National Park Service
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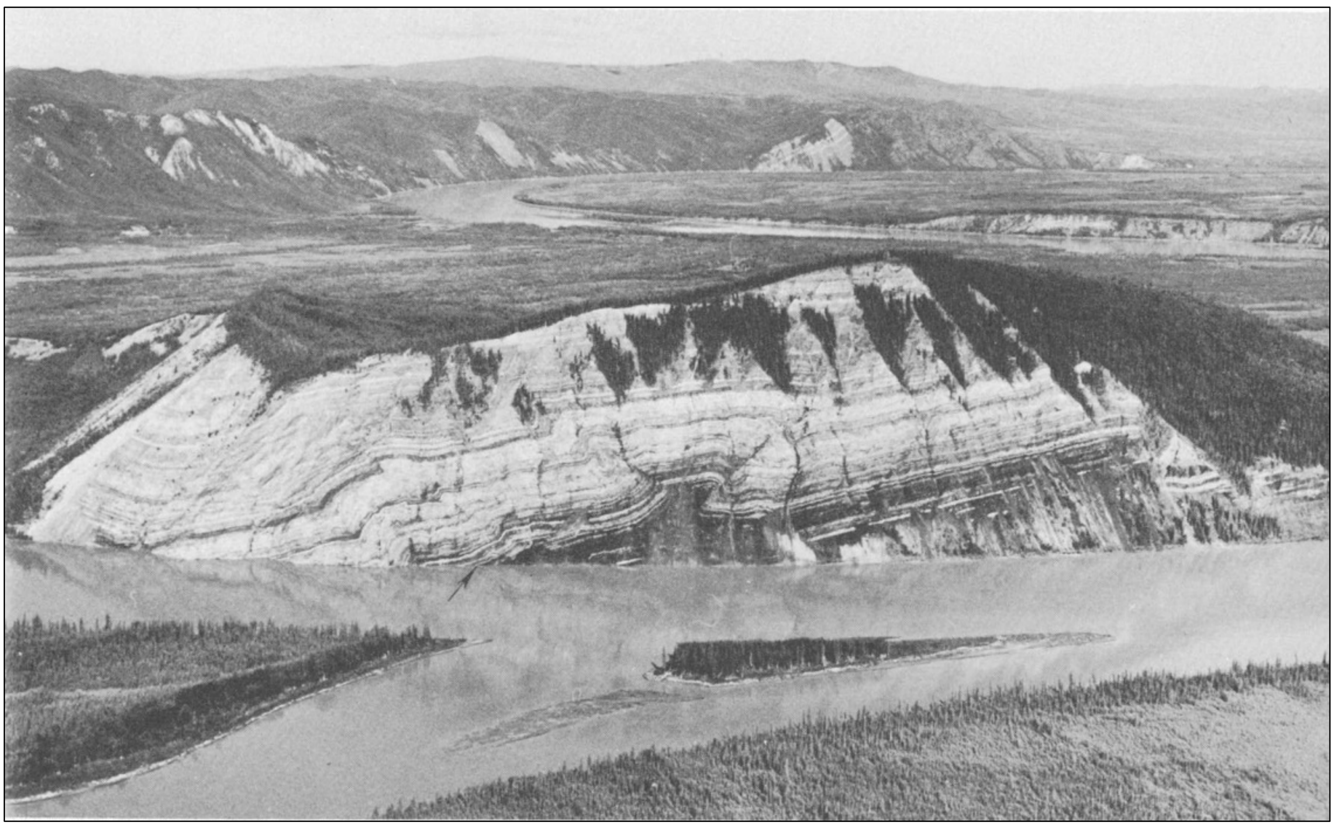
Natural Resource Stewardship and Science

National Park Service Geologic Type Section Inventory

Central Alaska Inventory & Monitoring Network

Natural Resource Report NPS/CAKN/NRR—2022/2369



ON THE COVER
Type locality cliff exposures of the Calico Bluff Formation at Calico Bluff along the Yukon River in Yukon-Charley Rivers National Preserve. The cliff section measures about 457 m (1,500 ft) thick and consists of interlayered shale and limestone that are folded and faulted. Figure 2 from Brabb (1969).

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Executive Summary

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

There are several different categories of geologic or stratigraphic units (supergroup, group, formation, member, bed) that form a hierarchical system of classification. The mapping of stratigraphic units involves the evaluation of lithologies (rock types), bedding properties, thickness, geographic distribution, and other factors. Mappable geologic units may be described and named through a rigorously defined process that is standardized and codified by the professional geologic community (North American Commission on Stratigraphic Nomenclature 2021). In most instances when a new geologic unit (such as a formation) is described and named in the scientific literature, a specific and well-exposed section or exposure area of the unit is designated as the stratotype (see "Definitions" below). The type section is an important reference exposure for a named geologic unit that 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 is 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 planning team from the NPS Geologic Resources Division who proposed and designed this inventory selected the Greater Yellowstone Inventory and Monitoring Network (GRYN) as the pilot network for initiating this project (Henderson et al. 2020). Through the research undertaken to identify the geologic stratotypes 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 report for the Central Alaska Inventory & Monitoring Network (CAKN).

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 CAKN shows there are currently three designated stratotypes for Denali National Park and Preserve (DENA) that can be subdivided into one type section, one type locality, and one reference section; Wrangell-St. Elias National Park and Preserve (WRST) has eight type sections, five type localities, eight type areas, and four reference sections; and Yukon-Charley Rivers National Preserve (YUCH) has ten type sections, five type localities, one type area, and one reference section (Table 1).

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

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

Park	Unit Name (map symbol)	Reference	Stratotype Location	Age
DENA	Mount Galen Volcanics	Decker and Gilbert 1978	Type locality: designated as narrow ridge extending from Stony Creek, southwest to top of Mount Galen in Mount McKinley National Park, Mount McKinley B-1 Quadrangle, west central Alaska Range, AK	Eocene–Oligocene
DENA	Teklanika Formation	Gilbert et al. 1976	Type section: ridge along east side of upper Teklanika River, from 5–6.5 km (3.1–4 mi) south of Calico Creek, in Denali National Park, central Alaska Range, Healy C-6 Quadrangle (scale 1:63,360), AK	Paleocene
DENA	Cantwell Formation (Tcv)	Wolfe and Wahrhaftig 1970	Reference section: western walls of Nenana Canyon between Clear Creek and Carlo	Cretaceous–Paleocene
WRST	White River Ash Bed	Pewe 1975	Type section: on the north side of the White River about 13 km (8 mi) downstream from the source of the river in Russell Glacier and about 50 km (31 mi) west of the Alaska–Canada border, McCarthy D-2 Quadrangle)	Holocene
WRST	Frederika Formation	MacKevett 1970a	Type area: in sec. 5, T. 2 S., R. 18 E., McCarthy C-4 Quadrangle, southern AK	middle Miocene
WRST	MacColl Ridge Formation (Kmr)	Jones and MacKevett 1969	Type section: about 4.8 km (3 mi) east of western boundary of McCarthy A-4 Quadrangle and trends southward from the contact with the Chititu Formation to near the crest of MacColl Ridge, McCarthy A-4 Quadrangle, southern AK	Late Cretaceous
WRST	Moonshine Creek Formation	Jones and MacKevett 1969	Type area: Moonshine Creek in McCarthy C-4 Quadrangle, southern Wrangell Mountains, southern AK	late Early–early Late Cretaceous
WRST	Schulze Formation (Ks)	Jones and MacKevett 1969	Type area: upland north of Sourdough Peak east of upper reaches of Nikolai Creek, McCarthy B-5 Quadrangle, southern AK	late Early–early Late Cretaceous
WRST	Chititu Formation (Kc, Kch)	Jones and MacKevett 1969	Type area: exposures north and south of Young Creek, in northwestern part of McCarthy A-4 Quadrangle, and south of latitude of Copper Creek, in southern part of McCarthy B-4 Quadrangle, southeastern AK Reference sections (2): exposures that extend north and south of Young Creek about 6.4 km (4 mi) east of the western border of the McCarthy A-4 Quadrangle	Late Cretaceous

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

Park	Unit Name (map symbol)	Reference	Stratotype Location	Age
WRST	Chisana Formation (Kc)	Richter and Jones 1973	Type section: lower part in valley of Bonanza Creek, in secs. 25, 35, and 36, T. 4 N., R. 19 E.; upper part in valley of Toby Creek, in secs. 28, 33, and 34, T. 4 N., R. 20 E., Nabesna A-2 Quadrangle, southern AK	Early Cretaceous
WRST	Kennicott Formation (Kk)	Martin 1926; Jones and MacKevett 1969	Type locality: at Kennicott Pass (now known as Fourth of July Pass) Type locality (redefined): hillsides east of Fohlin Creek and north of Bear Creek mainly in the southwestern part of the McCarthy C-6 Quadrangle, but to a lesser extent in the northwestern part of the adjoining McCarthy B-6 Quadrangle	Early Cretaceous
WRST	Kuskulana Pass Formation	MacKevett et al. 1978	Type section: exposures in upper drainage basin of Trail and Slatka Creeks near Kuskulana Pass, extending south from NE/4 SE/4 sec. 32, T. 3 S., R. 10 E., to NE/4 SW/4 NW/4 sec. 5, T. 4 S., R. 10 E., McCarthy C-8 Quadrangle, Wrangell Mountains, AK	Early Cretaceous
WRST	Berg Creek Formation	MacKevett et al. 1978	Type section: from west of Berg Creek to 1.8 km (1.1 mi) south of Kuskulana Pass; exposures from SE/4 SW/4 sec. 34, T. 3 S., R. 9 E. southward to south part of SE/4 NW/4 sec. 3, T. 4 S., R. 9 E., McCarthy C-8 Quadrangle, Wrangell Mountains, AK	Early Cretaceous
WRST	Root Glacier Formation	MacKevett 1969	Type locality: designated as hillside east of upper part of McCarthy Creek, McCarthy C-5 Quadrangle, southern AK	Late Jurassic
WRST	Nizina Mountain Formation (Jn)	MacKevett 1969	Type locality: outcrops that partly girdle the ridge that extends southward from Nizina Mountain, McCarthy C-5 Quadrangle, southern AK	Middle Jurassic
WRST	McCarthy Formation (JTRm)	Moffit and Capps 1911	Type locality: between McCarthy Creek and Nizina River, Nizina–Tanana region, southern AK	Late Triassic–Early Jurassic
WRST	Nizina Limestone	Martin 1916	Type section: cliffs on west side of Nizina River opposite mouth of Chitistone River, Nizina–Tanana region, southern AK	Late Triassic
WRST	Chitistone Limestone (TRcn)	Moffit and Capps 1911; Martin 1916	Type section: in Nizina Valley, at junction of Nizina and Chitistone Rivers	Late Triassic

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

Park	Unit Name (map symbol)	Reference	Stratotype Location	Age
WRST	Nikolai Greenstone (TRn)	Glen et al. 2011	Type section: in the Wrangell Mountains	Middle–Late Triassic
WRST	Skolai Group	Smith and MacKevett 1970	Type area: extending southeastward from SW/4 sec. 15, T. 2 S., R. 17 E., to terminal moraine of Frederika Glacier, McCarthy C-4 Quadrangle, southern AK Reference section: designated in secs. 26, 27, 33, 34, and 35, T. 5 S., R. 18 E. along upper Glacier Creek near the eastern border of the McCarthy B-4 Quadrangle	Pennsylvanian–early Permian
WRST	Hasen Creek Formation (Ph)	Smith and MacKevett 1970	Type area: valley walls of Hasen Creek, in secs.11 and 12, T. 4 S., R. 17 E., McCarthy Quadrangle, southern AK	early Permian
WRST	Golden Horn Limestone Lentil, Hasen Creek Formation	Smith and MacKevett 1970	Type area: north side of Skolai Creek extending west from peak of Golden Horn to Tinplate Hill, in sec. 23, T. 2 S., R. 17 E., McCarthy C-4 Quadrangle, southern AK	early Permian
WRST	Station Creek Formation	Smith and MacKevett 1970	Type area: extends 5.6 km (3.5 mi) west from point 1.6 km (1 mi) south of Station Creek, a tributary of Frederika Creek, southern Wrangell Mountains, northeastern McCarthy C-4 Quadrangle, southern AK	Pennsylvanian–early Permian
WRST	Strelna Metamorphics (PPNast)	Plafker et al. 1989	Reference section: headwaters of Canyon Creek, in SW/4 sec. 12, T. 6 S., R. 6 E., Valdez B-1 Quadrangle, southern AK	Middle Pennsylvanian–early Permian
YUCH	Kandik Group	Brabb 1969	Type locality: designated as in vicinity of Kandik River and along valley of Yukon River from mouth of Glenn Creek to top of Biederman Bluff, east-central AK	Early Cretaceous
YUCH	Kathul Graywacke of Kandik Group (Kka)	Brabb 1969	Type section: exposures on middle to upper south slope of Kathul Mountain, north of Yukon River, from 0.8–1.5 km (0.5–0.9 mi) southeast of benchmark 3122 (Kat), in sec. 18, T. 6 N., R. 27 E., Charley River B-3 Quadrangle, east-central AK	Early Cretaceous

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

Park	Unit Name (map symbol)	Reference	Stratotype Location	Age
YUCH	Biederman Argillite of Kandik Group (Kb)	Brabb 1969	Type section: exposures in Biederman Bluff face on northwest side of Yukon River, 6.4 km (4 mi) northwest of mouth of Kandik River, in NW/4 sec. 32, T. 7 N., R. 25 E., Charley River B-4 Quadrangle, east-central AK Reference section: 0.4 km (0.25 mi) downstream from mouth of Glenn Creek to 1.6 km (1 mi) southeast of benchmark 3122 on Kathul Mountain	Early Cretaceous
YUCH	Keenan Quartzite of Kandik Group (Kke)	Brabb 1969	Type section: exposures on west bank of Yukon River, 0.8 km (0.5 mi) downstream from mouth of Glenn Creek, in sec. 36, T. 6 N., R. 27 E., Charley River B-3 Quadrangle, east-central AK	Early Cretaceous
YUCH	Glenn Shale (KJTRa)	Brabb 1969	Type section: along banks of Washington Creek, a tributary of Yukon River, from NW/4 sec. 24, T. 5 N., R. 26 E. to NW/4 sec.12, T. 5 N., R. 26 E., Charley River B-3 Quadrangle, east-central AK	Middle Triassic–Early Cretaceous
YUCH	Tahkandit Limestone (PZl)	Mertie 1930; Brabb and Grant 1971	Type section (composite): 1) exposure along a narrow slough of the Yukon River in the northwest corner of sec. 17, T. 4 N., R. 30 E., lat. 65°10.8′ N, long. 141°41.9′ W. in the Charlie River A-2 Quadrangle; and 2) a prominent limestone cliff located several hundred meters or feet south of the Nation River mouth on the west bank of the Yukon River	early Permian
YUCH	Calico Bluff Formation (PNMcb)	Brooks and Kindle 1908; Brabb 1969; Armstrong 1975	Type locality: Calico Bluff on Yukon River, about 24 km (15 mi) below Eagle, east-central AK	Middle Mississippian–Early Pennsylvanian
YUCH	Ford Lake Shale (PNMDf)	Brabb 1969	Type section: east and west banks of Yukon River from 3.2 km (2 mi) east of Ford Lake to 4 km (2.5 mi) northeast of Ford Lake in Eagle D-1 Quadrangle, east-central AK	Late Devonian–Late Mississippian
YUCH	Nation River Formation (Dnr)	Mertie 1930	Type locality: exposures at and below the mouth of the Nation River, on the northeast bank of the Yukon River	Late Devonian
YUCH	McCann Hill Chert (Dka)	Churkin and Brabb 1965	Type section: along creek about 0.8 km (0.5 mi) east of Benchmark 4085 except for uppermost 30 m (100 ft) which is on ridge crest extending north, McCann Hill, east-central AK	Devonian

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

Park	Unit Name (map symbol)	Reference	Stratotype Location	Age
YUCH	Woodchopper Volcanics (Dwv)	Mertie 1930; Churkin et al. 1982	Type locality: outcrops along both banks of Yukon River from mouth of Coal Creek, Woodchopper Creek on downstream extending on south bank just beyond mouth of Thanksgiving Creek, Eagle–Circle district, east-central AK	Devonian
YUCH	Jones Ridge Formation (OCjru)	Brabb 1967	Type section: in center sec. 3, T. 3 N., R. 33 E., across Jones Ridge to western part of sec. 10, T. 3 N., R. 33 E., near Canadian border, east-central AK	Cambrian–Ordovician
YUCH	Hillard Limestone (OCh)	Brabb 1967	Type section (composite): cliffs 2.6 km (1.6 mi) west of Hillard Peak (NE/4 sec. 3, T. 1 N., R. 33 E.); cliff about 2.1 km (1.3 mi) north-northeast of Hillard Peak; and section about 0.8 km (0.5 mi) east-northeast of Hillard Peak, east-central AK	Cambrian–Early Ordovician
YUCH	Adams Argillite (Ca)	Brabb 1967	Type section: at east end of Limestone Hogback, in W/2 sec. 31, T. 2 N., R. 33 E., east-central AK	early Cambrian
YUCH	Funnel Creek Limestone (Cf)	Brabb 1967	Type area: in valley walls of tributaries of Tatonduk River, from 1.6 km (1 mi) southwest to 4.8 km (3 mi) south of mouth of Funnel Creek, in secs. 17, 20, 21, 27, and 28, T. 2 N., R. 33 E., Hillard Peak area, east-central AK	early Cambrian
YUCH	Tindir Group (PCt, PCtu, PCtsl, PCtb, PCtlc, PCtl)	Cairnes 1914; Mertie 1930	Type locality: along Tindir Creek and between Ettrain and Harrington Creeks along Alaska–Yukon boundary, east-central AK	Mesoproterozoic–Cambrian

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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. A special thanks to Kristen Janssen (Alaska Division of Geological & Geophysical Surveys) for the permission to use figures in this publication. 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.

