-exposed section or exposure area of the unit is designated as the stratotype (see Definitions, p. 16). The type section is an important reference exposure for a named geologic unit which presents a relatively complete and representative example for this unit. Geologic stratotypes are important both historically and scientifically, and should be available for other researchers to evaluate in the future.

The inventory of all geologic stratotypes throughout the 423 units of the NPS is an important effort in documenting these locations in order that NPS staff recognize and protect these areas for future studies. The focus adopted for completing the baseline inventories throughout the NPS was centered on the 32 inventory and monitoring networks (I&M) established during the late 1990s. The I&M networks are clusters of parks within a defined geographic area based on the ecoregions of North America (Fenneman 1946; Bailey 1976; Omernik 1987). These networks share similar physical resources (geology, hydrology, climate), biological resources (flora, fauna), and ecological characteristics. Specialists familiar with the resources and ecological parameters of the network, and associated parks, work with park staff to support network level activities (inventory, monitoring, research, data management).

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

The goal of this project is to consolidate information pertaining to geologic type sections that occur within NPS-administered areas, in order that this information is available throughout the NPS to inform park managers and to promote the preservation and protection of these important geologic landmarks and geologic heritage resources. The review of stratotype occurrences for the SEAN shows there are currently no designated stratotypes for KLG0 or SITK; GLBA has six type sections and one type locality.

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

## Acknowledgments

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

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

Thanks to our NPS colleagues in the Southeast Alaska Inventory & Monitoring Network and various network parks, including Jamie Womble, Andrew Bliss, and Nina Chambers (SEAN); Lisa Etherington (GLBA) and Lewis Sharman (GLBA retired); Carolyn Furbish (KLGO); Jessica Perkins (SITK); and Mike Loso and Mark Miller (WRST). We also extend our appreciation to Robert B. Blodgett (USGS emeritus), Susan Karl, and Ric Wilson (USGS), for sharing their knowledge about Alaskan geology.

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



## Dedication

We are pleased to dedicate the Southeast Alaska Inventory & Monitoring Network Geologic Type Section Inventory to Lewis Sharman, retired NPS natural resource management specialist. Lewis's career with the NPS began as a volunteer at Rocky Mountain National Park in 1976 and he has since held positions at Saguaro National Park, Gulf Islands National Seashore, Everglades National Park, Denali National Park and Preserve, and Gates of the Arctic National Park and Preserve. In 1994, Lewis began work at Glacier Bay National Park and Preserve where he spent more than 20 years before retirement. Lewis has been a champion for Glacier Bay's geology and paleontology during his career and we thank him for his outstanding service to the NPS.



Lewis Sharman, retired NPS–GLBA.



## Introduction

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

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

The goals of this project are to (1) systematically report the assigned stratotypes that occur within national park boundaries, (2) provide detailed descriptions of the stratotype exposures and their locations, and (3) reference the stratotype assignments from published literature. It is important to note that this project cannot verify a stratotype for a geologic unit if one has not been formally assigned and/or published. Additionally, numerous stratotypes are located geographically outside of national park boundaries, but only those within 48 km (30 mi) of park boundaries will be mentioned in this report.

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

This inventory fills a void in basic geologic information for parks. Instances where geologic stratotypes occurred within NPS areas were determined through research of published geologic literature and maps. Sometimes the lack of specific locality or other data limited determination of whether a particular stratotype was located within NPS administered boundaries. Below are the primary justifications that warrant this inventory of NPS geologic stratotypes.

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

## Geology and Stratigraphy of the SEAN I&M Network Parks

The Southeast Alaska Inventory & Monitoring Network (SEAN) consists of three national park units in coastal southeastern Alaska that include Glacier Bay National Park and Preserve (GLBA), Klondike Gold Rush National Historical Park (KLGOR), and Sitka National Historical Park (SITK) (Figure 1). The parks that comprise the Southeast Alaska Network vary in size from 45.7 ha (113 acres; SITK) to nearly 1.12 million ha (2.77 million acres; GLBA).

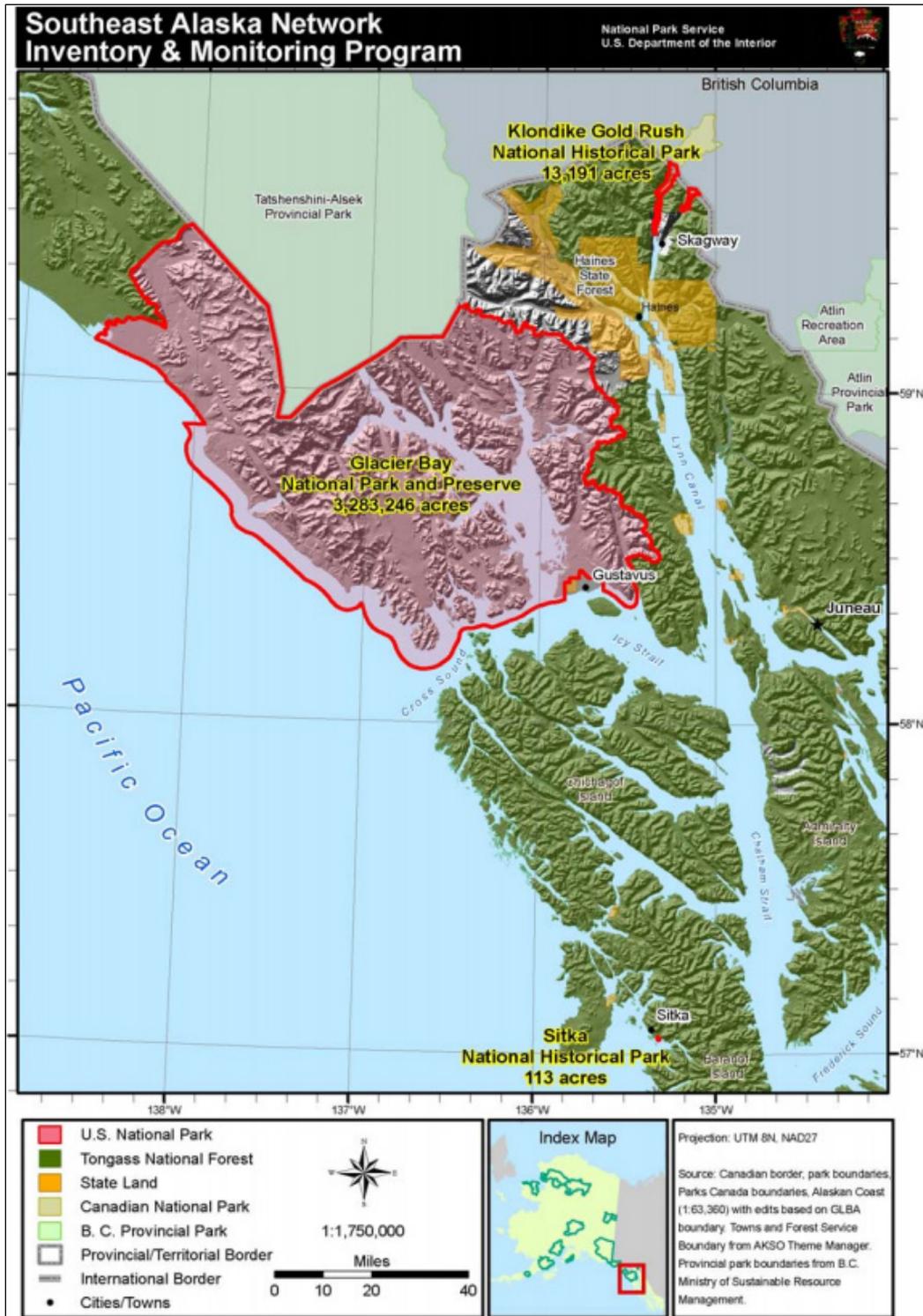
It is important to note that Wrangell-St. Elias National Park and Preserve (WRST) belongs to both SEAN and the Central Alaska Inventory & Monitoring Network (CAKN). SEAN monitors about 193 km (120 mi) of WRST coastline and the outer coast of Glacier Bay. It is difficult for the CAKN to address park vital signs south of the Bagley ice field and there is an ecological contrast to the rest of the network, making this part of WRST a better fit with SEAN. For further information on WRST, please see the CAKN geologic type section inventory report.

Southeast Alaska consists of a narrow stretch of coastline and offshore islands between British Columbia and the Pacific Ocean. Thousands of islands south of Glacier Bay are known as the Alexander Archipelago. Most of southeast Alaska consists of steep, rocky terrain, with a landscape dominated by glacial activity. The coastline and islands are dominated by fjords.

Southeast Alaska is part of the extensive cordillera along the west coast of North America. The northern portion of the cordillera consists of fault-bounded blocks of crustal rock known as terranes. Many of the terranes contain rocks which range from Neoproterozoic to Mesozoic in age, recording 500 million years (or more) of Earth history before accretion to the North American cratonic margin during the last 100–200 million years (see Appendix B for a geologic time scale). The Fairweather Range and the contiguous St. Elias Mountains form the highest mountains along the north Pacific coast. Mount St. Elias is 5,408 m (18,008 ft) and Mount Fairweather is 4,600 m (15,300 ft) in height. Continued northward oblique transpressional translation movement of the Pacific plate relative to North America results in ongoing uplift.