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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 Central Alaska Inventory & Monitoring Network Geologic Type Section Inventory to Alaskan paleontologist Robert Blodgett. Robert has been a great friend and contributor to the National Park Service Paleontology Program for many years. His knowledge and understanding of Alaska geology and paleontology is unrivaled, and he is the primary subject matter expert on guiding us to better understand the complex geology of Alaska and its national parks. Many thanks Robert!

Robert Blodgett (individual on right) conducting fieldwork at Shellabarger Pass, Denali National Park and Preserve, Alaska.

Introduction

The NPS Geologic Type Section Inventory Project ("Stratotype Inventory Project") is a continuation of, and complements the work performed by the Geologic Resources Inventory (GRI). The GRI is funded by the NPS Inventory & Monitoring Program and administered by the Geologic Resources Division (GRD). The GRI is designed to compile and present baseline geologic resource information available to park managers, and advance science-informed management of natural resources in the national parks. The goals of the GRI 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 2021). The importance of stratotypes lies in the fact that they represent important comparative sites where past investigations can be built upon or re-examined, and can serve as teaching sites for the next generation of students (Brocx et al. 2019). The geoheritage significance of stratotypes is analogous to libraries and museums in that they are natural repositories of Earth history and record the physical and biologic evolution of our planet.

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 are presented in this report.

This geologic type section inventory for the parks of the Central Alaska Inventory & Monitoring Network (CAKN) 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 has stepped up to undertake this important inventory for the NPS.

This inventory fills a void in basic geologic information compiled by the NPS at most 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 frequently 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 on 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 cannot proactively monitor the stability, condition, or potential impacts to these locations during normal park operations or planning. This lack of information also hinders the protection of these localities from activities that 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 that are established on NPS administered lands. Through this inventory, the associated report, and close communication with park and I&M Network staff, we hope there will be an increased awareness about these important geologic landmarks in parks. In turn, the awareness of these resources and their significance may be recognized in park planning and operations, to ensure that geologic stratotypes are preserved and available for future study.

Geology and Stratigraphy of the CAKN I&M Network Parks

The Central Alaska Inventory & Monitoring Network (CAKN) consists of three NPS units in south-central, east-central, and southeastern Alaska (Figure 1). It is important to note that Wrangell-St. Elias National Park and Preserve (WRST) belongs to both the CAKN and the Southeast Alaska Inventory & Monitoring Network (SEAN). The 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 it a better fit with SEAN.

Figure 1. Map of Central Alaska I&M Network parks, including Denali National Park and Preserve (DENA), Wrangell-St. Elias National Park and Preserve (WRST), and Yukon-Charley Rivers National Preserve (NPS).

The geologic history of the parks of the CAKN is complex and subject to evolving scientific interpretations (Santucci et al. 2011). Southern Alaska lies along a tectonically active continental margin that records convergence between the North American continental plate and the Pacific oceanic plate. The tall mountain ranges, volcanoes and other features are evidence of the geologic history along the continental margin and plate boundary. The geology of this geographic area, particularly DENA and WRST, is dominated by a series of terranes accreted during the latter half of the Mesozoic Era (Christeson et al. 2010; see Appendix B for a geologic time scale). Accreted terranes are large assemblages of rocks that originally formed elsewhere, were subsequently transported by plate tectonic processes, and ultimately collided with and accreted onto a different plate, in this case North America. Rocks deposited after the terrane accretion, referred to as "post-accretionary rocks", are also exposed in the parks.

YUCH is geographically located further from the continental margin than DENA and WRST, and so consequently the park is less heavily influenced by terrane accretion. Rocks within the northeastern portion of YUCH are further from the western continental margin and were not impacted by the tectonic events along the plate boundary. The Tintina Fault divides YUCH into two distinct geologic areas: one northeast and one southwest of the fault. The area southwest of the Tintina Fault consists of a complex sequence of igneous rocks and metamorphosed sedimentary rocks. These rocks were probably metamorphosed and juxtaposed against the western margin of North America when several small microplates (or terranes) collided during the Mesozoic. Northeast of the Tintina Fault, the northeast corner of YUCH consists of a sequence of un-metamorphosed Precambrian and Paleozoic passive margin (non-volcanic continental margin characterized by carbonate, shale [mudstone], and sandstone rocks) rocks that represents the westernmost extension of the Paleozoic North American continent. The northeastern portion of YUCH is one of the rare locations in North America where such an extensive geologic history is preserved, spanning from the Precambrian to the Cenozoic. The northwest corner of YUCH, lying north of the Tintina Fault and separated to the east from the northeast corner by a northeast-trending belt of Cretaceous flysch (forming the Kandik Basin), represents a poorly understood collage of accreted terranes. The Yukon River and its tributaries cut through these ancient sedimentary rocks, exposing a remarkable record of the floral and faunal history of east-central Alaska (Santucci et al. 2011).

Precambrian

The Precambrian is represented in DENA and YUCH. In DENA the Wickersham Grit is a Proterozoic unit. In YUCH the Proterozoic Tindir Group includes the most ancient rocks exposed in the park (Kaufman et al. 1992).

Paleozoic

The Paleozoic is well-represented within DENA in a number of terranes. Many of the terranes appear to be exotic to North America and accreted onto the continent. However, there may be Paleozoic rocks in DENA that originated in North America.

Below is a list of terranes mapped in DENA:

- Dillinger Terrane (Early Ordovician–Devonian)
- McKinley Terrane (Silurian–Triassic)
- Yukon–Tanana Terrane (Devonian–Mississippian)
- Windy Terrane (Early Devonian–Late Triassic) (potentially some older units)
- Mystic Terrane (Early Devonian–Early Jurassic)
- Chulitna Terrane (Late Devonian–Early Jurassic)

- Pingston Terrane (Pennsylvanian–Triassic)

Within WRST the Paleozoic is represented by Devonian through Permian geologic units associated with terranes. The oldest Paleozoic unit is the Kaskawulsh Group in the Alexander Terrane. Below are the various terranes within WRST that have Paleozoic components:

- Alexander Terrane (Devonian–Pennsylvanian)
- Wrangellia Terrane, eastern Alaska Range and northern Wrangell Mountains (Pennsylvanian–Permian)
- Wrangellia Terrane, southern Wrangell Mountains and Saint Elias Mountains (Mississippian–Permian)

The Paleozoic rocks within YUCH span from the Cambrian through the Permian (Santucci et al. 2011). During the early and middle Paleozoic, the YUCH area was part of an ancestral platform referred to as the Yukon Shelf. The platform was situated between the Brooks Geosyncline (basin along the continental margin) to the north and the Cordilleran Geosyncline to the south. The interior of the shelf subsided during the Ordovician and Early Devonian, forming a trough (Brosgé and Dutro 1973). Paleozoic sediments were extensively eroded during the Pennsylvanian.

Mesozoic

The Mesozoic geology of CAKN parks includes both accretionary and post-accretionary rocks.

Within DENA the Mesozoic portions of accretionary terranes include:

- Yukon–Tanana Terrane (Triassic)
- Farewell Terrane (Triassic–Jurassic)
- Chulitna Terrane (Triassic–Jurassic)
- Windy Terrane (Triassic–Cretaceous)
- McKinley Terrane (Triassic–Cretaceous)
- Pingston Terrane (Triassic)
- West Fork Terrane (Jurassic)
- Kahiltna Assemblage (Late Jurassic–Late Cretaceous)

The Mesozoic rocks of WRST are associated with the Wrangellia Terrane and are divided into two sections:

- Wrangellia Terrane, eastern Alaskan Range and northern Wrangell Mountains
- Wrangellia Terrane, southern Wrangell Mountains and St. Elias Mountains

Within YUCH the following Mesozoic units are mapped:

- Glenn Shale (Triassic–Early Cretaceous)
- Kandik Group (Early Cretaceous)

Cenozoic

The Cenozoic rocks of the CAKN parks represent non-accretionary units.

At DENA, the uppermost Cantwell Formation may extend into the Paleocene. Rocks of the Usibelli Group are mapped in DENA and are Eocene through Miocene in age. Finally, the Nenana Gravel is a Miocene and Pliocene unit.

The Cenozoic geology of WRST consists of a sequence of sedimentary, metamorphic, and igneous rocks, some of which are part of the Yakutat Terrane. The Yakutat Terrane is the last of the seven terranes in WRST. There are periods of volcanism at WRST which date to the latest Oligocene or earliest Miocene. These volcanic sequences are mapped in the Wrangell Volcanic Field.

Unnamed rocks of Cretaceous to Cenozoic are present in YUCH.

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 CAKN parks: DENA, WRST, and YUCH on February 24–26, 2004.

Following the scoping meeting, the GRI map team converts the geologic maps identified in the mapping plan to GIS data in accordance with the GRI data model. After the map is completed, the GRI report team uses these data, as well as the scoping summary and additional research, to prepare the GRI report. As of 2020, GRI reports have been completed for DENA, while the reports for WRST and YUCH have not yet been initiated. 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 CAKN 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 sometimes labels on geologic maps are used to distinguish geologic map units. The unit labels consist of an uppercase letter (or symbol for some ages) 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) and work by Bernknopf et al. (1993) provide more information about geologic maps and their uses.

Geologic maps are typically one of three types: surficial, bedrock, or a combination of both. 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, geologic processes, and/or depositional environment. GRI has produced various maps for the CAKN 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 data set 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 to produce the GRI GIS data sets for the CAKN 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 YUCH was compiled using data model version 2.3, which is available at https://www.nps.gov/articles/gri-geodatabase-model.htm; the DENA and WRST 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 DENA, WRST, or YUCH from the unit list.

The following components are part of the dataset:

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

GRI Map Posters

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

Use Constraints

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

Minor inaccuracies may exist regarding the locations of geologic features relative to other geologic or geographic features on the posters. Based on the source map scales (1:100,000, 1:63,360, 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

Described here are the methods employed and definitions adopted during this inventory of geologic type sections located within the administrative boundaries of the parks in the CAKN. This report is part of an inventory of geologic type sections throughout the National Park System. Therefore, the methods, definitions, and challenges identified here pertain not only to the parks of the CAKN, 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 that transcend state boundaries. Geologic formations and other units that cross state boundaries may be referenced with different names in each of the states the units are mapped. An example is 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, 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).

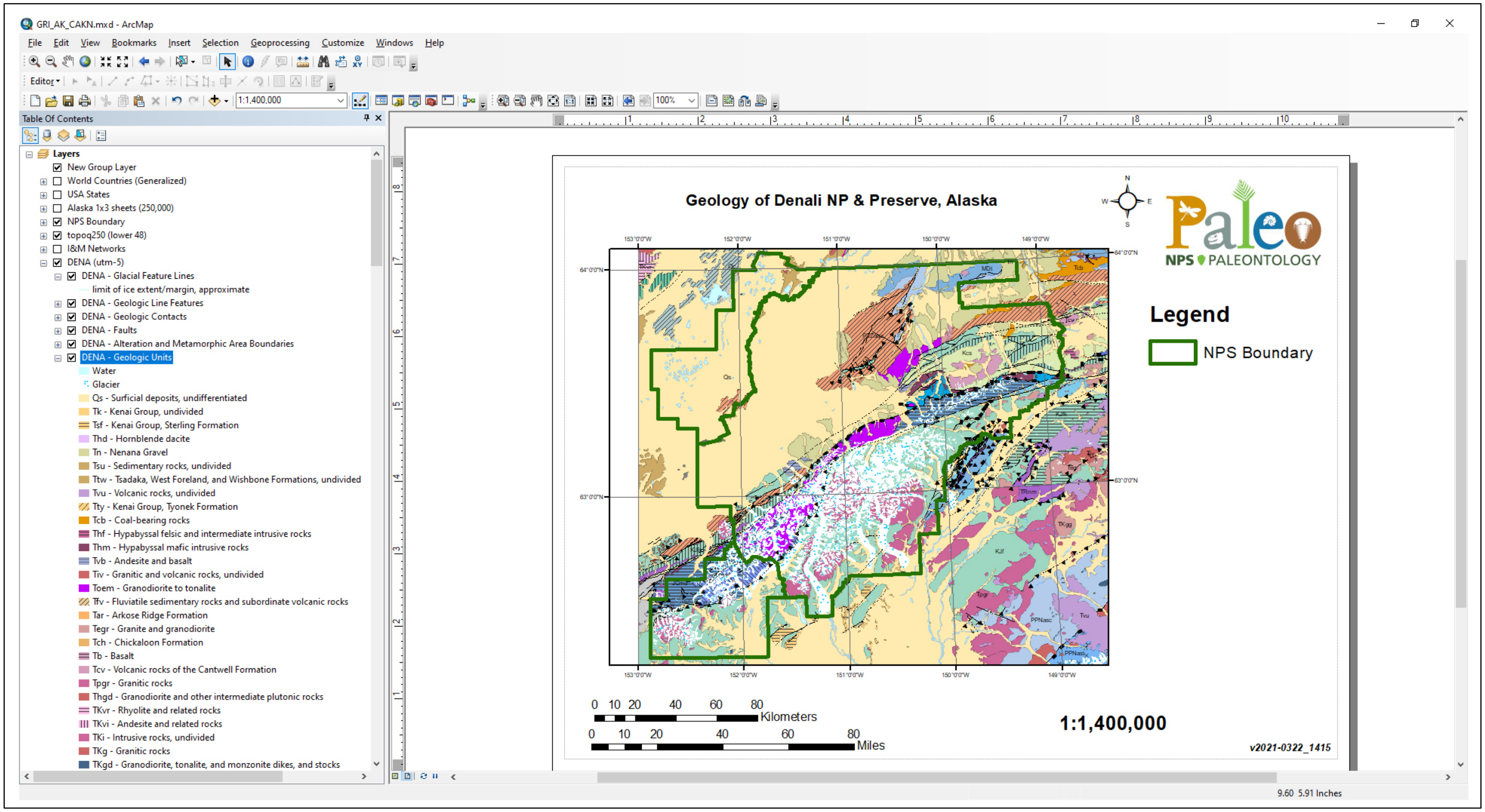


Figure 2. Screenshot of digital geologic map of Denali National Park and Preserve showing mapped units.

Each map unit name is then queried in the USGS Geologic Names Lexicon online database ("GEOLEX", a national compilation of names and descriptions of geologic units) at https://ngmdb.usgs.gov/Geolex/search. Information provided by GEOLEX includes 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 Calico Bluff Formation.