The Coast Mountains are a north–south trending mountain chain on the eastern boundary of Southeast Alaska consisting of metamorphic and plutonic rocks of the Coast Mountains Complex. The metamorphic rocks in the Coast Mountains Complex have been assigned to the Yukon Tanana and Stikine terranes of the Intermontane superterrane. A sequence of less metamorphosed rocks occurs west of the Coast Mountains and is recognized as the Insular superterrane. The Alexander, Wrangellia, Taku, and Chugach terranes are part of the Insular superterrane. Upper Mesozoic rocks of the Gravina–Nutzotin belt were deposited on the Intermontane superterrane after its accretion to North America, and on the Insular superterrane before and during its accretion to North America.

Thick ice sheets have carved the coastal mountains and mountainous islands along the coast since the Miocene. Glaciers continue to shape the rugged terrain of Southeast Alaska and glacier features dominate the landscape. Southeast Alaska is world-renowned for tidewater glaciers and the calving of glacial ice to form icebergs. The many fjords and channels throughout the area are the result of glacial erosion.



**Figure 1.** Map of Southeast Alaska I&M Network parks, including Glacier Bay National Park and Preserve (GLBA), Klondike Gold Rush National Historical Park (KLGO), and Sitka National Historical Park (SITK) (NPS).

## **Precambrian**

Precambrian rocks are not exposed in the parks of the SEAN network.

## **Paleozoic**

The oldest rocks in SEAN parks are Silurian strata exposed in GLBA. These geologic units include the Willoughby Limestone and Tidal Formation. The Pyramid Peak and Rendu Formations span from Late Silurian through Early Devonian in GLBA. The Early–Middle Devonian Black Cap Limestone and the Early Permian Pybus Formation are also present in GLBA. Metamorphic rocks of the Coast Mountains Complex in KLGO have Paleozoic sources (protoliths).

## **Mesozoic**

Undifferentiated Late Cretaceous intrusive rocks, which extend into the Paleogene, are mapped in KLGO. Mesozoic-age igneous rocks and associated sedimentary rocks are reported from western GLBA.

## **Cenozoic**

Paleocene and Eocene intrusive rocks are mapped at KLGO. At GLBA, Paleocene to Miocene intrusive rocks are mapped north and east of Glacier Bay, and the Oligocene Cenotaph Volcanics and Miocene Topsy Formation are mapped west of Glacier Bay. The Middle Miocene–Early Pliocene Yakataga Formation and the Late Pleistocene Forest Creek Formation are also mapped in western GLBA.



# National Park Service Geologic Resource Inventory

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

## **GRI Products**

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

Scoping meetings bring together park staff and geologic experts to review and assess available geologic maps, develop a geologic mapping plan, and discuss geologic features, processes, and resource management issues that should be addressed in the GRI report. Scoping sessions were held on the following dates for the SEAN parks: SITK on June 16, 2009; KLG0 on June 16–17, 2009; and GLBA on June 18, 2009.

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

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

## ***Geologic Map Data***

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

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

### ***Geologic Maps***

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

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

### ***Source Maps***

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

### ***GRI GIS Data***

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

GRI GIS data are available on the GRI publications website (<https://www.nps.gov/subjects/geology/geologic-resources-inventory-products.htm>) and through the NPS Integrated Resource Management Applications (IRMA) Data Store portal

(<https://irma.nps.gov/DataStore/Search/Quick>). Enter “GRI” as the search text and select GLBA, KLGO, or SITK from the unit list.

The following components are part of the data set:

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

### **GRI Map Posters**

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

### **Use Constraints**

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

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



## Methods

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

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

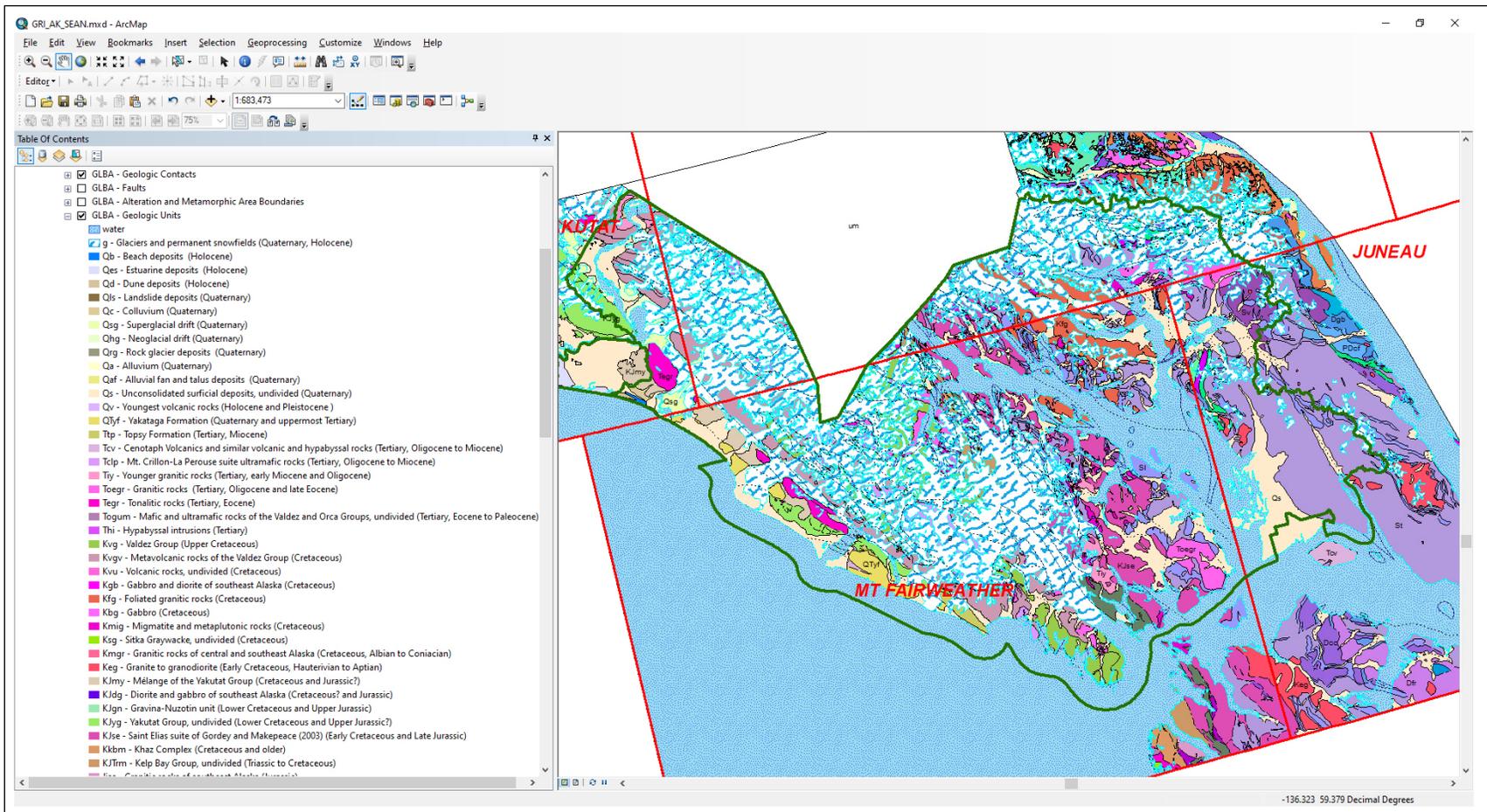
Stratigraphic nomenclature may change over time with refined stratigraphic field assessments and discovery of information through the expansion of stratigraphic mapping and measured sections. One important observation regarding stratigraphic nomenclature relates to differences in use of geologic names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

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

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

### Methodology

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



**Figure 2.** Screenshot of digital bedrock geologic map of Glacier Bay National Park and Preserve showing mapped units.

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

The screenshot displays the USGS GEOLEX search result for the Cenotaph Volcanics unit. At the top, the USGS and AASG logos are visible, along with navigation links for USGS HOME, CONTACT USGS, and SEARCH USGS. Below the logos is a navigation menu with options: Home, Catalog, Lexicon, MapView, New Mapping, Standards, and Comments. The main heading is "National Geologic Map Database" with a sub-heading "Geolex — Unit Summary".

The search results for the "Geologic Unit: Cenotaph" are as follows:

- Usage:** Cenotaph Volcanics (AK\*)
- Geologic age:** Tertiary, Oligocene, early(?)\* to Miocene, middle\*
- Type section, locality, area and/or origin of name:** Type section: along south shore of Cenotaph Island in Lituya Bay, Lituya district, southeastern AK (Plafker, 1967).
- AAPG geologic province:** Alaska Southeastern region\*

Additional features include a "Significant Publications" link and a box containing "Correlation charts", "GNC Archives", "N.A. Stratigraphic Code", and "More Resources". At the bottom, there are links for ACCESSIBILITY, FOIA, PRIVACY, and POLICIES AND NOTICES, along with social media icons for Twitter, Facebook, Google+, YouTube, and Instagram. The footer contains the text: "U.S. Department of the Interior | U.S. Geological Survey", "Supported by the National Cooperative Geologic Mapping Program", "Page Contact Information: Personnel", and "Page Last Modified: Thu 06 Aug 2020 07:27:49 PM MDT".

**Figure 3.** GEOLEX search result for the Cenotaph Volcanics unit.

Published GEOLEX stratotype spatial information is provided in three formats: (1) descriptive, using distance from nearby points of interest; (2) latitude and longitude coordinates; or (3) Township/Range/Section (TRS) coordinates. TRS coordinates are based upon subdivisions of a

single 93.2 km<sup>2</sup> (36 mi<sup>2</sup>) township into 36 individual 2.59 km<sup>2</sup> (1 mi<sup>2</sup>) sections, and were converted into Google Earth (.kmz file) locations using Earth Point (<https://www.earthpoint.us/TownshipsSearchByDescription.aspx>). They are typically presented in an abbreviated format such as “sec. [#], T. [#] [N. or S.], R. [#] [E. or W.]”. The most accurate GEOLEX descriptions using TRS coordinates can help locate features within 0.1618 km<sup>2</sup> (0.0625 mi<sup>2</sup>). Once stratotype locality information provided for a given unit is geolocated using Google Earth, a GRI digital geologic map of the national park is draped over it. This step serves two functions: to improve accuracy in locating the stratotype, and validating the geologic polygon for agreement with GEOLEX nomenclature. Geolocations in Google Earth are then converted into an ArcGIS format using a “KML to Layer” conversion tool in ArcMap.

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

AutoSave Off SEAN Type Section Inventory Search Timothy Henderson TH

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Clipboard Font Alignment Number Styles Cells Editing Analysis

AG0 Hyd Formation, volcanic member

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Formation	Type Section Not Designated?	Type Section in NPS Boundary?	QC on GoogleEarth	Non-NPS type section locality	Publication	Desc. Geospatial Info	Coordinate Geospatial Info	Geologic Age_Era	Geologic Age_Period	Heirarchy	Geolex	Map Symbol	
21	Hyd Group sedimentary rocks, undivided	X				Wilson et al. 2015			Mesozoic	Upper Triassic	Hyd Group	NO	TRhgs	
22	<b>HYD GROUP</b>		NO		Type locality: southeast shore of Loney 1964				Mesozoic	Upper and Middle Triassic	Hyd Group	YES	TRhg	
23	Burnt Island Conglomerate		NO		Type locality: reefs between Bur Muffler 1967				Mesozoic	Late Triassic	Hyd Group	YES		
24	Chapin Peak Formation		NO		Type locality: Chapin Peak-Dowr Berg 1973				Mesozoic	Late Triassic	Hyd Group	YES		
25	Cornwallis Limestone		NO		Type locality: northwest shore o Muffler 1967				Mesozoic	Late Triassic	Hyd Group	YES		
26	Hamilton Island Limestone		NO		Type locality: northwest tip of H. Muffler 1967				Mesozoic	Late Triassic	Hyd Group	YES		
27	Hound Island Volcanics		NO		Type locality: shores of Hound Is Muffler 1967				Mesozoic	Late Triassic	Hyd Group	YES		
28	Nehenta Formation		NO		Type locality: Nehenta Bay-Thon Berg 1973				Mesozoic	Late Triassic	Hyd Group	YES		
29	Puppets Formation		NO		Type locality: the Puppets-Puncf Berg 1973				Mesozoic	Late Triassic	Hyd Group	YES		
30	Goon Dip Greenstone		NO		Type section: upper valley of Go Loney et al. 1963				Mesozoic	Triassic(?)		YES	TRn	
31	Nikolai and Goon Dip Greenstones and equivalent	X				Wilson et al. 2015			Mesozoic	Late and Middle Triassic		NO	TRn	
32	Whitestripe Marble of southeast Alaska		NO		Type locality: Whitestripe Moun Loney et al. 1963				Mesozoic	Triassic?		YES	TRwm	
33	Metamorphic rocks of Dundas Bay	X				Wilson and Karl 2019			Mesozoic	Triassic or older		NO	TRPZdb	
34	Porcupine slate of Redman and others (1985)	X				Redman et al. 1985; Gilbert et al. 1987			Paleozoic	late Paleozoic		NO	PZps	Pre
35	Pybus Formation		NO		Type locality: exposures along th Loney 1964				Paleozoic	Early Permian		YES		
36	Sitth-gha-ee Peak Formation of Brew (1997)	X				Brew 1997			Paleozoic	Permian		NO		Pap
37	Cannery Formation		NO		Type locality: exposures in and a Loney 1964				Paleozoic	Devonian to Permian		YES	PDcf	
38	Iyoukeen Formation		NO		Type locality: exposures on Iyou Loney et al. 1963				Paleozoic	Mississippian		YES	MDip	
39	Peratrovich Formation		NO		Type locality: exposures on south Eberlein and Churkin 1970				Paleozoic	Mississippian		YES	MDip	
40	Freshwater Bay Formation		NO		Type locality: near the head of Fr Loney et al. 1963				Paleozoic	Late Devonian		YES	Dfr	
41	Port Refugio Formation		NO		Type locality: exposures at Port Eberlein and Churkin 1970				Paleozoic	Late Devonian		YES	Dfr	
42	Black Cap Limestone		YES - GLBA	YES		Rossman 191 Type section: Black Cap Mountain, southeast AK (Rossman 191)			Paleozoic	Devonian		YES	Dbc	
43	Karheen Formation		NO		Type locality: exposures along th Eberlein and Churkin 1970				Paleozoic	Devonian		YES	Dcc	
44	Cedar Cove Formation		NO		Type section: extends from a poi Loney et al. 1963				Paleozoic	Devonian		YES	Dcc	
45	Gambier Bay Formation		NO		Type locality: exposures along th Loney 1964				Paleozoic	Devonian		YES	Dgb	
46	Willoughby Limestone		YES - GLBA			Rossman 191 Type section: Willoughby Island, southeastern Alaska (Rossman 191)			Paleozoic	Late Silurian		YES	Sw	
47	Tidal Formation		YES - GLBA			Rossman 191 Type section: southwest flank of the 3,594 ft peak 2.8 (Rossman 191)			Paleozoic	Late Silurian		YES	St, Stl	
48	Rendu Formation		YES - GLBA			Rossman 191 Type section: southwest flank of the 2,978 ft mountain (Rossman 191)			Paleozoic	Late Silurian		YES	Sr	
49	Pyramid Peak Limestone		YES - GLBA			Rossman 191 Type section: west side of Pyramid Peak and lower ea (Rossman 191)			Paleozoic	Late Silurian		YES	Sp	
50	Four Winds complex of Gilbert and others (1987)	X				Gilbert et al. 1987			Paleozoic to Precambrian	Neoproterozoic to Silurian	Four Winds complex	YES	SZfw	Pro

GLBA KLGO SITK

Ready 90%

**Figure 4.** Stratotype inventory spreadsheet of SEAN displaying attributes appropriate for geolocation assessment. Purple highlighted cells represent geologic units supplemented to the GRI list for GLBA.

## Definitions

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

- 1) **Unit stratotype:** the **type section** for a stratified deposit or the **type area** for a non-stratified body that serves as the standard for recognition and definition of a geologic unit (North American Commission on Stratigraphic Nomenclature 2005). Once a unit stratotype is assigned, it is never changed (unless the unit is abandoned). The term “unit stratotype” is commonly referred to as “type section” and “type area” in this report.
- 2) **Type locality:** the specific geographic locality encompassing the unit stratotype of a formally recognized and defined unit. On a broader scale, a type area is the geographic territory encompassing the type locality. Before development of the stratotype concept, only type localities and type areas were designated for many geologic units that are now long- and well-established (North American Commission on Stratigraphic Nomenclature 2005).
- 3) **Reference sections:** for well-established geologic units for which a type section was never assigned, a reference section may serve as an invaluable standard in definitions or revisions. A principal reference section may also be designated for units whose stratotypes have been destroyed, covered, or are otherwise inaccessible (North American Commission on Stratigraphic Nomenclature 2005). Multiple reference sections can be designated for a single unit to help illustrate heterogeneity or some critical feature not found in the stratotype. Reference sections can help supplement unit stratotypes in the case where the stratotype proves inadequate (North American Commission on Stratigraphic Nomenclature 2005).
- 4) **Lithodeme:** the term “lithodeme” is defined as a mappable unit of plutonic (igneous rock that solidified at great depth) or highly metamorphosed or pervasively deformed rock and is a term equivalent in rank to “formation” among stratified rocks (North American Commission on Stratigraphic Nomenclature 2005). The formal name of a lithodeme consists of a geographic name followed by a descriptive term that denotes the average modal composition of the rock (example: Cathedral Peak Granodiorite). Lithodemes are commonly assigned type localities, type areas, and reference localities.