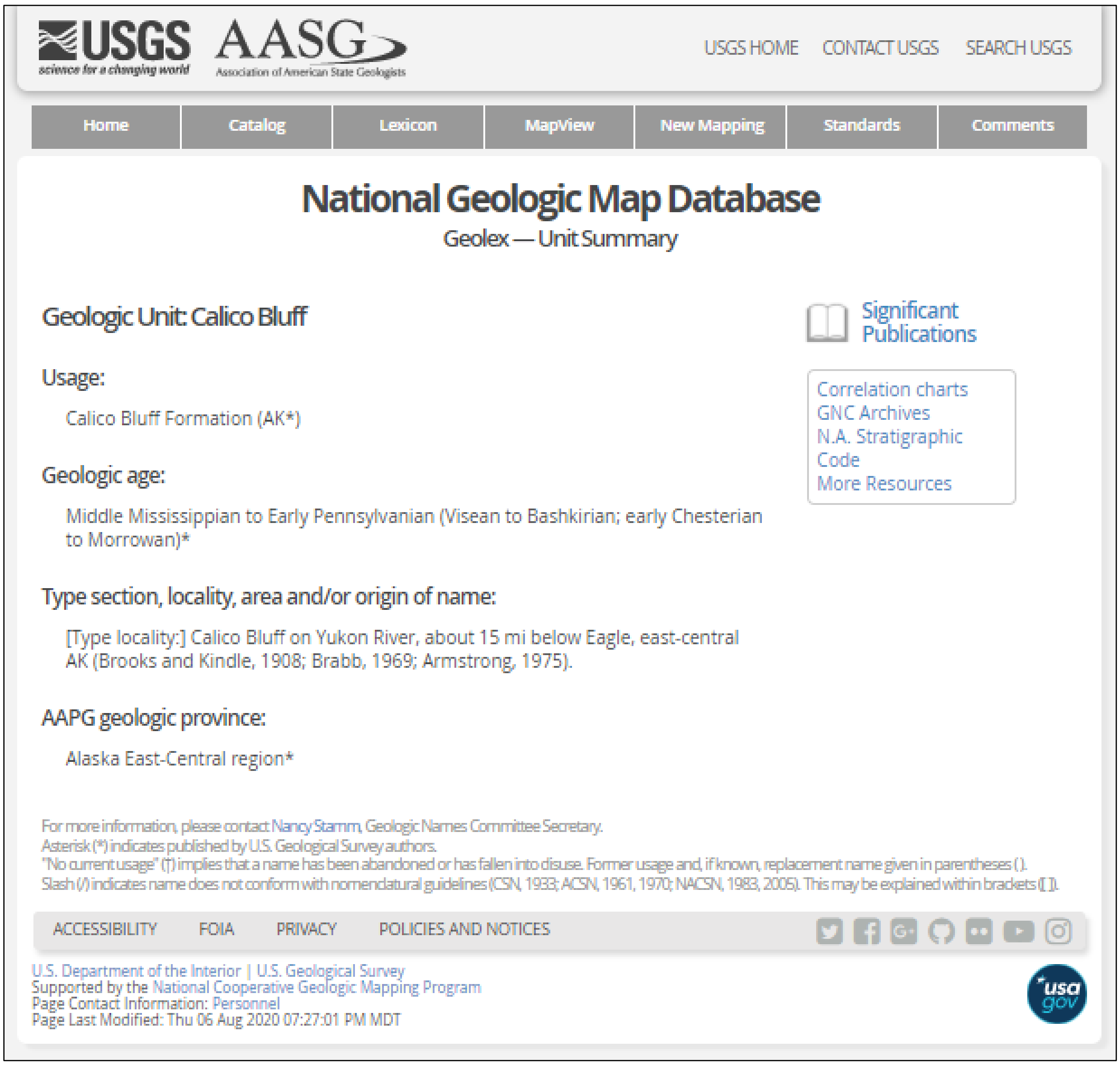
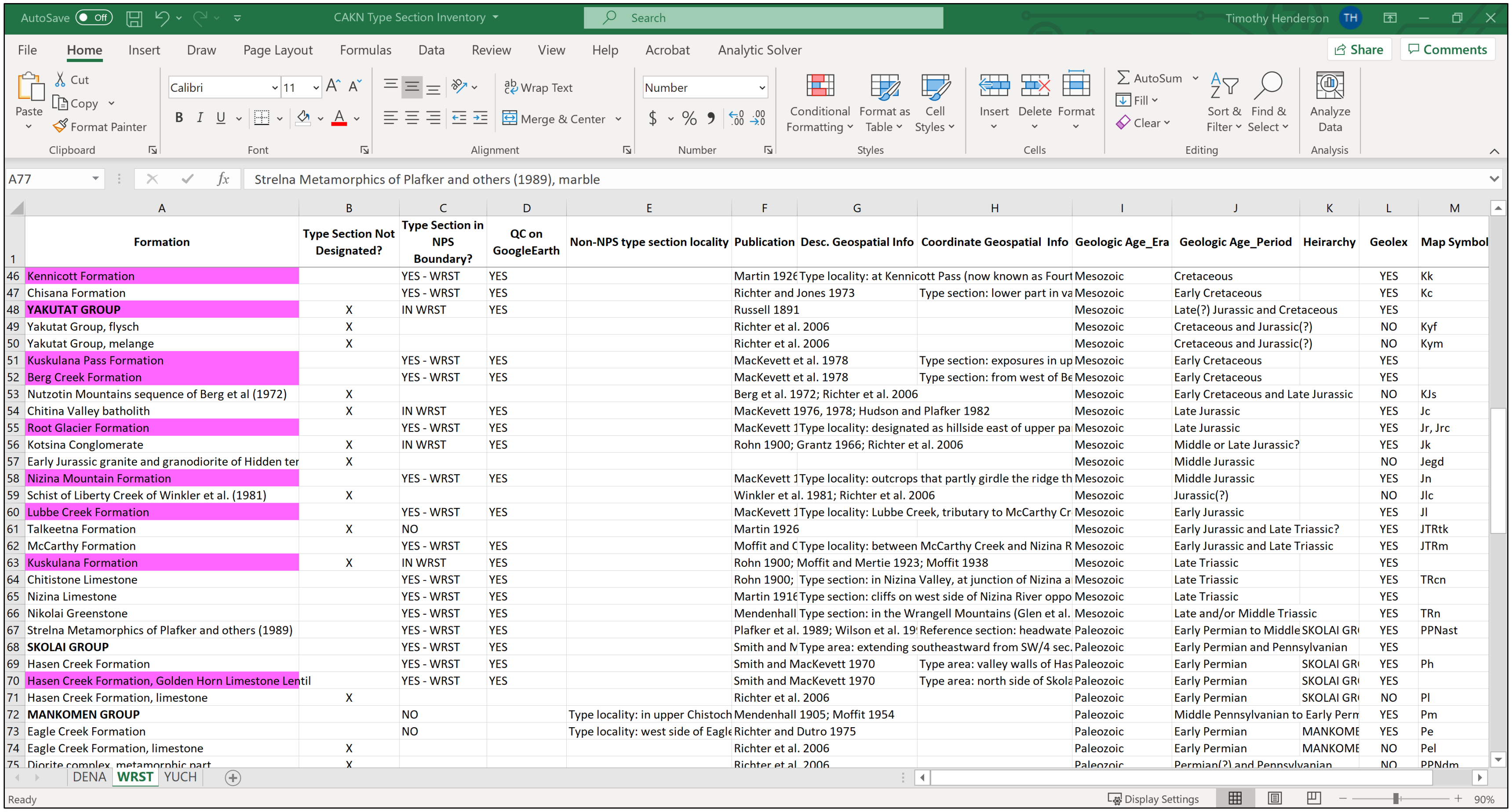


Figure 3. GEOLEX search result for the Calico Bluff Formation unit.

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^2 (36 mi^2) township into 36 individual 2.59 km^2 (1 mi^2) sections, and were converted into Google Earth (.kmz file) locations using Earth Point (https://www.earthpoint.us/TownshipsSearchByDescription.aspx). 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^2 (0.0625 mi^2). Once stratotype locality information provided for a given unit is geolocated using Google Earth, a GRI digital geologic map of the national park is draped over it. This step serves two functions: to improve accuracy in locating the stratotype, and validating the geologic polygon for agreement with GEOLEX nomenclature. Geolocations in Google Earth are then converted into an ArcGIS format using a "KML to Layer" conversion tool in ArcMap.

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).



	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
46	Kennicott Formation		YES - WRST	YES		Martin 1926	Type locality: at Kennicott Pass (now known as Fourt		Mesozoic	Cretaceous		YES	Kk
47	Chisana Formation		YES - WRST	YES		Richter and Jones 1973		Type section: lower part in va	Mesozoic	Early Cretaceous		YES	Kc
48	**YAKUTAT GROUP**	X	IN WRST	YES		Russell 1891			Mesozoic	Late(?) Jurassic and Cretaceous		YES	
49	Yakutat Group, flysch	X				Richter et al. 2006			Mesozoic	Cretaceous and Jurassic(?)		NO	Kyf
50	Yakutat Group, melange	X				Richter et al. 2006			Mesozoic	Cretaceous and Jurassic(?)		NO	Kym
51	Kuskulana Pass Formation		YES - WRST	YES		MacKevett et al. 1978		Type section: exposures in up	Mesozoic	Early Cretaceous		YES	
52	Berg Creek Formation		YES - WRST	YES		MacKevett et al. 1978		Type section: from west of Be	Mesozoic	Early Cretaceous		YES	
53	Nutzotin Mountains sequence of Berg et al (1972)	X				Berg et al. 1972; Richter et al. 2006			Mesozoic	Early Cretaceous and Late Jurassic		NO	KJs
54	Chitina Valley batholith	X	IN WRST	YES		MacKevett 1976, 1978; Hudson and Plafker 1982			Mesozoic	Late Jurassic		YES	Jc
55	Root Glacier Formation		YES - WRST	YES		MacKevett 1	Type locality: designated as hillside east of upper pa		Mesozoic	Late Jurassic		YES	Jr, Jrc
56	Kotsina Conglomerate	X	IN WRST	YES		Rohn 1900; Grantz 1966; Richter et al. 2006			Mesozoic	Middle or Late Jurassic?		YES	Jk
57	Early Jurassic granite and granodiorite of Hidden ter	X							Mesozoic	Middle Jurassic		NO	Jegd
58	Nizina Mountain Formation		YES - WRST	YES		MacKevett 1	Type locality: outcrops that partly girdle the ridge th		Mesozoic	Middle Jurassic		YES	Jn
59	Schist of Liberty Creek of Winkler et al. (1981)	X				Winkler et al. 1981; Richter et al. 2006			Mesozoic	Jurassic(?)		NO	Jlc
60	Lubbe Creek Formation		YES - WRST	YES		MacKevett 1	Type locality: Lubbe Creek, tributary to McCarthy Cr		Mesozoic	Early Jurassic		YES	Jl
61	Talkeetna Formation	X	NO			Martin 1926			Mesozoic	Early Jurassic and Late Triassic?		YES	JTRtk
62	McCarthy Formation		YES - WRST	YES		Moffit and C	Type locality: between McCarthy Creek and Nizina R		Mesozoic	Early Jurassic and Late Triassic		YES	JTRm
63	Kuskulana Formation	X	IN WRST	YES		Rohn 1900; Moffit and Mertie 1923; Moffit 1938			Mesozoic	Late Triassic		YES	
64	Chitistone Limestone		YES - WRST	YES		Rohn 1900;	Type section: in Nizina Valley, at junction of Nizina a		Mesozoic	Late Triassic		YES	TRcn
65	Nizina Limestone		YES - WRST	YES		Martin 1916	Type section: cliffs on west side of Nizina River oppo		Mesozoic	Late Triassic		YES	
66	Nikolai Greenstone		YES - WRST	YES		Mendenhall	Type section: in the Wrangell Mountains (Glen et al.		Mesozoic	Late and/or Middle Triassic		YES	TRn
67	Strelna Metamorphics of Plafker and others (1989)		YES - WRST	YES		Plafker et al. 1989; Wilson et al. 19		Reference section: headwate	Paleozoic	Early Permian to Middle	SKOLAI GR	YES	PPNast
68	**SKOLAI GROUP**		YES - WRST	YES		Smith and M	Type area: extending southeastward from SW/4 sec.		Paleozoic	Early Permian and Pennsylvanian		YES	
69	Hasen Creek Formation		YES - WRST	YES		Smith and MacKevett 1970		Type area: valley walls of Has	Paleozoic	Early Permian	SKOLAI GR	YES	Ph
70	Hasen Creek Formation, Golden Horn Limestone Lentil		YES - WRST	YES		Smith and MacKevett 1970		Type area: north side of Skola	Paleozoic	Early Permian	SKOLAI GR	YES	
71	Hasen Creek Formation, limestone	X				Richter et al. 2006			Paleozoic	Early Permian	SKOLAI GR	NO	Pl
72	**MANKOMEN GROUP**		NO		Type locality: in upper Chistoch	Mendenhall 1905; Moffit 1954			Paleozoic	Middle Pennsylvanian to Early Perm		YES	Pm
73	Eagle Creek Formation		NO		Type locality: west side of Eagle	Richter and Dutro 1975			Paleozoic	Early Permian	MANKOME	YES	Pe
74	Eagle Creek Formation, limestone	X				Richter et al. 2006			Paleozoic	Early Permian	MANKOME	NO	Pel
75	Diorite complex, metamorphic part	X				Richter et al. 2006			Paleozoic	Permian(?) and Pennsylvanian		NO	PPNdm

Figure 4. Stratotype inventory spreadsheet of the CAKN displaying attributes appropriate for geolocation assessment. Purple highlighted cells represent geologic units supplemented to the GRI unit listing for WRST.

Definitions

In order to clarify, standardize, and consistently reference stratigraphic concepts, principles, and definitions, the North American Stratigraphic Code is recognized and adopted for this inventory. This code seeks to describe explicit practices for classifying and naming all formally defined geologic units. An important designation for a geologic unit is known as a ***stratotype***—the standard exposure (original or subsequently designated) for a named geologic unit or boundary and constitutes the basis for definition or recognition of that unit or boundary (North American Commission on Stratigraphic Nomenclature 2021). There are several variations of stratotype referred to in the literature and this report, and they are defined as follows:

1) **Unit stratotype**: the **type section** for a stratified deposit or the **type area** for a non-stratified body that serves as the standard for recognition and definition of a geologic unit (North American Commission on Stratigraphic Nomenclature 2021). Once a unit stratotype is assigned, it is never changed. The term "unit stratotype" is commonly referred to as "type section" and "type area" in this report.
2) **Type locality**: the specific geographic locality encompassing the unit stratotype of a formally recognized and defined unit. On a broader scale, a type area is the geographic territory encompassing the type locality. Before development of the stratotype concept, only type localities and type areas were designated for many geologic units that are now long- and well-established (North American Commission on Stratigraphic Nomenclature 2021).
3) **Reference sections**: for well-established geologic units for which a type section was never assigned, a reference section may serve as an invaluable standard in definitions or revisions. A principal reference section may also be designated for units whose stratotypes have been destroyed, covered, or are otherwise inaccessible (North American Commission on Stratigraphic Nomenclature 2021). Multiple reference sections can be designated for a single unit to help illustrate heterogeneity or some critical feature not found in the stratotype. Reference sections can help supplement unit stratotypes in the case where the stratotype proves inadequate (North American Commission on Stratigraphic Nomenclature 2021).
4) **Lithodeme**: the term "lithodeme" is defined as a mappable unit of plutonic (igneous rock that solidified at great depth) or highly metamorphosed and pervasively deformed rock and is a term equivalent in rank to "formation" among stratified rocks (North American Commission on Stratigraphic Nomenclature 2021). The formal name of a lithodeme consists of a geographic name followed by a descriptive term that denotes the average modal composition of the rock (example: Cathedral Peak Granodiorite). Lithodemes are commonly assigned type localities, type areas, and reference localities.

Denali National Park and Preserve (DENA)

Denali National Park and Preserve (DENA) is located approximately 120 km (75 mi) southwest of Fairbanks and 160 km (100 mi) north of Anchorage in Denali and Matanuska-Susitna Boroughs, south-central Alaska (Figure 5). DENA was established on December 2, 1980 from the incorporation of former Mt. McKinley National Park (established February 26, 1917) and Denali National Monument (established December 1, 1978). The national park and preserve protect approximately 2,458,477 hectares (6,075,029 acres) of vast and varied geological landscape that includes portions of the Alaska Range and Denali (previously known as Mount McKinley), North America's highest peak at 6,190 m (20,310 ft) (National Park Service 2016). DENA was designated an International Biosphere Reserve in 1976, containing a rich biological community that includes caribou, Dall sheep, moose, grizzly bears, timber wolves, more than 160 bird species, and more than 1,500 plant species.

The geology of DENA is the result of active tectonic processes of southern Alaska that are still uplifting the Alaska Range along the Denali fault system (Thornberry-Ehrlich 2010). The whole of DENA consists of accreted terranes (land masses added to a continent through plate tectonics) that are fault-bounded and geologically distinct from one another. Most of these terranes consist of igneous intrusive rocks and sedimentary sequences with a wide range of ages spanning from the Cambrian–Ordovician Lyman Hills Formation to Quaternary surficial deposits. Some of the oldest rocks in DENA are represented by Precambrian-age metamorphic rocks found in the Alaska Range (Figures 6 and 7). Glaciers cover a large portion of the surface area in DENA and have carved through thousands of meters of rock to create U-shaped valleys (Thornberry-Ehrlich 2010). The powerful erosion of glaciers has transported vast amounts of sediment and revealed a rich geologic history that scientists continue to decipher today.

DENA contains three identified stratotypes that are subdivided into one type section, one type locality, and one reference section (Table 2; Figure 8). In addition to the designated stratotypes located within DENA, a list of stratotypes located within 48 km (30 mi) of park boundaries is included here for reference. These nearby stratotypes include the Ordovician–Silurian Post River Sandstone (type section) and Graptolite Canyon Member of the Post River Sandstone (type section); Devonian Barren Ridge Limestone (type section); Devonian–Mississippian Totatlanika Schist (type locality); Cretaceous–Cenozoic Cantwell Formation (type locality); Eocene–Miocene Usibelli Group (type section) and Healy Creek Formation (type section); and the Miocene Suntrana Formation (type section), Lignite Creek Formation (type locality), Grubstake Formation (type locality and reference section), Sanctuary Formation (type section), and California Creek Member of the Totatlanika Schist (type locality).

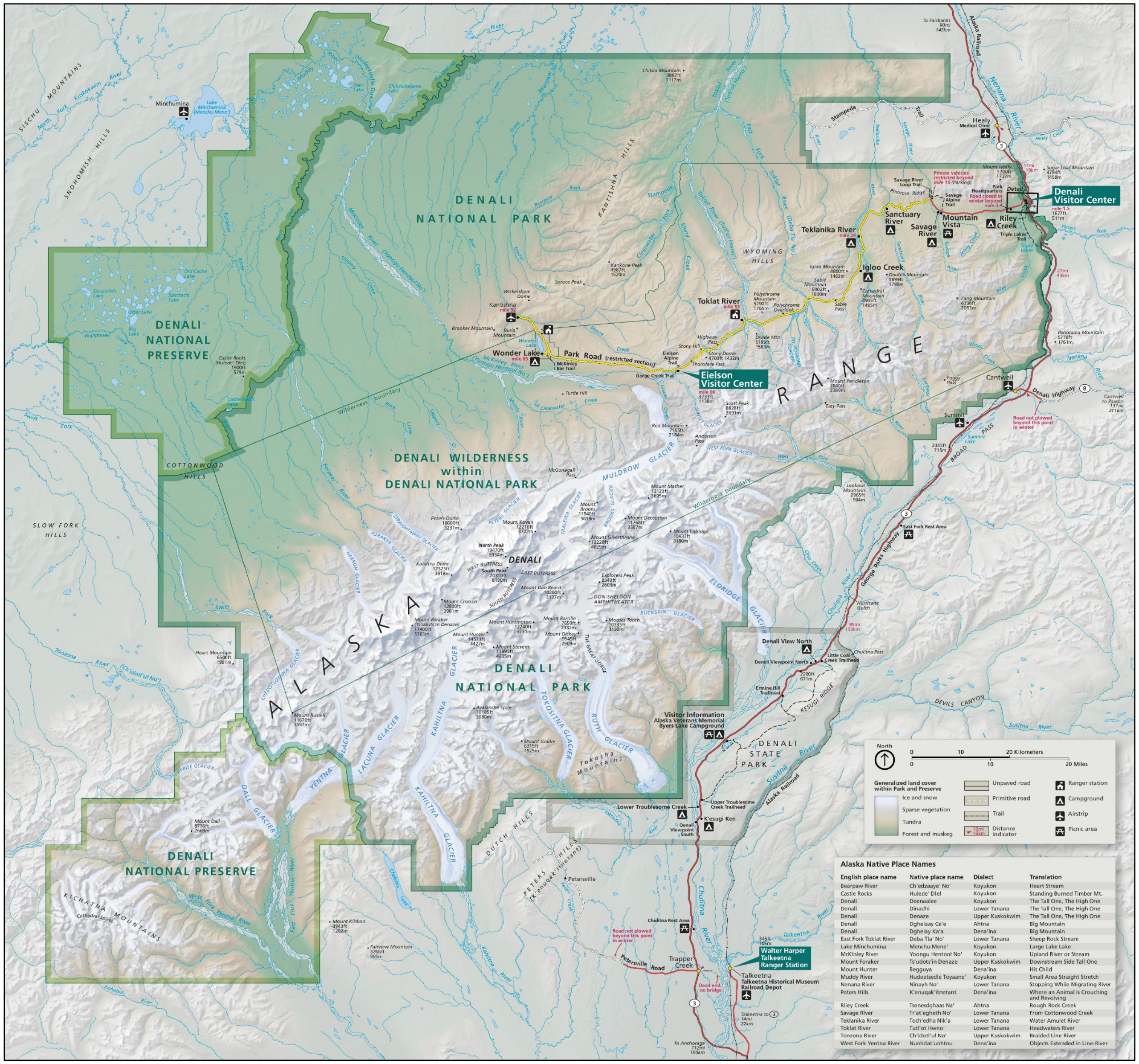


Figure 5. Park map of DENA, Alaska (NPS).

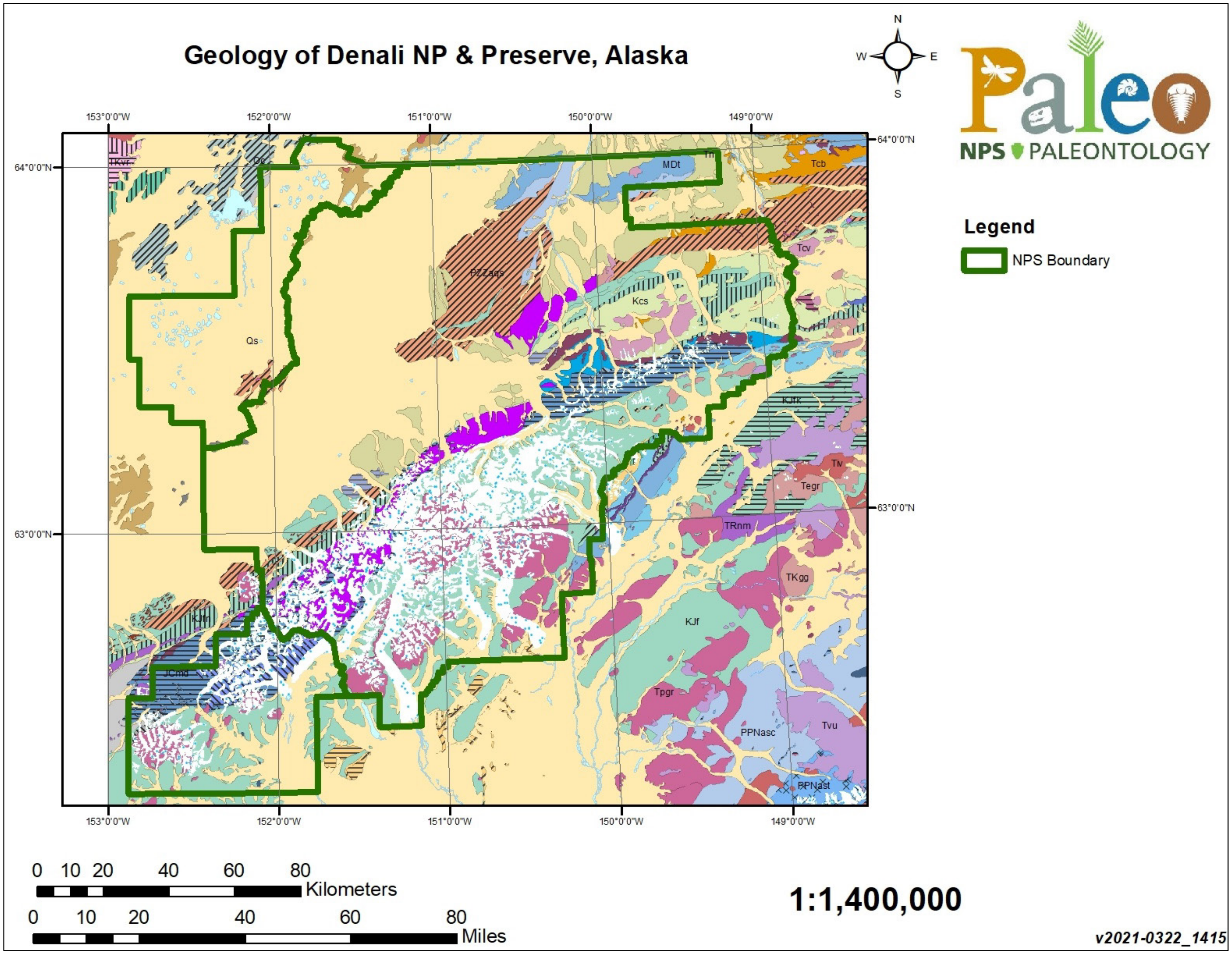


Figure 6. Geologic map of DENA, Alaska; see Figure 7 for map units. Projection is in UTM 5.

Figure 7. Geologic map legend of DENA, Alaska.

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

Unit Name (map symbol)	Reference	Stratotype Location	Age
Mount Galen Volcanics	Decker and Gilbert 1978	Type locality: designated as narrow ridge extending from Stony Creek, southwest to top of Mount Galen in Mount McKinley National Park, Mount McKinley B-1 Quadrangle, west central Alaska Range, AK	Eocene–Oligocene
Teklanika Formation	Gilbert et al. 1976	Type section: ridge along east side of upper Teklanika River, from 5–6.5 km (3.1–4 mi) south of Calico Creek, in Denali National Park, central Alaska Range, Healy C-6 Quadrangle (scale 1:63,360), AK	Paleocene
Cantwell Formation (Tcv)	Wolfe and Wahrhaftig 1970	Reference section: western walls of Nenana Canyon between Clear Creek and Carlo	Cretaceous–Paleocene

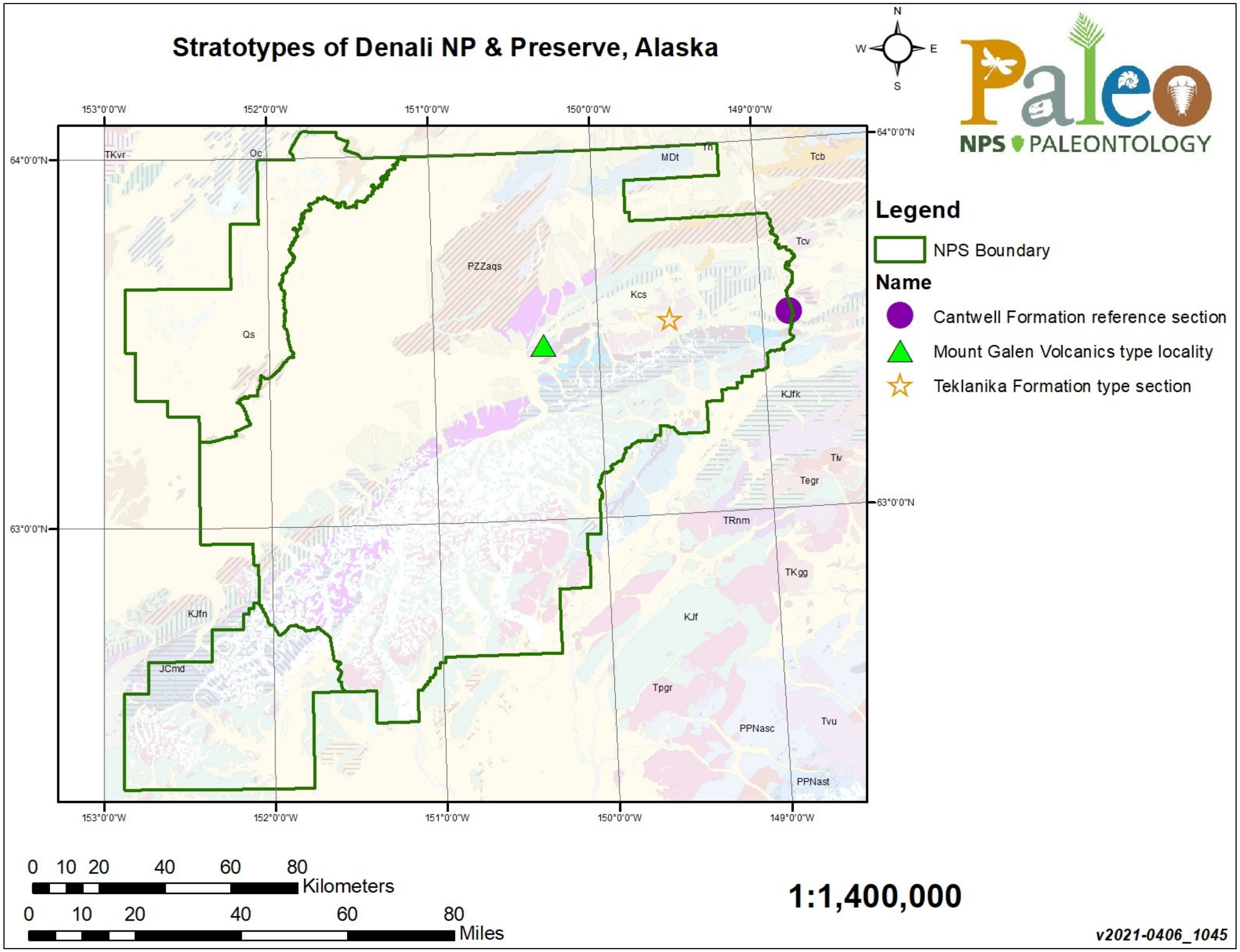


Figure 8. Modified geologic map of DENA showing stratotype locations. The transparency of the geologic units layer has been increased. Projection is in UTM 5.

Cantwell Formation

The Cretaceous–Paleocene Cantwell Formation was introduced by Eldridge (1900) and named after exposures along the Cantwell River in southern Alaska. Although the type locality of the formation is situated outside the DENA boundary to the east, Wolfe and Wahrhaftig (1970) described a reference section along the western walls of Nenana Canyon between Clear Creek and Carlo, DENA (Table 2; Figure 8). The reference section has a maximum measured thickness of 3,048 m (10,000 ft) and consists of interbedded conglomerate, sandstone, argillite, and coal with volcanic rocks near its upper surface (Wolfe and Wahrhaftig 1970). Stratigraphic relationships with the Cantwell Formation are complex as many units are in fault contact with it.

Teklanika Formation

The Paleocene Teklanika Formation was named by Gilbert et al. (1976) after the Teklanika River where the formation is well exposed. The type section of the formation forms the eastern ridge of the upper Teklanika River drainage approximately 5–6.5 km (3.1–4 mi) south of Calico Creek and measures more than 3,750 m (12,303 ft) thick (Table 2; Figures 8 and 9; Gilbert et al. 1976). Gilbert et al. (1976) subdivided the type section into six conformable units that consist of andesite, rhyolite, and basalt flows with interbedded felsic pyroclastic mudstone, tuff, and tuff breccia (Figure 9). Stratigraphically, the Teklanika Formation underlies Quaternary alluvium and conformably overlies the Cantwell Formation with exception to areas where it is in probable fault contact (Gilbert et al. 1976).

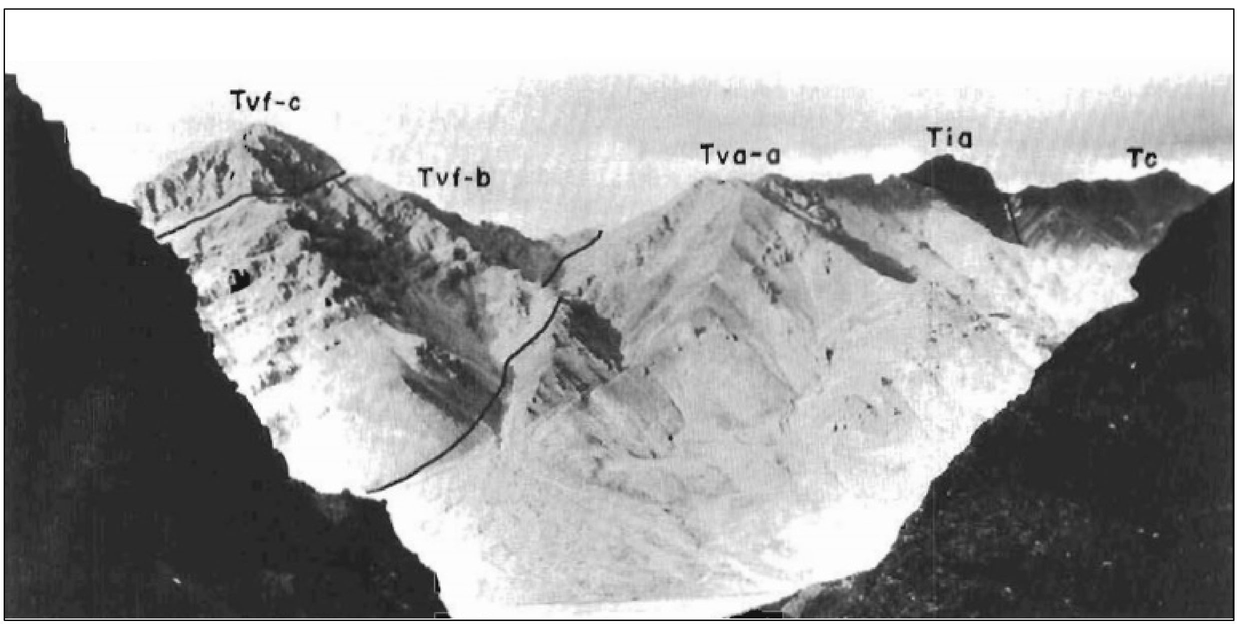


Figure 9. Type section exposure of the Teklanika Formation on the east side of upper Teklanika River, DENA. Tva-a, basal basalt flow unit; Tvf-b, andesite, tuff, and tuff breccia unit; Tvf-c, microcrystalline rhyolite flow unit; Tc, Cantwell Formation; Tia, mafic intrusion. Figure 3 from Gilbert et al. (1976).

Mount Galen Volcanics

The Eocene–Oligocene Mount Galen Volcanics were first proposed by Decker and Gilbert (1978) for a discontinuous series of andesitic and basaltic lava flows, breccia, and tuff exposed in the west-central Alaska Range. The formation is named after its type locality, which extends along a narrow ridge from Stony Creek southwest to the crest of Mount Galen, DENA (Table 2; Figures 8 and 10; Decker and Gilbert 1978). Exposures at the type locality have a minimum thickness of ~1,000 m (3,300 ft) and consist of volcanic breccia, tuff, and columnar-jointed basalt flows near Spring Creek that become dominantly volcanic breccia, flow breccia, tuff, and andesitic flows on the flanks of Mount Galen (Decker and Gilbert 1978). The Mount Galen Volcanics unconformably overlie the Cantwell Formation and conformably underlie Neogene coal-bearing sedimentary rocks.

Figure 10. Northwest view from ridge 1 km (0.6 mi) north of Eielson Visitor Center across the valley of Moose Creek toward the southwest end of Mount Galen. The valley is predominantly composed of the Mount Galen Volcanics in its type locality. Younger conglomerate in the middle distance conformably overlies the Mount Galen Volcanics. Figure 3 from Decker and Gilbert (1978).

Wrangell-St. Elias National Park and Preserve (WRST)

Wrangell-St. Elias National Park and Preserve (WRST) is located approximately 275 km (170 mi) east of Anchorage and shares a border with Canada (Figure 11). It is within Yakutat Borough and the Chugach, Copper River, and Southeast Fairbanks Census Areas of the Unorganized Borough in southeastern Alaska. Originally proclaimed as Wrangell-St. Elias National Monument on December 1, 1978, the park and preserve were established on December 2, 1980 (National Park Service 2016). WRST is the largest unit of the National Park Service and encompasses 5,332,053 hectares (13,175,791 acres) of rugged, beautiful landscape at the convergence of the Alaska, Chugach, St. Elias, and Wrangell mountain ranges. The landscape of WRST is decorated with massive peaks, volcanoes, numerous glaciers, huge rivers, and a rich biological community. The rich diversity of natural and cultural resources at WRST has been recognized and designated as an International World Heritage Site in 1979 (National Park Service 2016).

WRST is a geologist's wonderland, with a diverse landscape that attracts researchers from around the world in the fields of volcanism, glaciation, plate tectonics, geochronology, and Quaternary geology. Situated in one of the most geologically active regions of North America, WRST has experienced volcanic activity, subduction, and uplift resulting in massive mountain ranges. The geology of WRST is composed of a patchwork of accreted terranes (land masses added to a continent through plate tectonics) that have slowly built Alaska through geologic time. Each of these terranes is fault-bounded and contains distinct structural, paleontological, and sedimentological features. The park and preserve contains a wide variety of Mesozoic and Cenozoic sedimentary and igneous units, with some of the oldest units represented by late Paleozoic metamorphic complexes (Figures 12 and 13).

WRST contains 25 identified stratotypes that are subdivided into eight type sections, five type localities, eight type areas, and four reference sections (two of which are for one formation) (Table 3; Figure 14). In addition to the designated stratotypes located within WRST, a list of stratotypes located within 48 km (30 mi) of park boundaries is included here for reference. These nearby stratotypes include the Pennsylvanian–Permian Mankomen Group (type locality) and Slana Spur Formation (type locality); Permian Eagle Creek Formation (type locality); Eocene Tokun Formation (type area) and Kulthieth Formation (type locality); Eocene–Miocene Poul Creek Formation (type locality); and the Miocene–Holocene Yakataga Formation (type section).