## Glacier Bay National Park and Preserve (GLBA)

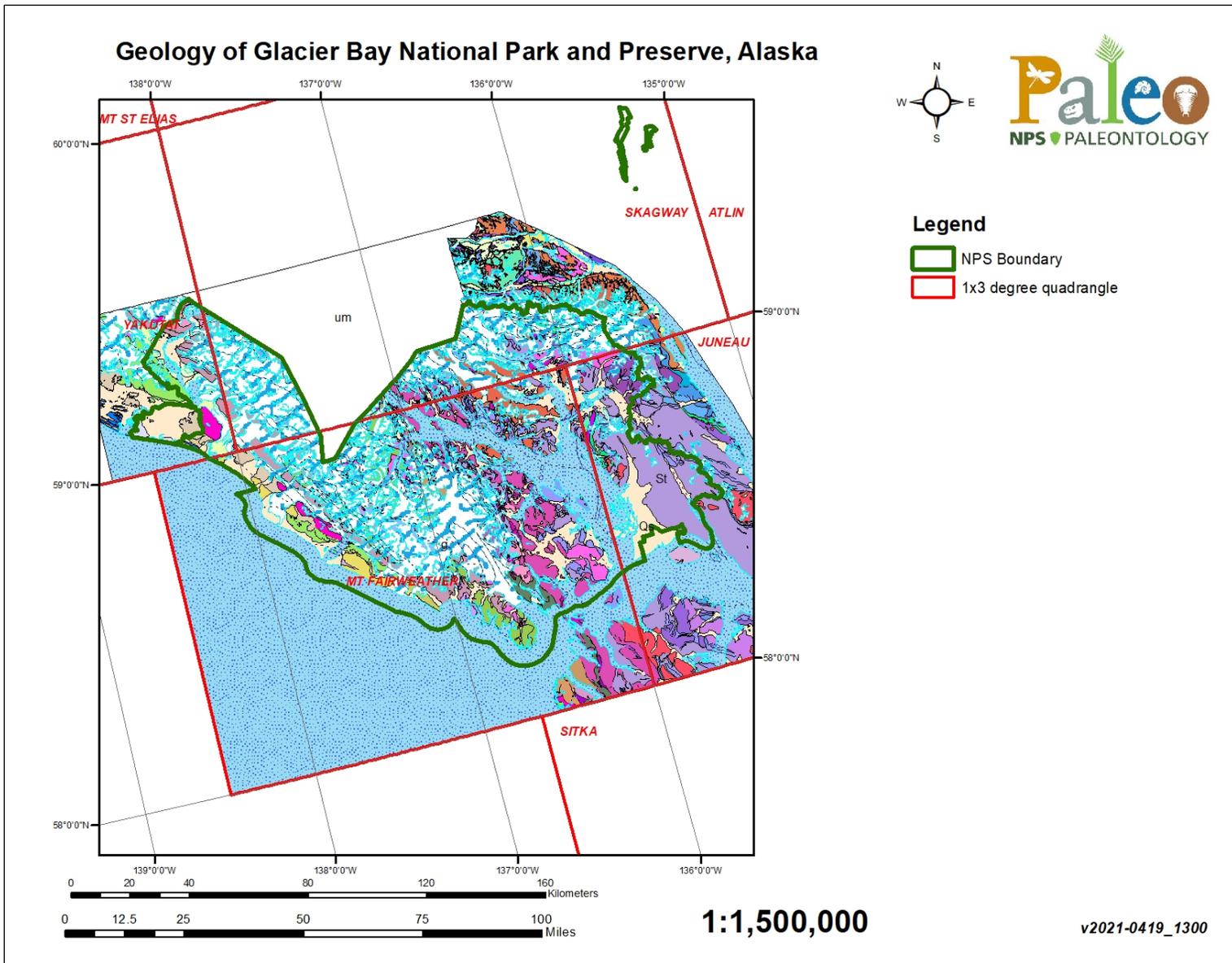
Glacier Bay National Park and Preserve (GLBA) is located in Glacier Bay and the Fairweather Range approximately 70 km (43 mi) northwest of Juneau in the Hoonah–Angoon Census Area and Yakutat Borough, southeastern Alaska (Figure 5). Originally proclaimed as Glacier Bay National Monument on February 26, 1925, the park unit was re-established as a national park and preserve on December 2, 1980 (Anderson 2017). Encompassing 1,328,093 hectares (3,281,789 acres), GLBA protects a rugged wilderness decorated with coastal mountains, glaciers, ice fields, temperate rainforests, scenic coastlines, and deep-sheltered fjords. The United Nations designated GLBA a World Biosphere Reserve (1986) and a World Heritage Site (1992) for its rich diversity of natural resources (Anderson 2017). Visitors to GLBA can enjoy a wide range of activities that include backpacking, birdwatching, camping, fishing, hiking, kayaking, mountaineering, and rafting.

The geology of GLBA reflects a dynamic geologic landscape situated above the collision zone between two tectonic plates. The park and preserve's extreme topography and active seismicity is driven by interactions between the North American continental crustal plate and Pacific oceanic crustal plate. The North American–Pacific plate boundary is marked by the Fairweather–Queen Charlotte Fault system that cuts across the western edge of GLBA. Plate tectonic processes cause the denser Pacific oceanic plate to subduct under the less dense North American continental plate, slowly adding terranes (fault-bounded landmasses that include island arcs, oceanic plateau, or continental margin fragments) to the western margin of North America. The region of GLBA is composed of four geologically unique terranes with a complex history of origin, juxtaposition, deformation, intrusion, and faulting (Brew 1988). The bedrock assemblage of GLBA consists of layered sedimentary rocks, volcanic rocks, and metavolcanic rocks spanning in age from the Silurian to the Quaternary (Figures 6 and 7; Brew and Kimball 1984; Brew et al. 1995). Although a long history of tectonism has uplifted the mountains at GLBA, glaciers have dramatically sculpted the landscape and produced a variety of features that include outwash plains, drumlins, eskers, and fjords.

GLBA contains seven identified stratotypes that are subdivided into six type sections and one type locality (Figure 8; Table 1). It is important to note that several type sections reported here from Rossman (1963) were originally described as “typical section”, but the intention of the author was that these designations represent stratotype descriptions (Robert B. Blodgett, USGS emeritus, pers. comm., 2021). In addition to the designated stratotypes located within GLBA, a list of stratotypes located within 48 km (30 mi) of park boundaries is included here for reference. These nearby stratotypes include the Devonian Freshwater Bay Formation (type locality), Cretaceous Shelter Formation (type locality), and the Cretaceous–Tertiary Coast Mountains Complex (type area).



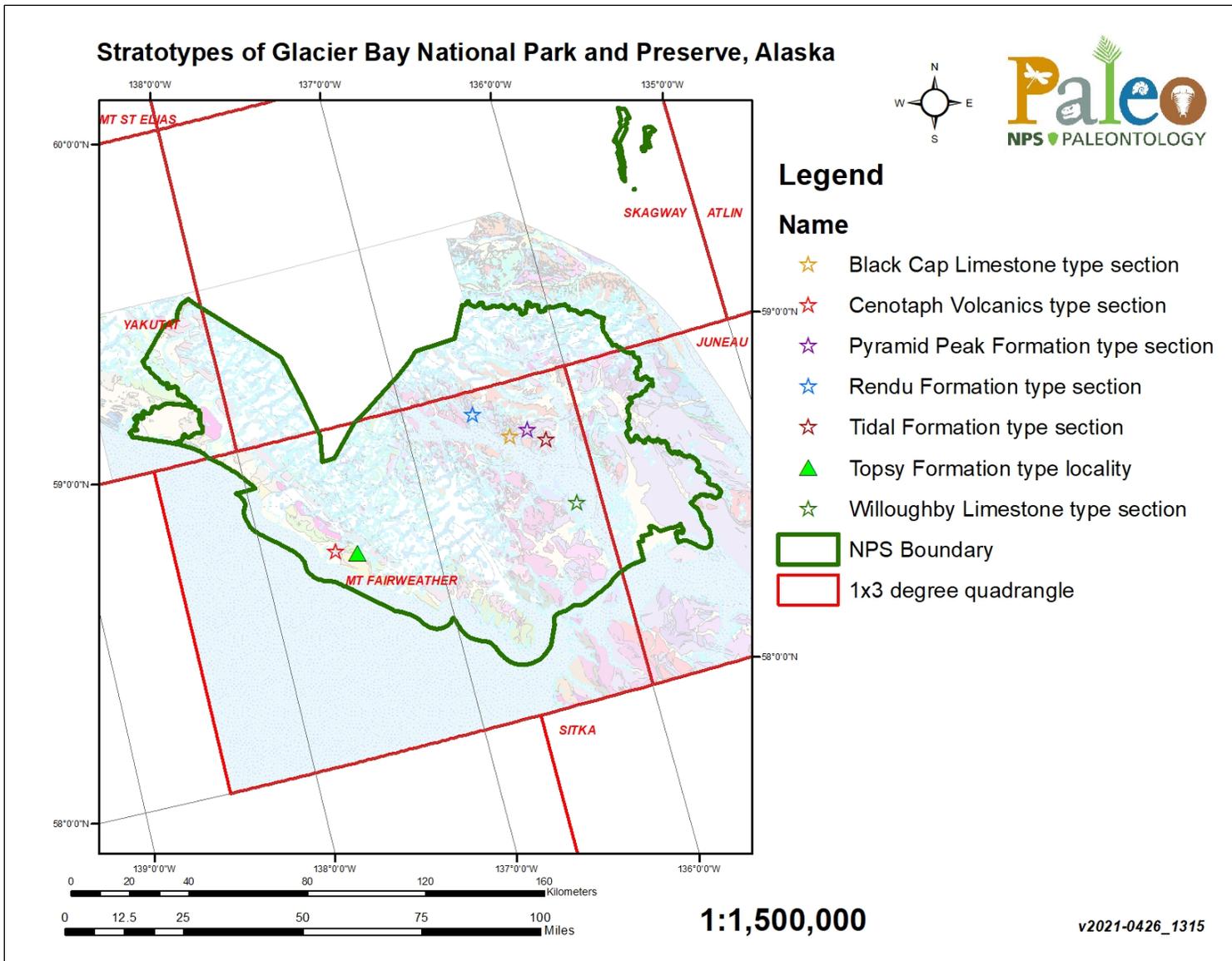
Figure 5. Park map of GLBA, Alaska (NPS).



**Figure 6.** Geologic map of GLBA, Alaska (see Figure 7 for legend).



Figure 7. Geologic map legend of GLBA, Alaska.



**Figure 8.** Modified geologic map of GLBA showing stratotype locations. The transparency of the geologic units layer has been increased. Type sections are indicated by stars and type localities by triangles.

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

Unit Name (map symbol)	Reference	Stratotype Location	Age
Topsy Formation (Ttp)	Plafker 1967	Type locality: designated along upper Topsy Creek, 11 km (7 mi) southeast of mouth of Lituya Bay, southeast Alaska	Miocene
Cenotaph Volcanics (Tcv)	Plafker 1967	Type section: along south shore of Cenotaph Island in Lituya Bay, Lituya district, southeast Alaska	Oligocene–Miocene
Black Cap Limestone (Dbc)	Rossmann 1963	Type section: Black Cap Mountain, southeast Alaska	Devonian
Rendu Formation (Sr)	Rossmann 1963	Type section: southwest flank of the 908 m (2,978 ft) mountain east of Rendu Inlet, southeast Alaska	Late Silurian
Pyramid Peak Limestone (Sp)	Rossmann 1963	Type section: west side of Pyramid Peak and lower eastern flank of Black Cap Mountain, at a point 1.6 km (1 mi) north of the northern shore of Tidal Inlet, Alaska	Late Silurian
Tidal Formation (St, Stl)	Rossmann 1963	Type section: southwest flank of the 1,095 m (3,594 ft) peak 4.5 km (2.8 mi) southeast of the eastern end of Tidal Inlet, southeast Alaska	Late Silurian
Willoughby Limestone (Sw)	Rossmann 1963	Type section: Willoughby Island, southeastern Alaska	Late Silurian

The Late Silurian Willoughby Limestone was named by Seitz (1959) after exposures that occur at Willoughby Island in Glacier Bay, southeastern Alaska. Rossman (1963) later designated the type section exposure on Willoughby Island where the unit forms prominent cliffs (Figures 8 and 9; Table 1). The unit is described as a massive, bluish-gray to white limestone that contains marine invertebrate fossils and sulfide mineral masses ranging from a fraction of an inch to several tens of feet in diameter (Seitz 1959; Rossman 1963). The thickest section of the formation measures about 1,026 m (3,366 ft) and comprises the entirety of Marble Mountain (Rossman 1963). Although neither the upper nor basal contacts of the Willoughby Limestone were recognized by Rossman (1963), the formation was inferred to underlie the Tidal Formation. A more recent analysis by Rohr and Blodgett (2013) and Rohr et al. (2013) interprets the Willoughby Limestone and Tidal Formation as coeval units that represent lateral facies change across a carbonate shelf-to-basin transition.



**Figure 9.** View looking northeast across Berg Bay toward Willoughby Island, type section location of the Willoughby Limestone. The East Arm and Mt. Wright are situated in the background (NPS/BILL EICHENLAUB).

The Willoughby Limestone contains a moderately abundant Late Silurian megafauna, including the large distinctive bivalve genus *Pycinodesma* (Kirk 1927a, 1927b—perhaps the largest known Paleozoic bivalve genus), the gypiduloid brachiopod *Sapelnikoviella* (Blodgett 2013; Blodgett et al. 2013), the gastropod genus *Bathmopterus* (Kirk 1928; re-illustrated in Knight 1941), the gastropod genus *Kirkospira* (Rohr and Blodgett 2003), a large new species of the gastropod *Coelocaulus* (Rohr et al. 2003) and aphrosalpingid sphinctozoan sponges. The bivalve *Pycinodesma* is so abundant locally to even form large shell banks (Figure 10). This same fauna is essentially recognized throughout the length of the Alexander terrane of southeast Alaska, the latter terrane being thought to be derived by rifting along the eastern margin of the Siberian paleocontinent in Late Devonian time (Blodgett et al. 2010). Collectively, the Willoughby Limestone, Tidal Formation, and basal portions of the Rendu and Pyramid Peak Formations were suggested by Blodgett et al. (2012:44) to represent the thickest known sequence of Silurian rocks in North America, perhaps even the world.



**Figure 10.** Outcrop of lagoonal limestone of the Willoughby Limestone with abundant *Pycinodesma* bivalve shells. This area on Willoughby Island is probably where the early collections by Edwin Kirk were made (NPS/VINCENT SANTUCCI; also used for Figure 6 in Rohr and Blodgett 2013).

The Late Silurian Tidal Formation was proposed by Rossman (1963) for a widespread argillaceous unit exposed along the shores of Tidal Inlet, southeastern Alaska. The type section is on the southwest flank of the 1,095 m (3,594 ft)-tall peak 4.5 km (2.8 mi) southeast of the eastern end of Tidal Inlet (Figure 8; Table 1; Rossman 1963). The thickness of the formation varies with a maximum continuous section measuring about 1,676 m (5,500 ft) (Rossman 1963). Lithologically, the formation consists of black to nearly white, well-indurated, fine-grained, calcareous (lime-rich) argillite (mud-rich sedimentary rock) that weathers brown or gray and contains finely detailed cross-bedding and internal structure (Figure 11; Rossman 1963). The formation contains a middle limestone member about 152–700 m (500–2,300 ft) thick that is composed of thin-bedded, light gray limestone (Rossman 1963). Additional lithologies of the unit include limestone conglomerate and breccia, and enigmatic olistoliths (deposits composed of a chaotic mass of heterogeneous material, such as blocks and mud) consisting of crystalline carbonate probably representing altered Willoughby Limestone (Figure 12; Rohr et al. 2013). The Tidal Formation underlies the Pyramid Peak Limestone, and its basal contact is enigmatic.



**Figure 11.** Exposures of the Tidal Formation consisting of sandy siltstone with a large proportion of argillaceous material, GLBA. Compass for scale is approximately 8 cm (3 in) in width. Figure 2 in Rossman (1963).

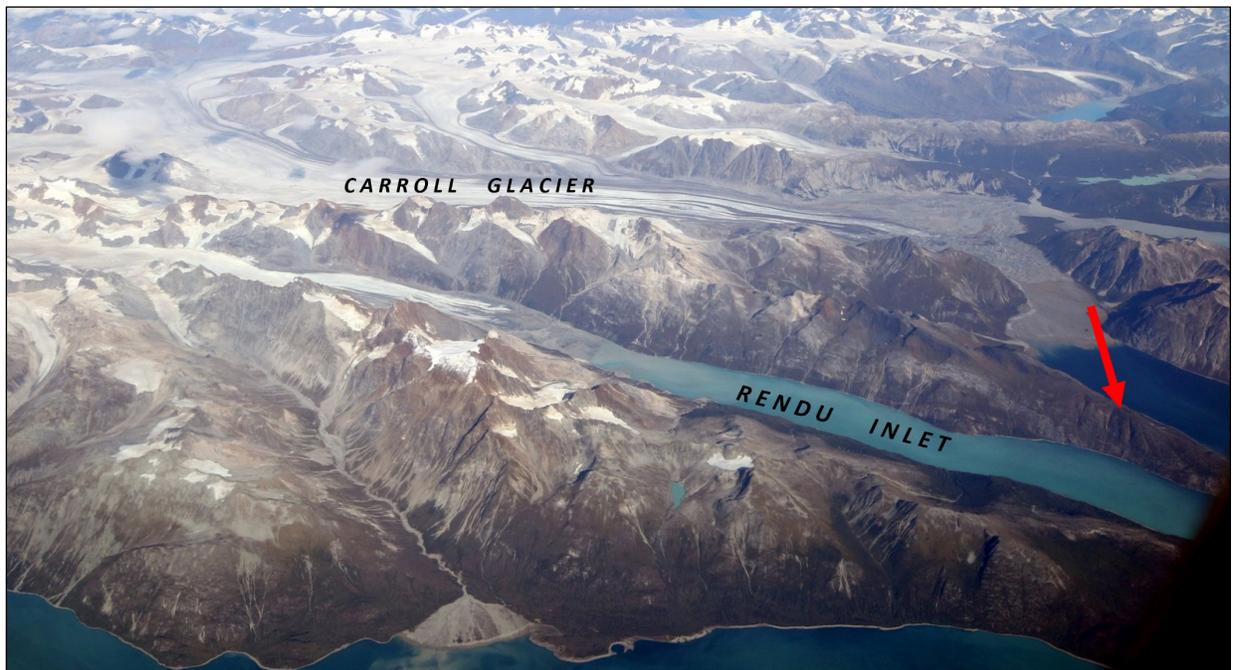


**Figure 12.** Limestone conglomerate and breccia representing debris blocks derived from upslope failure in the coeval Willoughby Limestone, and which have transported downslope into the Tidal Formation along Tidal Inlet, GLBA. The debris blocks themselves were probably derived from collapse along the platform–margin break in the laterally equivalent Willoughby Limestone. Figure 6 in Rohr et al. (2013).

The Late Silurian Pyramid Peak Limestone was named by Rossman (1963) after a sequence of limestone exposures on the west side of Pyramid Peak, GLBA. The type section is located on the west side of Pyramid Peak and the lower eastern flank of Black Cap Mountain at a point 1.6 km (1 mi) north of the northern shore of Tidal Inlet (Figure 8; Table 1; Rossman 1963). At the type section, the formation consists of light-colored, thin- to thick-bedded limestone with an upper sequence of

interbedded argillite and limestone (Rossman 1963). Maximum thickness of the unit is estimated at (2,200 ft) based on the attitude and outcrop width of apparently normal sections (Rossman 1963). The Pyramid Peak Limestone overlies the Tidal Formation and underlies the Rendu Formation.