Within the boundaries of WRST there are a few geologic units unique to the region that currently lack stratotype designation and are addressed under "Recommendations".

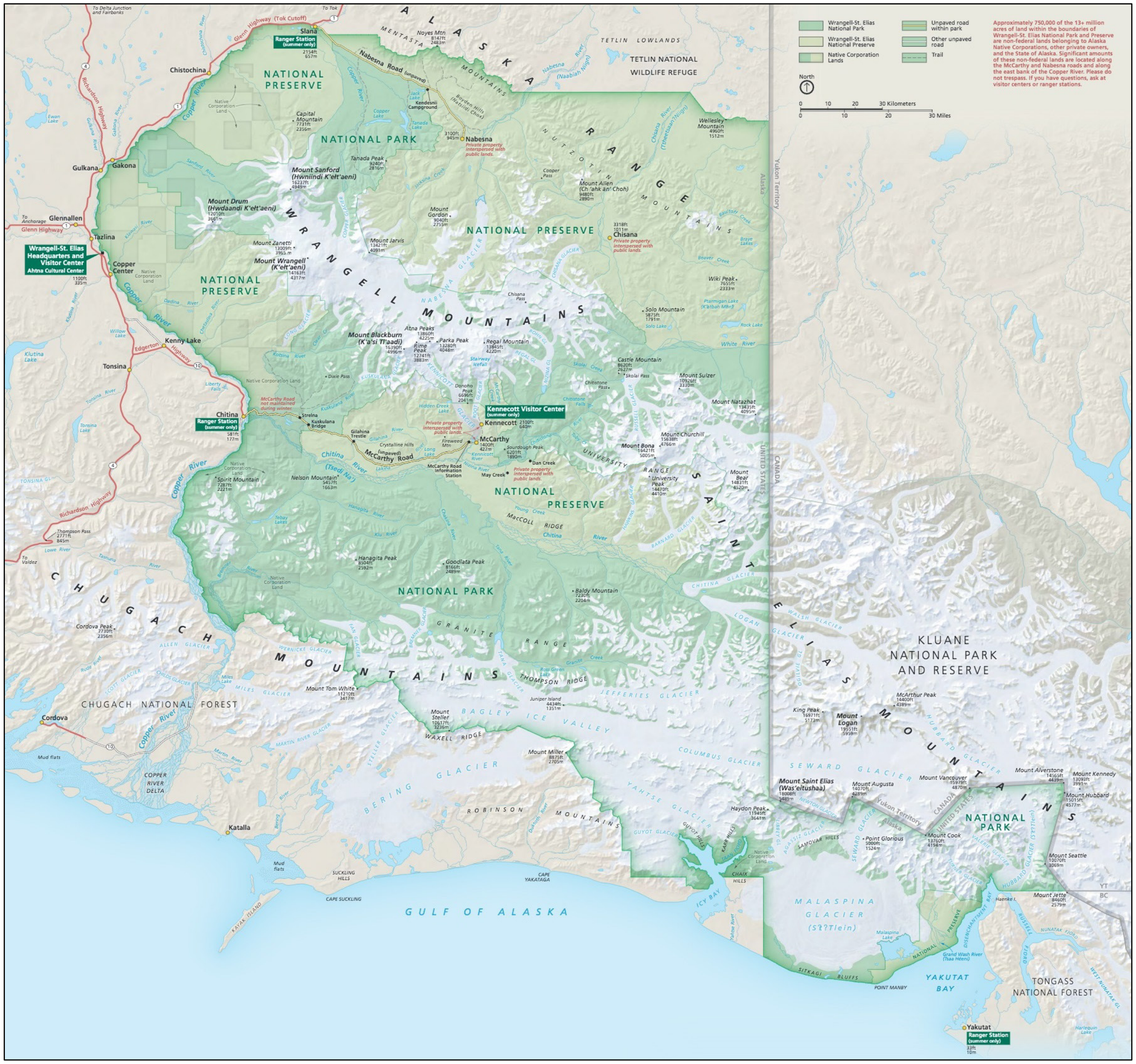


Figure 11. Park map of WRST, Alaska (NPS).

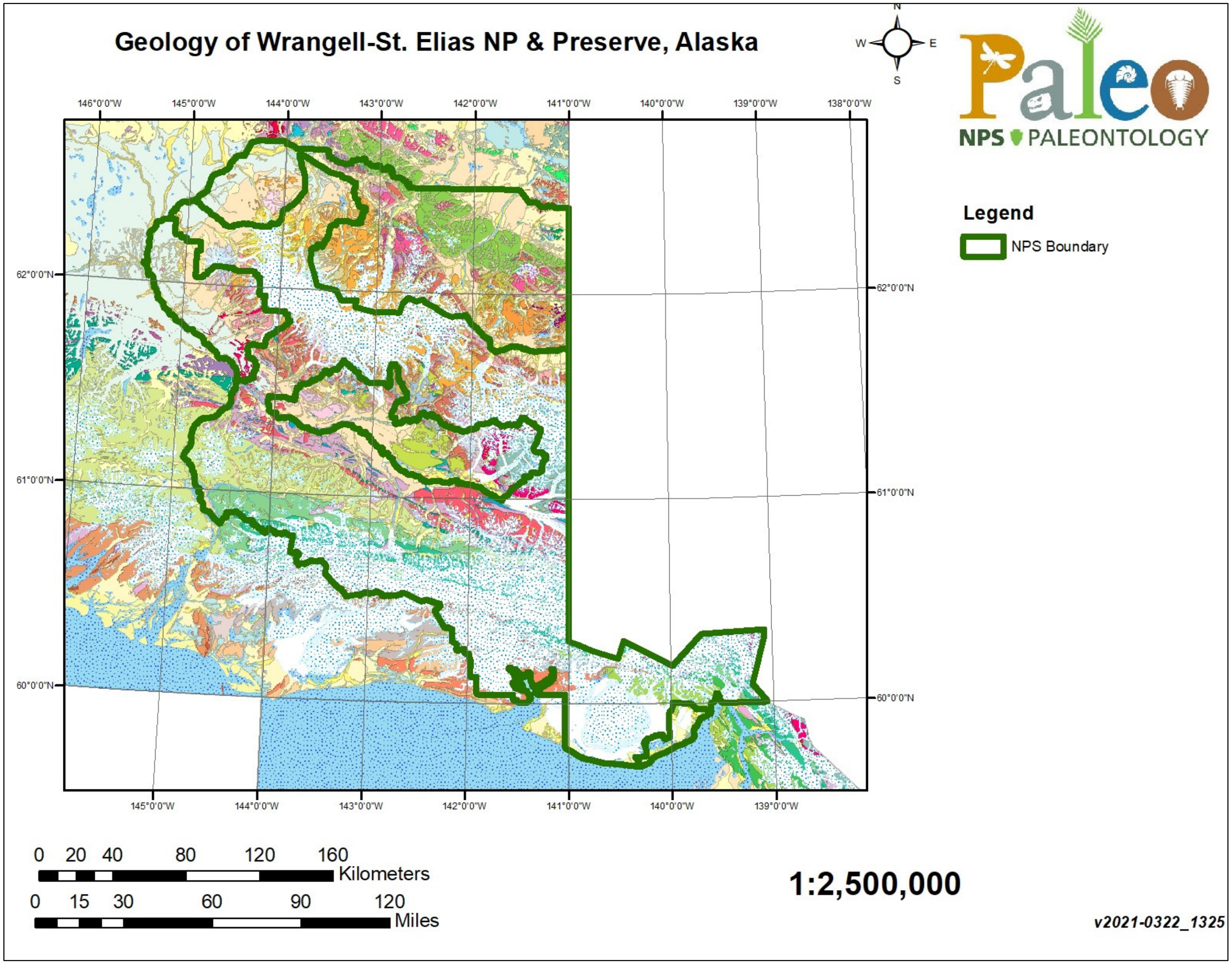


Figure 12. Geologic map of WRST, Alaska; see Figure 13 for map units. Projection is in UTM Zone 7.

Figure 13. Geologic map legend of WRST, Alaska.

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

Unit Name (map symbol)	Reference	Stratotype Location	Age
White River Ash Bed	Pewe 1975	Type section: on the north side of the White River about 13 km (8 mi) downstream from the source of the river in Russell Glacier and about 50 km (31 mi) west of the Alaska–Canada border, McCarthy D-2 Quadrangle)	Holocene
Frederika Formation	MacKevett 1970a	Type area: in sec. 5, T. 2 S., R. 18 E., McCarthy C-4 Quadrangle, southern AK	middle Miocene
MacColl Ridge Formation (Kmr)	Jones and MacKevett 1969	Type section: about 4.8 km (3 mi) east of western boundary of McCarthy A-4 Quadrangle and trends southward from the contact with the Chititu Formation to near the crest of MacColl Ridge, McCarthy A-4 Quadrangle, southern AK	Late Cretaceous
Moonshine Creek Formation	Jones and MacKevett 1969	Type area: Moonshine Creek in McCarthy C-4 Quadrangle, southern Wrangell Mountains, southern AK	late Early–early Late Cretaceous
Schulze Formation (Ks)	Jones and MacKevett 1969	Type area: upland north of Sourdough Peak east of upper reaches of Nikolai Creek, McCarthy B-5 Quadrangle, southern AK	late Early–early Late Cretaceous
Chititu Formation (Kc, Kch)	Jones and MacKevett 1969	Type area: exposures north and south of Young Creek, in northwestern part of McCarthy A-4 Quadrangle, and south of latitude of Copper Creek, in southern part of McCarthy B-4 Quadrangle, southeastern AK Reference sections (2): exposures that extend north and south of Young Creek about 6.4 km (4 mi) east of the western border of the McCarthy A-4 Quadrangle	Late Cretaceous
Chisana Formation (Kc)	Richter and Jones 1973	Type section: lower part in valley of Bonanza Creek, in secs. 25, 35, and 36, T. 4 N., R. 19 E.; upper part in valley of Toby Creek, in secs. 28, 33, and 34, T. 4 N., R. 20 E., Nabesna A-2 Quadrangle, southern AK	Early Cretaceous
Kennicott Formation (Kk)	Martin 1926; Jones and MacKevett 1969	Type locality: at Kennicott Pass (now known as Fourth of July Pass) Type locality (redefined): hillsides east of Fohlin Creek and north of Bear Creek mainly in the southwestern part of the McCarthy C-6 Quadrangle, but to a lesser extent in the northwestern part of the adjoining McCarthy B-6 Quadrangle	Early Cretaceous

Table 3 (continued). List of WRST stratotype units sorted by age with associated reference publications and locations.

Unit Name (map symbol)	Reference	Stratotype Location	Age
Kuskulana Pass Formation	MacKevett et al. 1978	Type section: exposures in upper drainage basin of Trail and Slatka Creeks near Kuskulana Pass, extending south from NE/4 SE/4 sec. 32, T. 3 S., R. 10 E., to NE/4 SW/4 NW/4 sec. 5, T. 4 S., R. 10 E., McCarthy C-8 Quadrangle, Wrangell Mountains, AK	Early Cretaceous
Berg Creek Formation	MacKevett et al. 1978	Type section: from west of Berg Creek to 1.8 km (1.1 mi) south of Kuskulana Pass; exposures from SE/4 SW/4 sec. 34, T. 3 S., R. 9 E. southward to south part of SE/4 NW/4 sec. 3, T. 4 S., R. 9 E., McCarthy C-8 Quadrangle, Wrangell Mountains, AK	Early Cretaceous
Root Glacier Formation	MacKevett 1969	Type locality: designated as hillside east of upper part of McCarthy Creek, McCarthy C-5 Quadrangle, southern AK	Late Jurassic
Nizina Mountain Formation (Jn)	MacKevett 1969	Type locality: outcrops that partly girdle the ridge that extends southward from Nizina Mountain, McCarthy C-5 Quadrangle, southern AK	Middle Jurassic
McCarthy Formation (JTRm)	Moffit and Capps 1911	Type locality: between McCarthy Creek and Nizina River, Nizina–Tanana region, southern AK	Late Triassic–Early Jurassic
Nizina Limestone	Martin 1916	Type section: cliffs on west side of Nizina River opposite mouth of Chitistone River, Nizina–Tanana region, southern AK	Late Triassic
Chitistone Limestone (TRcn)	Moffit and Capps 1911; Martin 1916	Type section: in Nizina Valley, at junction of Nizina and Chitistone Rivers	Late Triassic
Nikolai Greenstone (TRn)	Glen et al. 2011	Type section: in the Wrangell Mountains	Middle–Late Triassic
Skolai Group	Smith and MacKevett 1970	Type area: extending southeastward from SW/4 sec. 15, T. 2 S., R. 17 E., to terminal moraine of Frederika Glacier, McCarthy C-4 Quadrangle, southern AK Reference section: designated in secs. 26, 27, 33, 34, and 35, T. 5 S., R. 18 E. along upper Glacier Creek near the eastern border of the McCarthy B-4 Quadrangle	Pennsylvanian–early Permian
Hasen Creek Formation (Ph)	Smith and MacKevett 1970	Type area: valley walls of Hasen Creek, in secs.11 and 12, T. 4 S., R. 17 E., McCarthy Quadrangle, southern AK	early Permian

Table 3 (continued). List of WRST stratotype units sorted by age with associated reference publications and locations.

Unit Name (map symbol)	Reference	Stratotype Location	Age
Golden Horn Limestone Lentil, Hasen Creek Formation	Smith and MacKevett 1970	Type area: north side of Skolai Creek extending west from peak of Golden Horn to Tinplate Hill, in sec. 23, T. 2 S., R. 17 E., McCarthy C-4 Quadrangle, southern AK	early Permian
Station Creek Formation	Smith and MacKevett 1970	Type area: extends 5.6 km (3.5 mi) west from point 1.6 km (1 mi) south of Station Creek, a tributary of Frederika Creek, southern Wrangell Mountains, northeastern McCarthy C-4 Quadrangle, southern AK	Pennsylvanian–early Permian
Strelna Metamorphics (PPNast)	Plafker et al. 1989	Reference section: headwaters of Canyon Creek, in SW/4 sec. 12, T. 6 S., R. 6 E., Valdez B-1 Quadrangle, southern AK	Middle Pennsylvanian–early Permian

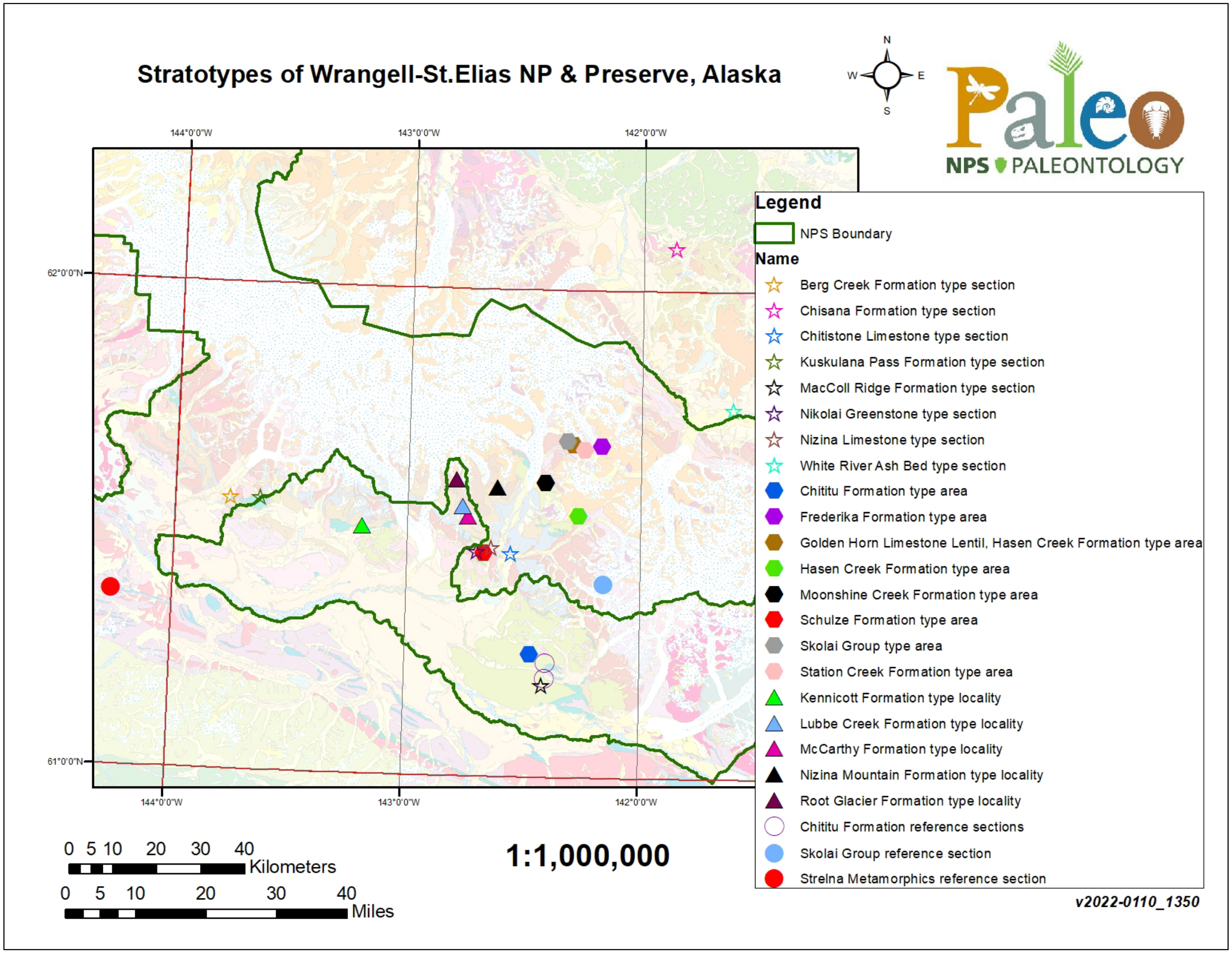


Figure 14. Modified geologic map of WRST showing stratotype locations. The transparency of the geologic units layer has been increased. Projection is in UTM Zone 7.