The Late Silurian Rendu Formation was named by Rossman (1963) after its type section exposure on the southwest flank of the 908 m (2,978 ft)-tall mountain east of Rendu Inlet, southeast Alaska (Figures 8 and 13; Table 1). The unit predominantly consists of varicolored, thin-bedded limestone and argillite with a maximum thickness of about 762 m (2,500 ft) (Rossman 1963). In certain exposures, the Rendu Formation has been intricately folded and thermally metamorphosed into a fine-grained hornstone that resembles chert (Figure 14; Rossman 1963). The formation underlies the Black Cap Limestone with apparent unconformity and gradationally overlies the Pyramid Peak Limestone (Rossman 1963).



**Figure 13.** View looking northeast across Rendu Inlet towards Carroll Glacier, GLBA. The type section of the Rendu Formation is located in the eastern slopes of the inlet (red arrow) (MIKE NOURSE).



**Figure 14.** Intricately folded sequence of the Rendu Formation composed of limestone and argillaceous limestone layers, GLBA. Figure 5 in Rossman (1963).

The Devonian Black Cap Limestone was proposed by Rossman (1963) and named after its type section exposure on Black Cap Mountain in southeastern Alaska (Figures 8 and 15; Table 1). The formation was recognized to be of Early and Middle Devonian age by Blodgett et al. (2012). The type section is a thick, structurally complex sequence measuring about 1,200 m (4,000 ft) that consists of black, thin-bedded limestone that becomes progressively lighter colored and thicker bedded upward (Rossman 1963). The unit contains an abundant assemblage of marine invertebrate fauna of Devonian-age (Rossman 1963). However, virtually no systematic studies have been undertaken on the fauna with the exception of a photograph of a new unnamed rotund atrypid brachiopod suggesting a Middle Devonian age (Blodgett et al. 2012:45, fig. 4). In addition, the distinctive Middle Devonian dasyclad (calcareous green alga) genus *Coelotrochium* is noted from the Black Cap Limestone (Blodgett et al. 2002:285; Blodgett et al. 2012:45). This formation contains a rich megafauna which still needs detailed description and illustration. The Black Cap Limestone overlies the Rendu Formation, and its upper contact is enigmatic.



**Figure 15.** North-facing view across Tidal Inlet toward Black Cap Mountain, type section location for the Black Cap Limestone, GLBA. Mount Merriam is situated in the center background and looms over Black Cap Mountain. Photograph by user “markbyzewski” available via Wikimedia Commons [https://commons.wikimedia.org/wiki/File:Merriam\\_Black\\_Cap.jpg](https://commons.wikimedia.org/wiki/File:Merriam_Black_Cap.jpg) (Creative Commons Attribution 2.0 Generic [CC-BY-2.0]; <https://creativecommons.org/licenses/by/2.0/deed.en>).

The Oligocene–Miocene Cenotaph Volcanics were named by Plafker (1967) after its type section exposure on Cenotaph Island in Lituya Bay, southeastern Alaska (Figures 8, 16, and 17; Table 1). The type section measures about 381 m (1,250 ft) and consists of a non-fossiliferous sequence of green, red, and purple andesitic volcanic breccia, tuff, and flows interbedded with tuffaceous (rich in volcanic ash) siltstone, glauconitic (rich in the green mineral glauconite) sandstone, pebble–cobble conglomerate, and minor coal (Plafker 1967). The Cenotaph Volcanics overlies pre-Tertiary rocks, intertongues with, and locally underlies the Topsy Formation, and also underlies the Yakataga Formation (Plafker 1967).

The Miocene Topsy Formation was originally described by Miller (1953, 1961) and formally named by Plafker (1967) after its type locality along upper Topsy Creek, 11 km (7 mi) southeast of the mouth of Lituya Bay, southeastern Alaska (Figure 8; Table 1). Type locality exposures are about 366 m (1,200 ft) thick and consist of resistant calcareous siltstone and sandstone with sparse marine fossils (Plafker 1967). In the type locality, the Topsy Formation underlies the Yakataga Formation and intertongues with, and in part, overlies the Cenotaph Volcanics (Plafker 1967). The age of the formation is early Miocene to early middle Miocene based on mollusk and fish taxa (Marincovich et al. 1976; Marincovich 1980).



**Figure 16.** View looking northeast at Lituya Bay and Cenotaph Island, type locality of the Cenotaph Volcanics, GLBA. Photo taken immediately after the historic 1958 Lituya Bay tsunami that beveled the lower tree line surrounding the bay. Mt. Crillon sits in the background to the right. Unlabeled version of photo in Plate 3B, Miller (1960).



**Figure 17.** Cenotaph Island, type locality of the Cenotaph Volcanics in Lituya Bay, GLBA. Red arrow indicates the rockslide scar of the historic 1958 tsunami. Cascade Glacier is in the middle background of the photo (NPS).

## **Klondike Gold Rush National Historical Park (KLG0)**

Klondike Gold Rush National Historical Park (KLG0) is located in coastal Alaska approximately 140 km (87 mi) northwest of Juneau in Skagway Borough, southeastern Alaska (Figure 18). Authorized on June 30, 1976, KLG0 preserves 5,259 hectares (12,996 acres) of trails, historical buildings, and exhibits dedicated to the 1898 gold rush. The discovery of gold in Canada's Yukon Territory in 1896 led to a stampede of gold-seekers venturing north to the towns of Skagway and Dyea with dreams of immediate riches. The National Park Service has restored more than 20 buildings from the Klondike Gold Rush era in downtown Skagway, Alaska, that house a visitor center, a Junior Ranger activity center, an international trail center, several museums, and federal leasing offices (Anderson 2017). Visitors to KLG0 can enjoy scenic ocean views, mountain peaks, boreal forests, lakes, waterfalls, and retrace the steps of gold-seekers along the historic Chilkoot and White Pass trails.

The geology of KLG0 is the result of complex plate tectonic processes associated with accretion of terranes to the North American continental crustal plate and subduction of the Pacific oceanic crustal plate. Interactions between the two plates have uplifted the Coast Mountains throughout southeast Alaska, and generated faults and fractures that were later filled by gold-bearing quartz veins. There are several faults in the region of Skagway and Dyea, including a branched, concealed fault that underlies the Taiya Inlet, Taiya River, and part of the Skagway River. The gold of the Klondike region is considered orogenic (associated with mountain-building processes); these processes involved high amounts of heat and pressure that dissolved gold-bearing minerals and re-mobilized the gold in hydrothermal fluids. These gold-bearing fluids precipitated gold and other minerals in quartz veins that filled shear zones, faults, and other fractures. The bedrock of KLG0 consists of Paleozoic rocks metamorphosed to gneiss (banded crystalline quartzo-feldspathic rocks) and migmatite (consisting of light-colored igneous material formed by partial melting of metamorphic rocks that contains inclusions of igneous and metamorphic rocks) occurring along the South Klondike Highway (Figure 19). These rocks were metamorphosed during emplacement of Jurassic–Eocene-age granitic igneous rocks of the Coast Mountains batholith. There are some spectacular exposures of gneiss and migmatite in roadcuts along the highway south of the U.S.–Canada border. Quaternary surficial deposits overlie these rocks.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of KLG0. There are also no identified stratotypes located within 48 km (30 mi) of KLG0 boundaries.

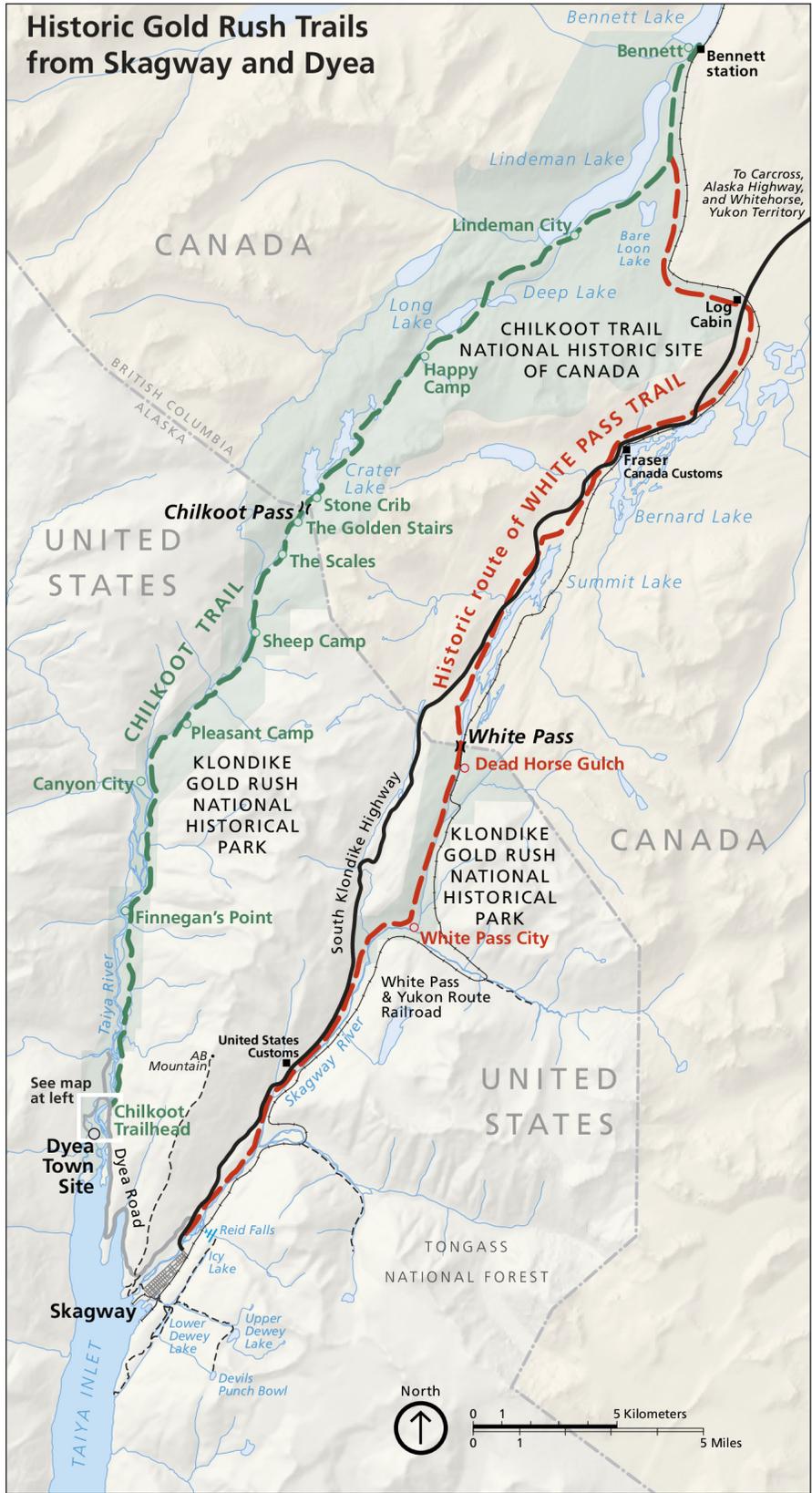
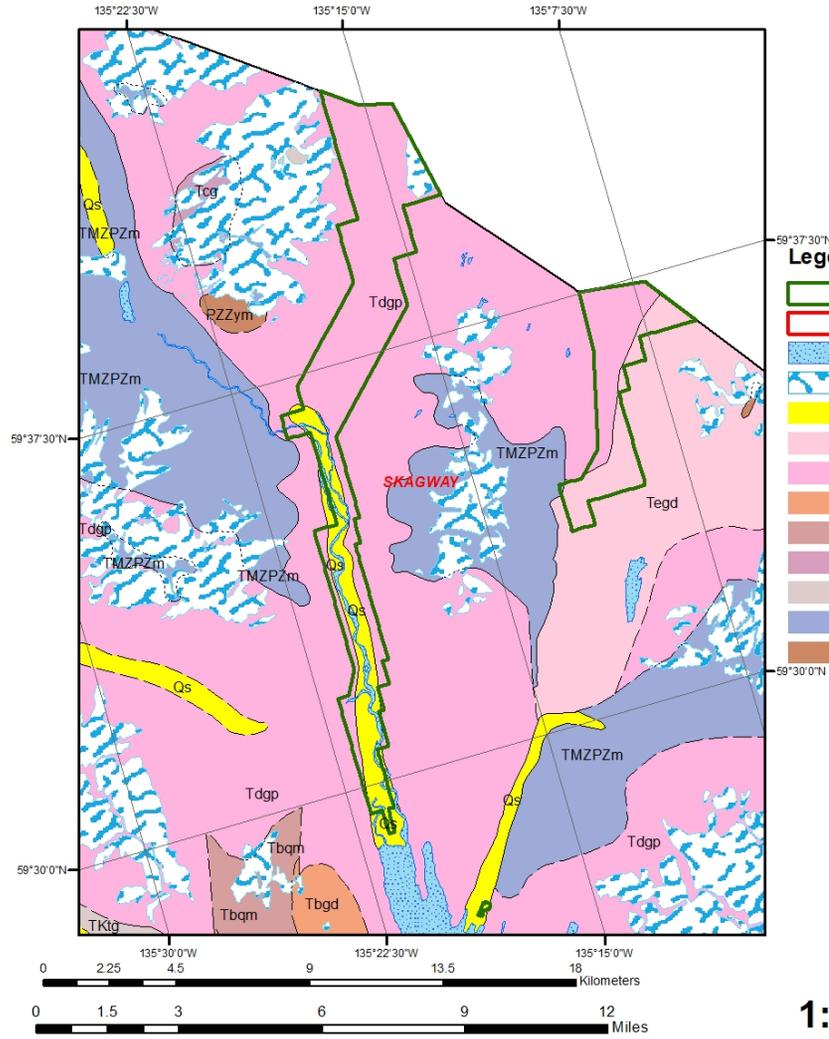


Figure 18. Park map of KLGO, Alaska (NPS).

# Geology of Klondike Gold Rush National Historical Park, Alaska



## Legend

- NPS Boundary
- 1x3 degree quadrangle
- Water
- g - Glaciers
- Qs - Surficial deposits, undifferentiated (Quaternary)
- Tegd - Granite and granodiorite (Tertiary (Eocene?))
- Tdgp - Porphyritic K-feldspar granodiorite (Tertiary (Eocene?))
- Tbgd - Euhedral biotite granodiorite of the Burro Creek pluton (Tertiary (Eocene?))
- Tbam - Biotite quartz monzonite of the Burro Creek pluton (Tertiary)
- Tcg - Clifford granite (Tertiary)
- TKtg - Foliated tonalite and granodiorite (Tertiary and Cretaceous)
- TMZPZm - Gneiss and migmatite (Paleozoic to Tertiary)
- PZZym - Marble (Paleozoic and Precambrian)

1:180,000

v2021-0419\_1050

Figure 19. Geologic map of KLGO, Alaska.



## Sitka National Historical Park (SITK)

Sitka National Historical Park (SITK) is located along the western shores of Baranof Island approximately 150 km (93 mi) southwest of Juneau in Sitka Borough, southeastern Alaska (Figure 20). Proclaimed a national monument on March 23, 1910, the park unit was re-designated as a national historical park on October 18, 1972. Encompassing approximately 47 hectares (116 acres), SITK preserves the site of the last major battle between invading Russian traders and the indigenous Tlingit tribe (Anderson 2017). On display along the scenic coastal trails at SITK are Tlingit and Haida totem poles. The Russian Bishop's House, originally constructed in 1842, is a restored piece of Russian–American architecture that represents part of Russia's little known colonial legacy in North America. Visitors to SITK can explore Tlingit culture and art, learn about the Russian colonial period in North America, or take a hike through temperate rainforest along the Totem Trail and Russian Memorial Loop.

The geology of the Sitka, Alaska area contains mountains, dormant volcanoes, and several faults that reflect one of the most tectonically active regions of North America. Numerous advances and retreats of Pleistocene glaciers have carved deep bays, steep valley walls, jagged coastlines, and sea cliffs, and left behind moraine deposits in the vicinity of SITK. The entirety of SITK geology consists of unconsolidated Quaternary-age deposits that contain glacial till, glacially deposited gravels, glacial erratics (rocks deposited by glaciers that differ from native rock types), and coastal marine deposits (Figure 21). Approximately half of the resources at SITK are coastal or marine, including about 1.6 km (1 mi) of shoreline that is constantly reworked by waves and tides.

As of the writing of this paper, there are no designated stratotypes identified within the boundaries of SITK. There are two identified stratotypes located within 48 km (30 mi) of SITK boundaries, for the Jurassic–Cretaceous Kelp Bay Group (type area) and Cretaceous Sitka Graywacke (type area), both units named and type localities designated by Berg and Hinckley (1963).



Figure 20. Park map of SITKA, Alaska (NPS).