Strelna Metamorphics

The Pennsylvanian–Permian Strelna Metamorphics is defined by Plafker et al. (1989) as the metamorphosed part of the (now abandoned) Strelna Formation of Moffit (1938). A reference section for the formation is designated at the headwaters of Canyon Creek (SW/4 sec. 12, T. 6 S., R. 6 E., Valdez B-1 Quadrangle), where the metamorphic rocks are well exposed (Table 3; Figure 14; Plafker et al. 1989). Rock types include five general lithologic endmembers consisting of greenschist, marble, schistose marble, quartzo-feldspathic-mica schist, and micaceous quartz schist (Plafker et al. 1989). The age of the unit predates the Middle Pennsylvanian and Late Jurassic meta-plutonic rocks that crosscut it, and is considered to be as old as Early Pennsylvanian by correlation along strike with rocks yielding age-diagnostic conodonts (Plafker et al. 1989).

Skolai Group

The Pennsylvanian–Permian Skolai Group was proposed by Smith and MacKevett (1970) to describe a thick sequence of low-grade metamorphic rocks consisting of lava flows and volcaniclastic sedimentary rocks, widely distributed in the eastern Wrangell Mountains. The group is named after excellent exposures along the upper reaches of Skolai Creek in the McCarthy C-4 Quadrangle. The type area of the Skolai Group is designated as exposures extending southeastward from near the southwest corner of sec. 15, T. 2 S., R. 17 E. (Copper River meridian) to the terminal moraine of Frederika Glacier (Table 3; Figures 14 and 15; Smith and MacKevett 1970). Exposed sections in the type area measure more than 2,400 m (8,000 ft) thick (Smith and MacKevett 1970). An attenuated reference section of the group measuring 1,700 m (5,500 ft) thick is found in secs. 26, 27, 33, 34, and 35, T. 5 S., R. 18 E. along upper Glacier Creek near the eastern border of the McCarthy B-4 Quadrangle (Table 3; Figure 14; Smith and MacKevett 1970). Stratigraphically, the Skolai Group is disconformably overlain by the Nikolai Formation, Wrangell Lava, and Frederika Formation.

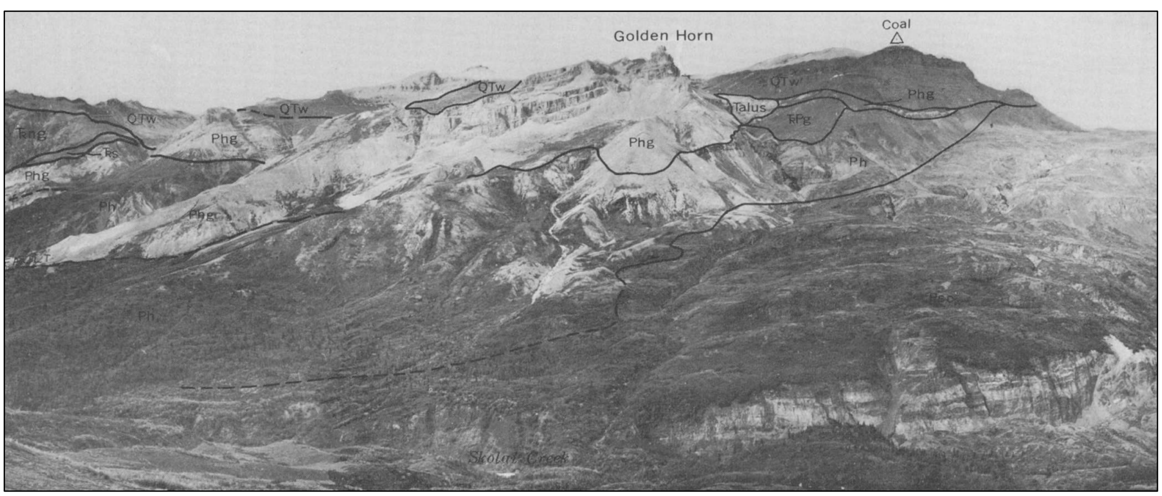


Figure 15. Type area of the Skolai Group and Golden Horn Limestone Lentil of the Hasen Creek Formation looking north across Skolai Creek toward Golden Horn, WRST. QTw, Wrangell Lava; TRng, Nikolai Greenstone; TRs, shale (mudstone) and siltstone; TRPg, gabbro; Ph, Hasen Creek Formation; Phg, Golden Horn Limestone Lentil; Psc, volcaniclastic member of the Station Creek Formation. Figure 3 from Smith and MacKevett (1970).

Station Creek Formation

The Pennsylvanian–Permian Station Creek Formation of the Skolai Group was first proposed by Smith and MacKevett (1970) and named after exposures near Station Creek, a tributary of Frederika Creek in the McCarthy C-4 Quadrangle. The type area of the formation is designated to be the area that extends for approximately 5.6 km (3.5 mi) west from about 1.6 km (1 mi) south of Station Creek (Table 3; Figure 14; Smith and MacKevett 1970). Exposures in the type area measure approximately 1,800–2,000 m (6,000–6,500 ft) thick (Smith and MacKevett 1970). The Station Creek Formation is subdivided by Smith and MacKevett (1970) into two informal members: 1) a lower volcanic flow member consisting of black and greenish-gray basalt and basaltic andesite flows; and 2) an upper volcaniclastic member composed of distinctive red beds of coarse volcanic breccia, black to dark gray volcanic siltstone and siltstone, interbedded tuff breccia, and delicately laminated volcanilutite. Graded bedding, load casts, and flame structures are commonly found in the upper member (Smith and MacKevett 1970). The formation conformably underlies the Hasen Creek Formation, and its basal contact is not exposed.

Hasen Creek Formation

The Permian Hasen Creek Formation of the Skolai Group was named by Smith and MacKevett (1970) after its type locality exposures in the valley walls of Hasen Creek in the southeastern part of the McCarthy C-4 Quadrangle (Table 3; Figure 14). The formation consists of thin-bedded chert, black shale, sandstone, carbonaceous bioclastic limestone, and minor conglomerate (Smith and MacKevett 1970). A conspicuous limestone lens occurs within the formation in the northern part of the McCarthy C-4 Quadrangle and is named the Golden Horn Limestone Lentil (Smith and MacKevett 1970). Maximum measured thickness of the formation (excluding the Golden Horn Limestone Lentil) is nearly 270 m (900 ft) (Smith and MacKevett 1970). The Hasen Creek Formation conformably overlies the Station Creek Formation and disconformably underlies the Nikolai Greenstone, Wrangell Lava, or Frederika Formation (MacKevett 1969; Smith and MacKevett 1970).

Golden Horn Limestone Lentil of the Hasen Creek Formation

The Golden Horn Limestone Lentil of the Hasen Creek Formation was named by Smith and MacKevett (1970) after Golden Horn (peak 6365) along Skolai Creek in the McCarthy C-4 Quadrangle, WRST. Smith and MacKevett (1970) designated the type area as the exposures on the north side of Skolai Creek extending westward from the Golden Horn to Tinplate Hill (Table 3; Figures 14 and 15). Thickest exposures of the Golden Horn Limestone Lentil measure approximately 240 m (800 ft) and forms yellow- and red-stained cliffs consisting of massive, coarse bioclastic grainstones and packstones (Smith and MacKevett 1970). The lentil is unconformably overlain by the Nikolai Greenstone, Wrangell Lava, or Frederika Formation.

Nikolai Greenstone

The Middle and Late Triassic Nikolai Greenstone was first described by Rohn (1900) for a series of copper vein-bearing greenstones at least 9,800 m (3,000 ft) thick that occur along the Nizina River in the Nizina–Tanana region, southern Alaska. Glen et al. (2011) refers to the original description of Rohn (1900) as the type section of the greenstone located in the Wrangell Mountains (Table 3;

Figure 14). MacKevett and Richter (1974) and MacKevett et al. (1978) describe the Nikolai Greenstone in the Wrangell Mountains as consisting of an extensive sequence of dark greenish-gray, altered tholeiitic basalt flows ranging ~0.3–15 m (1–50 ft) thick. Stratigraphically, the greenstone unconformably overlies the Skolai Group and unconformably underlies the Chitistone Limestone or younger rocks (MacKevett et al. 1978). It is important to note that the quadripartite division of the Triassic of the Wrangell Mountains into the Nikolai Greenstone, Chitistone Limestone, Nizina Limestone and overlying McCarthy Shale provides the key diagnostic sequence to recognizing the distinctive Wrangellia terrane, one of the primary accretionary elements of the western Cordillera of western North America (Jones et al. 1977). As noted by its authors, the terrane extends in the north from the Wrangell Mountains southward to the southern end of Vancouver Island in British Columbia, with a possible southeastern extension occurring in the Hells Canyon region of northeastern Oregon and adjacent western Idaho.

Chitistone Limestone

The Late Triassic Chitistone Limestone was first named by Rohn (1900) for well developed exposures along the Nizina River in the vicinity of its confluence with the Chitistone River. The type section is designated in the Nizina River Valley opposite the mouth of the Chitistone River, where the formation consists of massive bluish-gray limestone measuring 550–610 m (1,800–2,000 ft) thick (Table 3; Figure 14; Moffit and Capps 1911; Martin 1916). Martin (1916) states that the Chitistone Limestone rests with apparent conformity above the Nikolai Greenstone and conformably underlies the Nizina Limestone at the type section.

Nizina Limestone

The Late Triassic Nizina Limestone was first proposed by Martin (1916) to describe a succession of thin-bedded limestone with minor amounts of interstratified shale along the Nizina River. The type section of the formation is designated in the cliffs on the west side of the Nizina River opposite the mouth of the Chitistone River (Table 3; Figures 14 and 16; Martin 1916). At the type section the formation measures approximately 366 m (1,200 ft) thick and overlies a 610 m (2,000 ft) thick cliff sequence of the Chitistone Limestone (Martin 1916). Stratigraphically, the Nizina Limestone conformably overlies the Chitistone Limestone and is overlain by the McCarthy Formation.

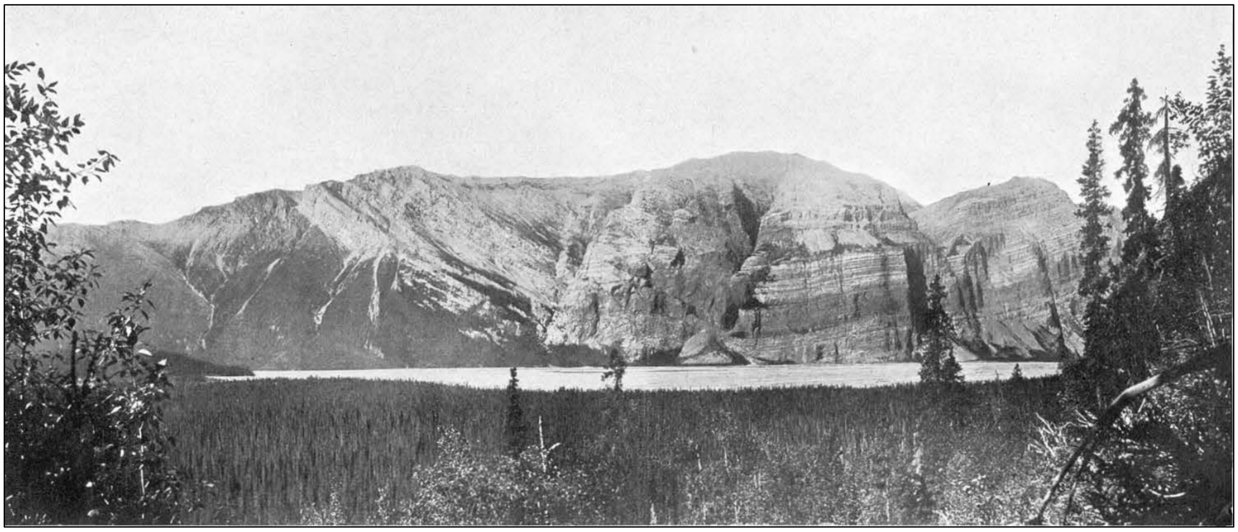


Figure 16. Type section cliff exposure of the Nizina Limestone on the west side of the Nizina River opposite the mouth of the Chitistone River. The Nizina Limestone type section measures 370 m (1,200 ft) and overlies a 610 m (2,000 ft)-thick sequence of the Chitistone Limestone. Plate V from Moffit and Capps (1911).

McCarthy Formation

The Late Triassic–Early Jurassic McCarthy Formation was first mentioned by Rohn (1900) to describe a series of shales (mudstones) and slates exposed along McCarthy Creek in the Nizina–Tanana region of southern Alaska. Moffit and Capps (1911) designated the type locality of the formation between McCarthy Creek and the Nizina River (Table 3; Figure 14). Type locality exposures measure as much as 910 m (3,000 ft) thick and consist predominantly of black, fissile shale with numerous thin limestone beds at its base (Moffit and Capps 1911). Detailed mapping by MacKevett (1963) redescribed the formation and subdivided the unit into two informal members: 1) lower shale, siltstone, and silty limestone member; and 2) an upper, predominantly silty limestone member. The McCarthy Formation unconformably underlies the Kennicott Formation and conformably overlies the Chitistone Limestone.

Nizina Mountain Formation

The Middle Jurassic Nizina Mountain Formation was named by MacKevett (1969) after its type locality exposures that partly girdle the ridge that extends southward from Nizina Mountain (Table 3; Figures 14 and 17). Type locality exposures measure approximately 410 m (1,350 ft) thick and form moderate slopes that have reddish-brown weathered surfaces (MacKevett 1969). The formation is dominantly composed of greenish-gray, fine-grained to very-fine grained graywacke with sparse shale partings and a few limy lenses and concretions (MacKevett 1969). The Nizina Mountain Formation disconformably underlies the Root Glacier Formation and disconformably overlies the Lubbe Creek Formation or McCarthy Formation.

Figure 17. Type locality exposures of the Nizina Mountain Formation (Jnm) unconformably overlain by younger Cretaceous rocks (K) east of Nizina Mountain, WRST. Relief shown is about 180 m (600 ft). Figure 7 from MacKevett (1969).

Root Glacier Formation

The Late Jurassic Root Glacier Formation was proposed by MacKevett (1969) to describe a thick sequence of clastic marine sedimentary rocks that occur on the ridges that border Root Glacier. MacKevett (1969) designated the type locality as the hillside east of the upper part of McCarthy Creek, where the formation is well exposed, less deformed, and occurs with less structural complications (Table 3; Figures 14 and 18). Type locality exposures have an estimated thickness from 396–1,219 m (1,300–4,000 ft) (MacKevett 1969). The formation mainly consists of poorly sorted, poorly bedded mudstone, siltstone, graywacke, and shale, and contains an intraformational facies of very coarse-grained sandstone and conglomerate that are more resistant than the surrounding rock (Figure 18; MacKevett 1969). Stratigraphically, the Root Glacier Formation disconformably overlies the Nizina Mountain Formation or Lubbe Creek Formation and unconformably underlies the Wrangell Lava or Quaternary surficial deposits.

Figure 18. Type locality exposures of the Root Glacier Formation (Jr) and its conglomerate facies (Jrc) along the east side of McCarthy Creek, WRST. The conglomerate forms conspicuous cliffs with a maximum thickness of about 60 m (200 ft). High terrain in the background consists of Wrangell Lava (QTw). Figure 8 from MacKevett (1969).

Berg Creek Formation

The Early Cretaceous Berg Creek Formation was named by MacKevett et al. (1978) to describe a distinctive belt of marine sedimentary rocks exposed from west of Berg Creek to about 1.8 km (1.1 mi) south of Kuskulana Pass within the McCarthy C-8 Quadrangle. MacKevett et al. (1978) designated the type section southward from the SE/4 SW/4 sec. 34, T. 3 S., R. 9. E. to the southern part of SE/4 NW/4 sec. 3, T. 4 S., R. 9 E. (Table 3; Figure 14). The type section measures approximately 250 m (820 ft) thick and consists of massive to medium-bedded, cross-bedded, near-shore marine deposits of light-gray or yellowish-brown, impure sandy limestone with greenish-gray, brown, and tan pebble conglomerate (MacKevett et al. 1978). The Berg Creek Formation unconformably overlies Triassic-age rocks or the Chitina Valley batholith, and conformably underlies the Kuskulana Pass Formation.

Kuskulana Pass Formation

The Early Cretaceous Kuskulana Pass Formation was proposed by MacKevett et al. (1978) to describe a sequence of exposures in the upper drainage basin of Trail and Slatka Creeks near Kuskulana Pass in the southeastern part of the McCarthy C-8 Quadrangle. The type section of the formation is approximately 300 m (980 ft) thick and extends from its lower contact with the Berg Creek Formation in NE/4 SE/4 SW/4 sec. 32, T. 3 S., R. 10 E. to its upper contact with the Kennicott Formation in NE/4 SW/4 NW/4 sec. 5, T. 4 S., R. 10 E. (Table 3; Figure 14; MacKevett et al. 1978). The Kuskulana Pass Formation consists of thin-bedded, dark greenish-gray or medium-gray, fine- to very-fine- grained sandstone, siltstone, and minor shale that conformably overlies the Berg Creek Formation and unconformably underlies the Kennicott Formation (MacKevett et al. 1978).