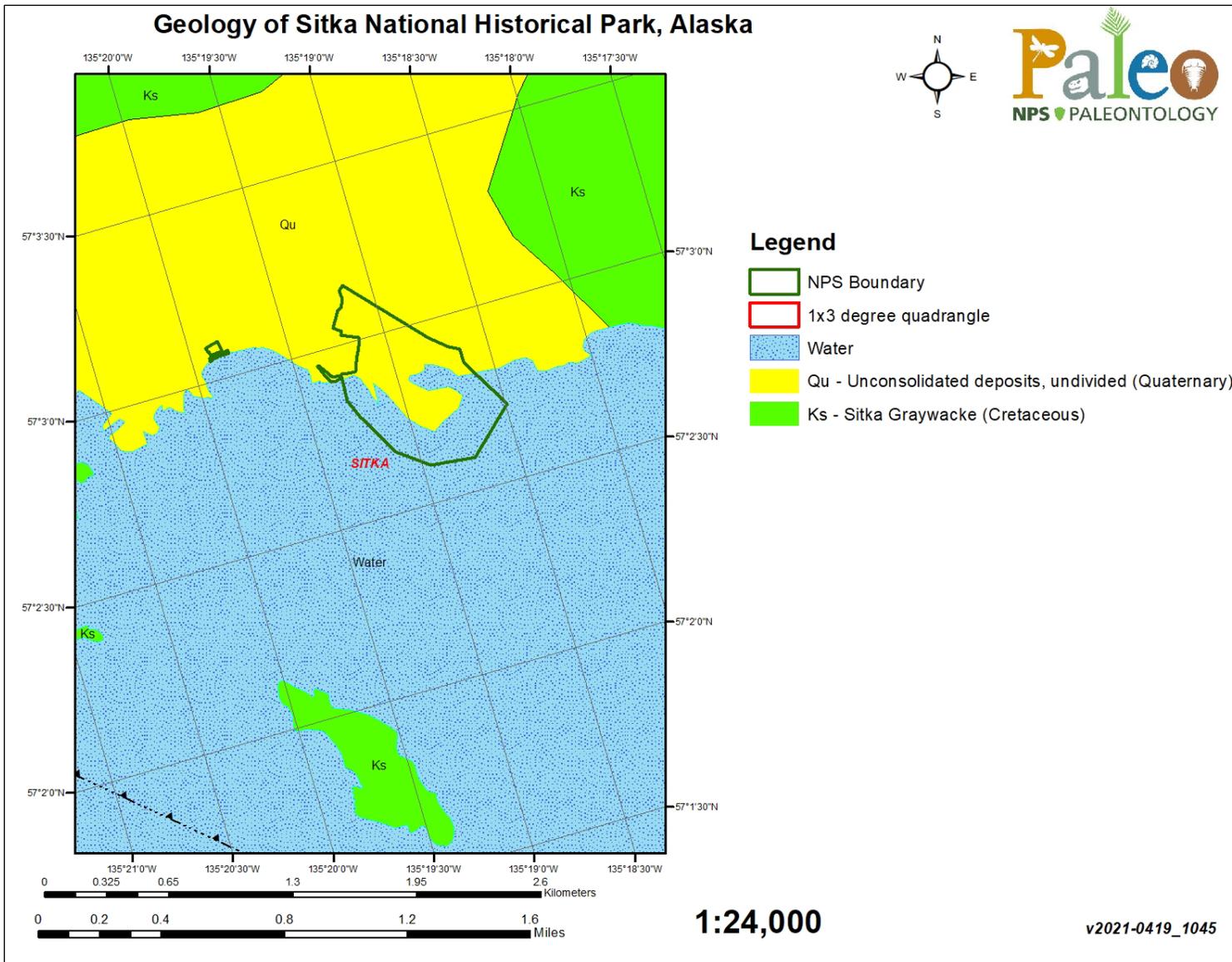


Figure 21. Geologic map of SITK, Alaska.



## Recommendations

- 1) The NPS Geologic Resources Division should work with park and network staff to increase their awareness and understanding of the scientific, historic, and geologic heritage significance of geologic stratotypes (type sections/localities/areas, reference sections, lithodemes). *Stratotypes represent unique geologic exposures and should be considered extremely important to protect for the advancement of the scientific community for future generations.*
- 2) Upon publication of the SEAN Geologic Type Section Inventory report, the NPS Geologic Resources Division should schedule a briefing for the staff of the SEAN and respective network parks on the significance of this report.
- 3) The NPS Geologic Resources Division should work with park and network staff to ensure they are aware of the locations of stratotypes in park areas. This information would be important to ensure that proposed park activities or development would not adversely impact the stability and condition of these geologic exposures. Preservation of stratotypes should not limit availability for future scientific research but help safeguard these exposures from infrastructure development.
- 4) The NPS Geologic Resources Division should work with park and network staff, the U.S. Geological Survey, state geological surveys, academic geologists, and other partners to formally assess potential new stratotypes as to their significance (international, national, or statewide), based on lithology, stratigraphy, fossils, or notable features using procedural code outlined by the North American Commission on Stratigraphic Nomenclature.
- 5) From the assessment in (4), NPS staff should focus on registering new stratotypes at state and local government levels where current legislation allows, followed by a focus on registering at federal and state levels where current legislation allows.
- 6) The NPS Geologic Resources Division should work with park and network staff to compile and update a central inventory of all designated stratotypes and potential future nominations.
- 7) The NPS Geologic Resources Division should ensure the park-specific Geologic Type Section Inventory Reports are widely distributed and available online.
- 8) The NPS Geologic Resources Division should work with park and network staff to regularly monitor geologic type sections to identify any threats or impacts to these geologic heritage features in parks.
- 9) The NPS Geologic Resources Division should work with park and network staff to obtain good photographs of each geologic type section within the parks. In some cases, where there may be active geologic processes (rock falls, landslides, coastal erosion, etc.), the use of photogrammetry may be considered for monitoring of geologic type sections. GPS locations should also be recorded when the photographs are taken and kept in a database.
- 10) The NPS Geologic Resources Division should work with park and network staff to consider the collection and curation of geologic/petrologic samples collected from type sections within respective NPS areas. Samples collected from type section exposures can be useful as reference specimens to support future studies, especially where stratotypes may be lost through natural processes or human activities.

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

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## Appendix A: Source Information for GRI Maps of SEAN Parks

### GLBA

- GMAP 2605: Crafford, T. C. 2001. Alaska Resource Data File: Skagway Quadrangle. U.S. Geological Survey, Reston, Virginia. Open-File Report 2001-193. Scale 1:250,000. Available at: <https://ardf.wr.usgs.gov/quadtable.php> (accessed August 31, 2021).
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- GMAP 76322: Wilson, F. H., and S. M. Karl. 2019. Glacier Bay National Park and Preserve, Alaska: a geologic map for the National Park Service. U.S. Geological Survey, Reston, Virginia. Unpublished map. Scale 1:250,000.

### KLGO

- GMAP 2605: Crafford, T. C. 2001. Alaska Resource Data File: Skagway Quadrangle. U.S. Geological Survey, Reston, Virginia. Open-File Report 2001-193. Scale 1:250,000. Available at: <https://ardf.wr.usgs.gov/quadtable.php> (accessed August 31, 2021).
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## **SITK**

- GMAP 75173: Berg, H. C., and D. J. Grybeck. 2005. Alaska Resource Data File: Sitka Quadrangle. U.S. Geological Survey, Reston, Virginia. Open-File Report 2005-137. Scale 1:250,000. Available at: <https://ardf.wr.usgs.gov/quadtable.php> (accessed August 31, 2021).
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# Appendix B: Geologic Time Scale

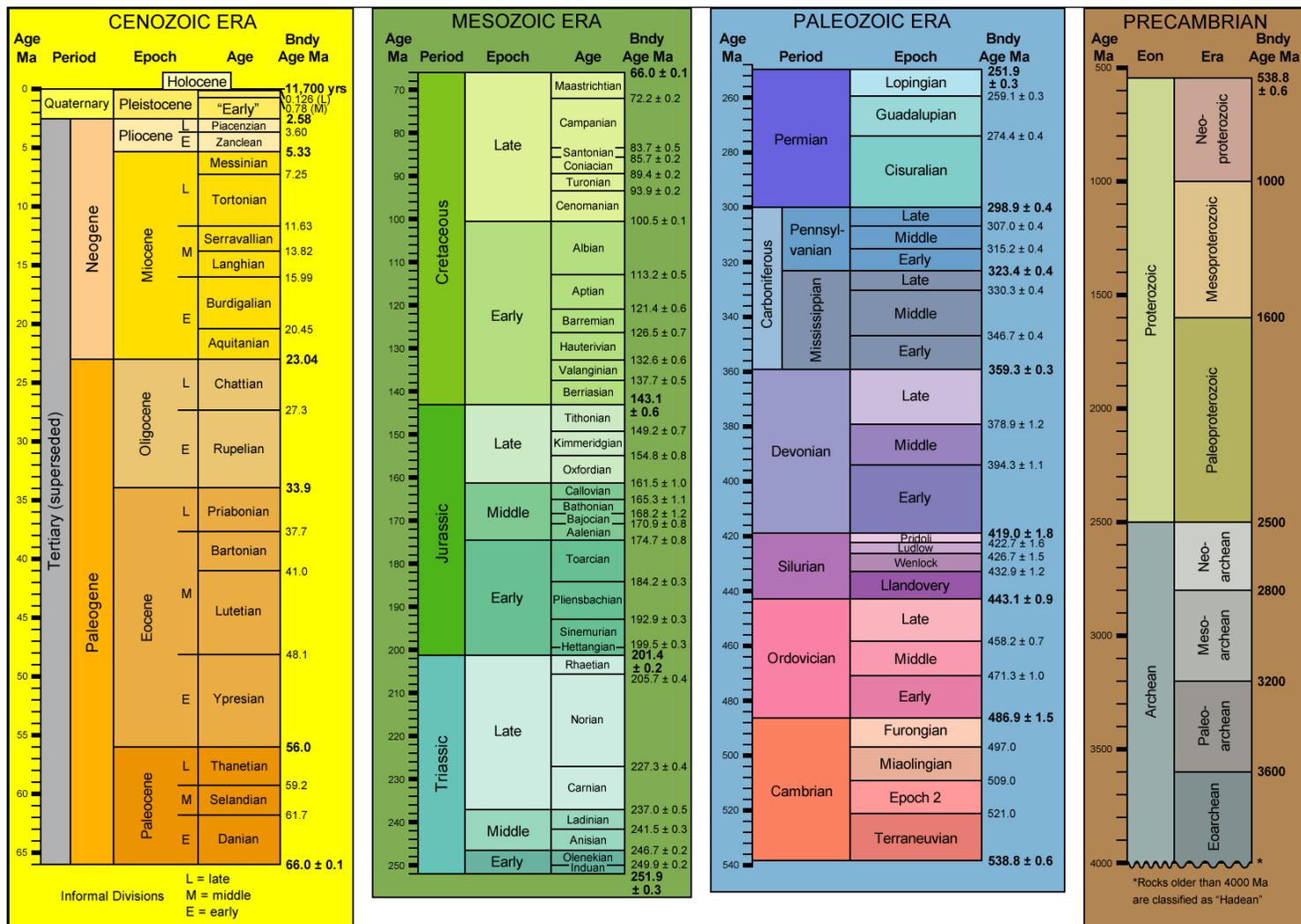


Figure B1. Geologic Time Scale. Ma=Millions of years old. Bndy Age=Boundary Age. Layout after 1999 Geological Society of America Time Scale (<https://www.geosociety.org/documents/gsa/timescale/timescl-1999.pdf>). Dates after Gradstein et al. (2020).



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

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