Kennicott Formation

The Early Cretaceous Kennicott Formation was first described by Rohn (1900) for exposures between Fohlin Creek and the summit of Kennicott Pass (now referred to as Fourth of July Pass) and east of Kennicott Glacier. Martin (1926) and Moffit (1938) designated the exposures at Fourth of July Pass the type locality of the formation. A redefined type locality by Jones and MacKevett (1969) is designated as the hillsides east of Fohlin Creek and north of Bear Creek in the southwestern part of the McCarthy C-6 Quadrangle (Table 3; Figure 14). Type locality exposures range in thickness from several tens of meters or feet to almost 150 m (500 ft) and consist of conglomerate, sandstone, siltstone, and shale (Jones and MacKevett 1969). Jones and MacKevett (1969) subdivided the formation into two units: 1) a lower unit composed dominantly of fine-grained sandstone with minor conglomerate that locally exhibit cross-bedding, graded bedding, and scour and fill relationships; and 2) an upper unit consisting of siltstone with minor amounts of shale, sandstone, and conglomerate. The Kennicott Formation unconformably overlies Triassic rocks of the Nikolai Greenstone, Chitistone Limestone, Nizina Limestone, and McCarthy Formation, and underlies Cretaceous rocks including the Schulze, Moonshine Creek, and Chititu Formations (Jones and MacKevett 1969).

Chisana Formation

The Early Cretaceous Chisana Formation was formally proposed by Richter and Jones (1973) for exposures near the settlement of Chisana in the Nabesna A-3 Quadrangle, Alaska. A composite type section of the formation is designated in the valley of Bonanza Creek in secs. 25, 35, and 36, T. 4 N., R. 19 E. (lower part), and in the valley of Toby Creek in secs. 28, 33, and 34, T. 4 N., R. 20 E. (upper part) in the Nabesna A-2 Quadrangle (Table 3; Figure 14; Richter and Jones 1973). Exposures at the type section measure more than 3,000 m (10,000 ft) thick and consist of marine and subaerial volcanic and volcaniclastic rocks (Richter and Jones 1973). The lower part of the formation consists of dark green to grayish-green fragmental volcanic rocks, minor dark-green porphyritic flows, thin beds of maroon volcanic sandstone and siltstone, and lenses of marine sedimentary rock composed of argillite, graywacke, conglomerate, and tuffaceous mudstone (Richter and Jones 1973). The upper part is composed of maroon and dark-green andesitic flows, volcanic conglomerate, light gray tuffs, and green to dark-green fragmental volcanic rocks interpreted to represent lahar and avalanche deposits (Berg et al. 1972; Richter and Jones 1973). The Chisana Formation conformably overlies Jurassic–Cretaceous mudstones and unconformably underlies Cretaceous sedimentary rocks.

Chititu Formation

The Late Cretaceous Chititu Formation was named by Jones and MacKevett (1969) after Chititu Creek in the southeastern part of the McCarthy B-5 Quadrangle. The type area is designated in the northwestern part of the McCarthy A-4 Quadrangle on both sides of Young Creek and the southern part of the McCarthy B-4 Quadrangle south of the latitude of Copper Creek (Table 3; Figure 14; Jones and MacKevett 1969). Two reference sections with an apparent thickness of 1,700 m (5,500 ft) extend north and south of Young Creek approximately 6.4 km (4 mi) east of the western boundary of the A-4 Quadrangle (Table 3; Figure 14; Jones and MacKevett 1969). Lithologically, the Chititu Formation predominantly consists of finely laminated mudstone with minor amounts of impure chert, fine-grained sandstone, and thin beds and lenses of impure limestone. The formation stratigraphically occurs conformably between the overlying MacColl Ridge Formation and underlying Kennicott Formation.

Schulze Formation

The Cretaceous Schulze Formation was proposed by Jones and MacKevett (1969) to describe a thin sequence of dominantly siliceous pelitic rocks exposed near the Schulze copper prospect in the McCarthy B-5 Quadrangle. The most extensive and well-developed exposures of the formation occur in the type area, designated on the upland north of Sourdough Peak east of the upper reaches of Nikolai Creek (Table 3; Figure 14; Jones and MacKevett 1969). Type area exposures range in thickness from 30–69 m (100–225 ft) and consist of gray siliceous rocks ("porcellanite"), chert, with interbedded sandstone and arenite that weather to pale yellow or yellowish-brown (Jones and MacKevett 1969). The Schulze Formation conformably underlies the Chititu Formation and unconformably overlies the Kennicott Formation.

Moonshine Creek Formation

The Cretaceous Moonshine Creek Formation was named by Jones and MacKevett (1969) after its type area exposures along Moonshine Creek in the McCarthy C-4 Quadrangle (Table 3; Figure 14). Type area exposures measure 1,070 m (3,500 ft) thick and dominantly consist of greenish-gray siltstone and sandstone of varying grain sizes that are subdivided into six informal members (Jones and MacKevett 1969). Many of the informal members contain abundant fossiliferous calcareous concretions. In the type area, the Moonshine Creek Formation unconformably overlies the Nikolai Greenstone and unconformably underlies Cenozoic rocks intercalated with older flows of the Wrangell Lava (Jones and MacKevett 1969).

MacColl Ridge Formation

The Late Cretaceous MacColl Ridge Formation was named by Jones and MacKevett (1969) after its type section exposure on MacColl Ridge approximately 5 km (3 mi) east of the western boundary of the McCarthy A-4 Quadrangle (Table 3; Figure 14). The type section measures about 760 m (2,500 ft) thick and consists of light to medium gray, coarse- to very coarse-grained sandstone that grades into conglomerate or siltstone and weather to diverse shades of brown (Jones and MacKevett 1969; MacKevett and Smith 1972). Stratigraphically, the MacColl Ridge Formation conformably overlies the Chititu Formation and unconformably underlies Quaternary surficial deposits.

Frederika Formation

The Miocene Frederika Formation was proposed by MacKevett (1970a) to describe a diverse sequence of nonmarine sedimentary rocks that gradationally overlie or are intercalated with older flows of the Wrangell Lava in the McCarthy C-4 Quadrangle. MacKevett (1970a) named the formation after the type area exposures located in the valley walls of a westward-flowing tributary of Frederika Creek southeast of the terminal end of Frederika Glacier (Table 3; Figure 14). The formation has a maximum measured thickness of about 460 m (1,500 ft) and is a heterogeneous assemblage of light-colored pebble conglomerate, coarse-grained sandstone, siltstone, fissile shale (mudstone), and minor amounts of dark, low-rank coal (MacKevett 1970a; Trop et al. 2012). The Frederika Formation unconformably overlies the Moonshine Creek Formation and gradationally underlies the Wrangell Lava.

White River Ash Bed

The Holocene White River Ash Bed was mentioned in reports by Schwatka (1885), Capps (1916a, 1916b), and Lerbekmo et al. (1968) to describe a distinctive ash bed widely distributed in east-central Alaska and the adjacent Yukon Territory of Canada. Pewe (1975) designated a type section for the ash bed on the north side of the White River near the mouth of North Fork Creek about 13 km (8 mi) downstream from the source of the river in Russell Glacier and about 50 km (31 mi) west of the Alaska–Canada border in the McCarthy D-2 Quadrangle (Table 3; Figure 14). The type section measures 0.75 m (2.5 ft) thick and consists of pumiceous glass that underlies a 2 m (7 ft) section of peat (Figure 19; Pewe 1975). The White River Ash Bed lies within and near the top of the Engineer Loess and has been radiometrically dated to 1,750 ± 110 to 1,520 ± 100 yr. B.P. (Fernald 1962; Pewe 1975).

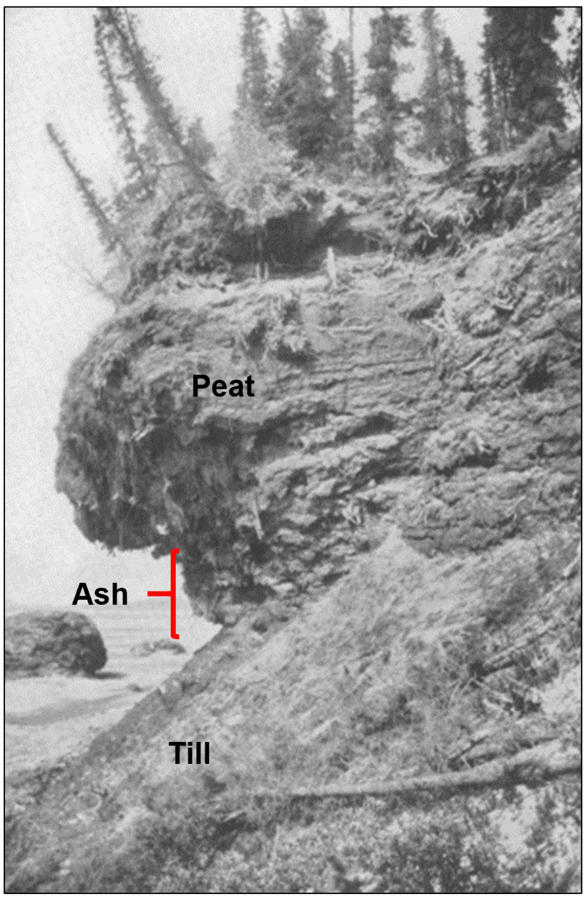


Figure 19. Type section bluff exposure of the White River Ash Bed along the north bank of the White River near the mouth of North Fork Creek, WRST. The ash bed consists of pumiceous glass 0.75 m (2.5 ft) thick that overlies Quaternary till and underlies a 2 m (7 ft) section of peat. Figure modified from Plate XV in Capps (1916b).

Yukon-Charley Rivers National Preserve (YUCH)

Yukon-Charley Rivers National Preserve (YUCH) is located approximately 175 km (110 mi) northeast of Fairbanks along the Alaska–Canada border in the Southeast Fairbanks and Yukon-Koyukuk Census Areas of the Unorganized Borough, east-central Alaska (Figure 20). Originally established as Yukon-Charley National Monument on December 1, 1978, the park unit was redesignated a national preserve on December 2, 1980. YUCH protects approximately 1,022,443 hectares (2,526,512 acres) of geologically diverse landscape, a 206 km (128 mi)-long tract of the Yukon River, and the entire Charley River basin (National Park Service 2016). The Yukon River and its tributaries have carved through rock to expose a remarkable geologic record of the region. YUCH contains a rich collection of historic and prehistoric cultural resources associated with the 1898 Alaskan gold rush, in addition to archeological relics of ancient Alaska Native tribes.

Situated in one of the most geologically active regions of North America, the geology of YUCH represents a collage of accreted terranes (land masses added to a continent through plate tectonics) that are fault-bounded and possess unique geological features. The Tintina Fault is an active strike-slip fault that is oriented northwest–southeast and divides the preserve into two distinct geologic areas (Figures 21 and 22). The geology southwest of the fault is dominantly composed of Triassic to Cenozoic-age plutonic rocks, metamorphosed sedimentary rocks of Mississippian to Late Triassic age, and late Paleozoic metamorphic rocks. Northeast of the fault, the geology is represented by a more diverse array of formations ranging in age from the Precambrian to the Pliocene. Some of the oldest units in YUCH belong to the Precambrian Tindir Group located in the northeast corner of the preserve. Any visitor to YUCH can observe the amazing geologic record exposed along the Yukon River, with a relatively intact sequence of rocks recording more than 600 million years.

YUCH contains 17 identified stratotypes that are subdivided into ten type sections, five type localities, one type area, and one reference section (Table 4; Figure 23). In addition to the designated stratotypes located within YUCH, a list of stratotypes located within 48 km (30 mi) of preserve boundaries is included here for reference. These nearby stratotypes include the Permian Step Conglomerate (type section) and the Cretaceous Keenan Quartzite (reference section).

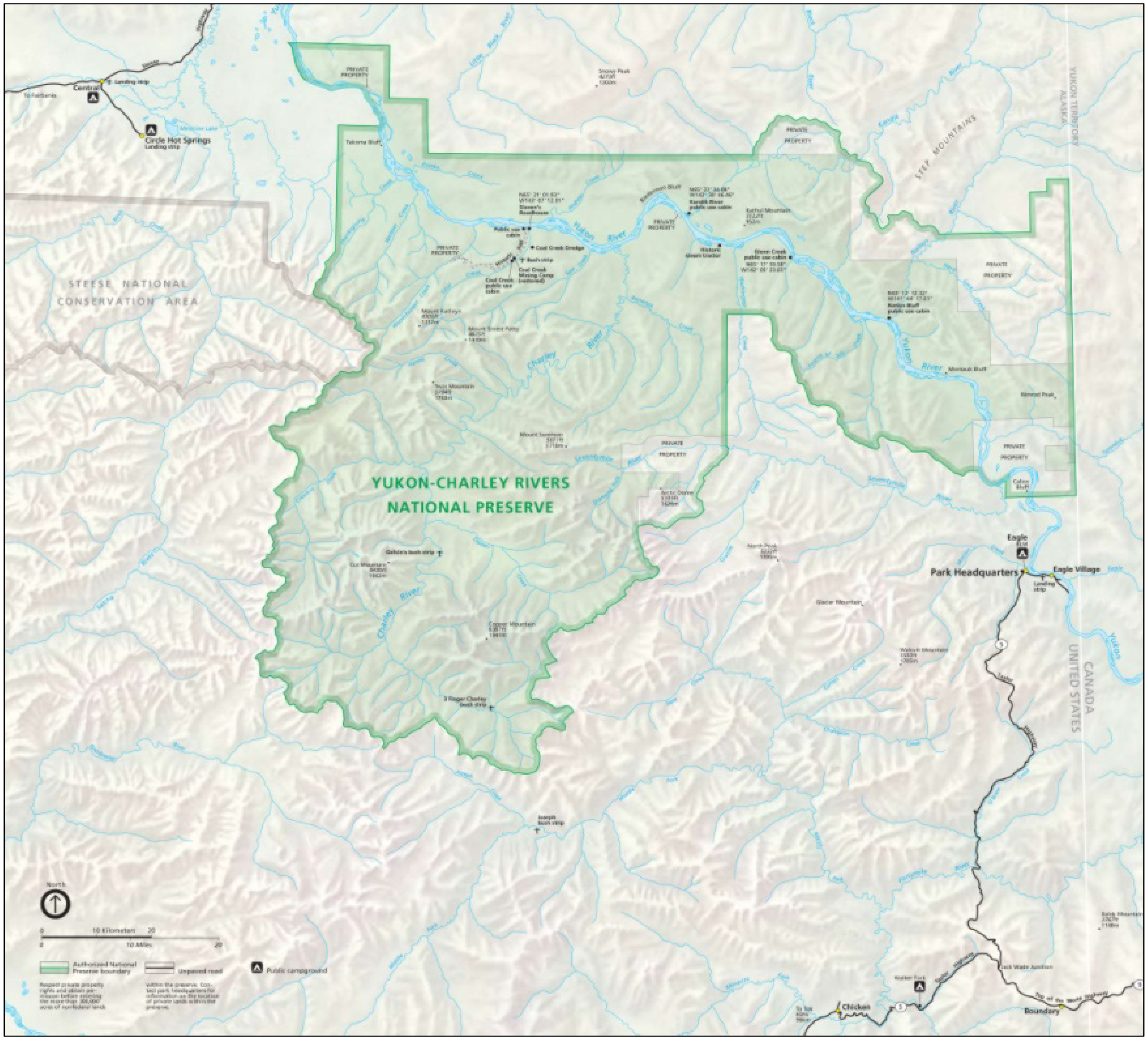


Figure 20. Park map of YUCH, Alaska (NPS).

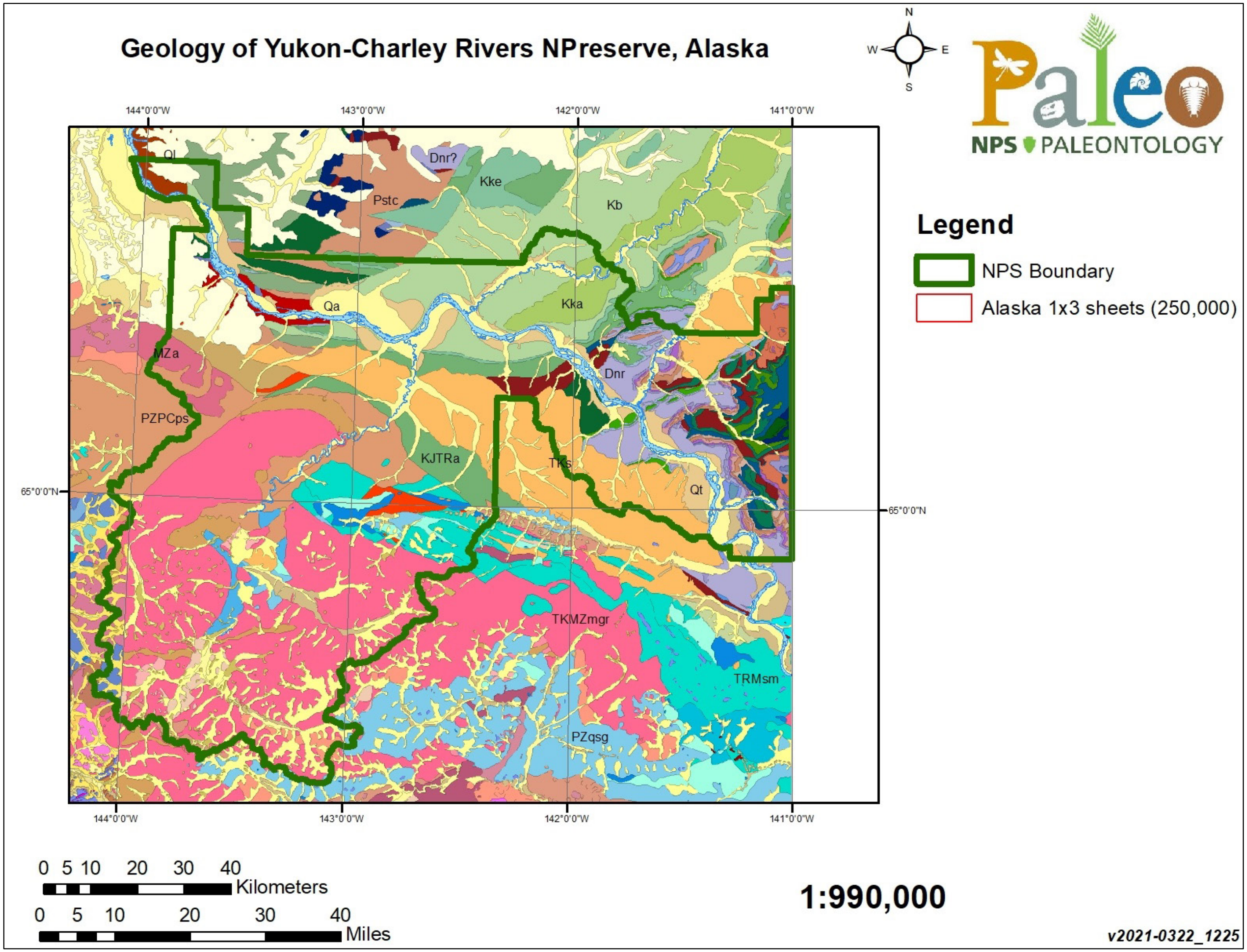


Figure 21. Geologic map of YUCH, Alaska; see Figure 22 for map units. Projection is in UTM Zone 7.

Figure 22. Geologic map legend of YUCH, Alaska.

Table 4. List of YUCH stratotype units sorted by age with associated reference publications and locations.

Unit Name (map symbol)	Reference	Stratotype Location	Age
Kandik Group	Brabb 1969	Type locality: designated as in vicinity of Kandik River and along valley of Yukon River from mouth of Glenn Creek to top of Biederman Bluff, east-central AK	Early Cretaceous
Kathul Graywacke of Kandik Group (Kka)	Brabb 1969	Type section: exposures on middle to upper south slope of Kathul Mountain, north of Yukon River, from 0.8–1.5 km (0.5–0.9 mi) southeast of benchmark 3122 (Kat), in sec. 18, T. 6 N., R. 27 E., Charley River B-3 Quadrangle, east-central AK	Early Cretaceous
Biederman Argillite of Kandik Group (Kb)	Brabb 1969	Type section: exposures in Biederman Bluff face on northwest side of Yukon River, 6.4 km (4 mi) northwest of mouth of Kandik River, in NW/4 sec. 32, T. 7 N., R. 25 E., Charley River B-4 Quadrangle, east-central AK Reference section: 0.4 km (0.25 mi) downstream from mouth of Glenn Creek to 1.6 km (1 mi) southeast of benchmark 3122 on Kathul Mountain	Early Cretaceous
Keenan Quartzite of Kandik Group (Kke)	Brabb 1969	Type section: exposures on west bank of Yukon River, 0.8 km (0.5 mi) downstream from mouth of Glenn Creek, in sec. 36, T. 6 N., R. 27 E., Charley River B-3 Quadrangle, east-central AK	Early Cretaceous
Glenn Shale (KJTRa)	Brabb 1969	Type section: along banks of Washington Creek, a tributary of Yukon River, from NW/4 sec. 24, T. 5 N., R. 26 E. to NW/4 sec.12, T. 5 N., R. 26 E., Charley River B-3 Quadrangle, east-central AK	Middle Triassic–Early Cretaceous
Tahkandit Limestone (PZl)	Mertie 1930; Brabb and Grant 1971	Type section (composite): 1) exposure along a narrow slough of the Yukon River in the northwest corner of sec. 17, T. 4 N., R. 30 E., lat. 65°10.8′ N, long. 141°41.9′ W. in the Charlie River A-2 Quadrangle; and 2) a prominent limestone cliff located several hundred meters or feet south of the Nation River mouth on the west bank of the Yukon River	early Permian
Calico Bluff Formation (PNMcb)	Brooks and Kindle 1908; Brabb 1969; Armstrong 1975	Type locality: Calico Bluff on Yukon River, about 24 km (15 mi) below Eagle, east-central AK	Middle Mississippian–Early Pennsylvanian

Table 4 (continued). List of YUCH stratotype units sorted by age with associated reference publications and locations.

Unit Name (map symbol)	Reference	Stratotype Location	Age
Ford Lake Shale (PNMDf)	Brabb 1969	Type section: east and west banks of Yukon River from 3.2 km (2 mi) east of Ford Lake to 4 km (2.5 mi) northeast of Ford Lake in Eagle D-1 Quadrangle, east-central AK	Late Devonian–Late Mississippian
Nation River Formation (Dnr)	Mertie 1930	Type locality: exposures at and below the mouth of the Nation River, on the northeast bank of the Yukon River	Late Devonian
McCann Hill Chert (Dka)	Churkin and Brabb 1965	Type section: along creek about 0.8 km (0.5 mi) east of Benchmark 4085 except for uppermost 30 m (100 ft) which is on ridge crest extending north, McCann Hill, east-central AK	Devonian
Woodchopper Volcanics (Dwv)	Mertie 1930; Churkin et al. 1982	Type locality: outcrops along both banks of Yukon River from mouth of Coal Creek, Woodchopper Creek on downstream extending on south bank just beyond mouth of Thanksgiving Creek, Eagle-Circle district, east-central AK	Devonian
Jones Ridge Formation (OCjru)	Brabb 1967	Type section: in center sec. 3, T. 3 N., R. 33 E., across Jones Ridge to western part of sec. 10, T. 3 N., R. 33 E., near Canadian border, east-central AK	Cambrian–Ordovician
Hillard Limestone (OCh)	Brabb 1967	Type section (composite): cliffs 2.6 km (1.6 mi) west of Hillard Peak (NE/4 sec. 3, T. 1 N., R. 33 E.); cliff about 2.1 km (1.3 mi) north-northeast of Hillard Peak; and section about 0.8 km (0.5 mi) east-northeast of Hillard Peak, east-central AK	Cambrian–Early Ordovician
Adams Argillite (Ca)	Brabb 1967	Type section: at east end of Limestone Hogback, in W/2 sec. 31, T. 2 N., R. 33 E., east-central AK	Early Cambrian
Funnel Creek Limestone (Cf)	Brabb 1967	Type area: in valley walls of tributaries of Tatonduk River, from 1.6 km (1 mi) southwest to 4.8 km (3 mi) south of mouth of Funnel Creek, in secs. 17, 20, 21, 27, and 28, T. 2 N., R. 33 E., Hillard Peak area, east-central AK	Early Cambrian
Tindir Group (PCt, PCtu, PCtsl, PCtb, PCtlc, PCtl)	Cairnes 1914; Mertie 1930	Type locality: along Tindir Creek and between Ettrain and Harrington Creeks along Alaska–Yukon boundary, east-central AK	Mesoproterozoic–Cambrian

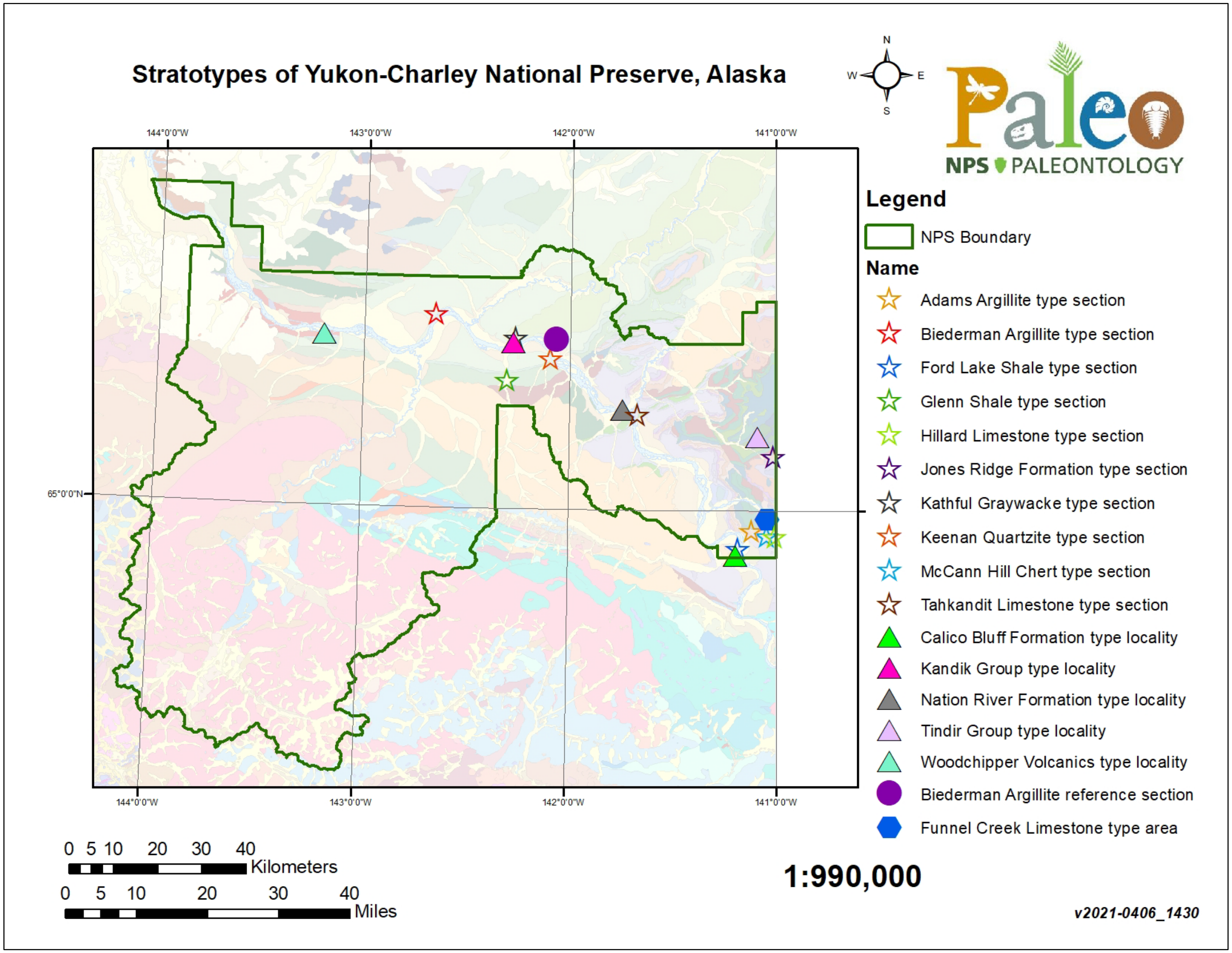


Figure 23. Modified geologic map of YUCH showing stratotype locations. The transparency of the geologic units layer has been increased. Projection is in UTM Zone 7.

Tindir Group

The Mesoproterozoic–Cambrian Tindir Group was originally named by Cairnes (1914) for exposures along Tindir Creek and between Ettrain and Harrington Creeks near the Alaska–Yukon border that Mertie (1930) later designated the type locality (Table 4; Figure 23). Type locality exposures have a minimum thickness of 1,500 m (5,000 ft) and consist of a heterogeneous assemblage of quartzite, dolostone, limestone, slate, shale, sandstone, and greenstone that have been considerably folded and faulted (Cairnes 1914). The Tindir Group underlies Cambrian-age limestones in several localities, but with more certainty at exposures at Jones Ridge (Mertie 1930).

Funnel Creek Limestone

The Early Cambrian Funnel Creek Limestone was proposed by Brabb (1967) to describe a massive sequence of carbonate exposures in the vicinity of the Alaska–Yukon border between Funnel Creek and Hillard Peak and between Tatonduk River, Hard Luck Creek, and Montauk Bluff. Brabb (1967) designated the type area of the limestone in the valley walls of three unnamed tributaries of the Tatonduk River from 1.6 km (1 mi) southwest to 4.8 km (3 mi) due south of the mouth of Funnel Creek, in secs. 17, 20, 21, 27, and 28, T. 2 N., R. 33 E. (Table 4; Figure 23). Type area exposures form craggy cliffs and scenic gorges with a measured thickness of more than 396 m (1,300 ft) (Figure 24; Brabb 1967). The Funnel Creek Limestone predominantly consists of light-gray limestone and dolostone, with few interbeds of dark-gray chert. It stratigraphically underlies the Adams Argillite and overlies the Tindir Group (Brabb 1967).

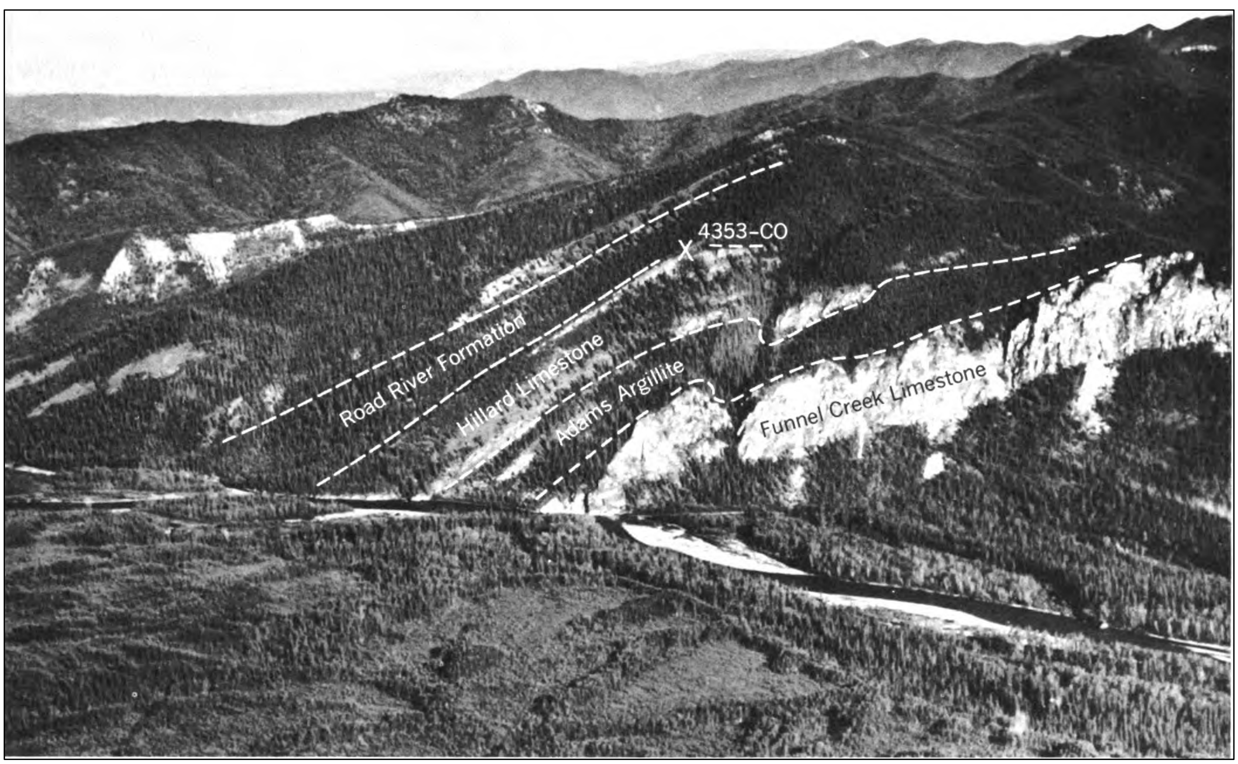


Figure 24. Northwest view of Paleozoic rock exposures along the Tatonduk River showing a prominent cliff of the Funnel Creek Limestone in its type area. Number indicates a fossil collection locality of Brabb (1967). Figure 4 from Brabb (1967).

Adams Argillite

The Early Cambrian Adams Argillite was named by Brabb (1967) after exposures in the vicinity of Adams Peak in east-central Alaska. The type section of the formation is located at the east end of Limestone Hogback in the W/2 sec. 31, T. 2 N., R. 33 E. and measures approximately 91 m (300 ft) (Table 4; Figures 23 and 25; Brabb 1967). Lithologically, the formation consists of massive, light brown quartzite interbedded with siltstone or grayish-green chloritic shale, and gray, green, and red argillite and shale (Brabb 1967). The Adams Argillite stratigraphically occurs between the overlying Hillard Limestone and underlying Funnel Creek Limestone.

Figure 25. Northeast view of Limestone Hogback along the Yukon River consisting of Cambrian-age strata of the Funnel Creek Limestone, Adams Argillite, and Hillard Limestone (NPS/JOSH SPICE). The type section of the Adams Argillite is located at the eastern end of the hogback.

Hillard Limestone

The Cambrian–Early Ordovician Hillard Limestone was proposed by Brabb (1967) for exposures in the vicinity of Hillard Peak between McCann Hill and the Yukon River. A composite type section for the formation is described from three separate locations: 1) in cliffs about 2.6 km (1.6 mi) east of Hillard Peak in the NE/4 sec. 3, T. 1 N., R. 33 E.; 2) in cliffs about 2.1 km (1.3 mi) north-northeast of Hillard Peak; and 3) about 0.8 km (0.5 mi) east-northeast of Hillard Peak (Table 4; Figures 23 and 26; Brabb 1967). Type section exposures have a maximum thickness of 150 m (500 ft) and consist of fine-grained, pale-yellowish-brown limestone, limestone edgewise conglomerate, and subordinate chert that are highly resistant to erosion (Brabb 1967). The Hillard Limestone overlies the Adams Argillite and unconformably underlies the Road River Formation.

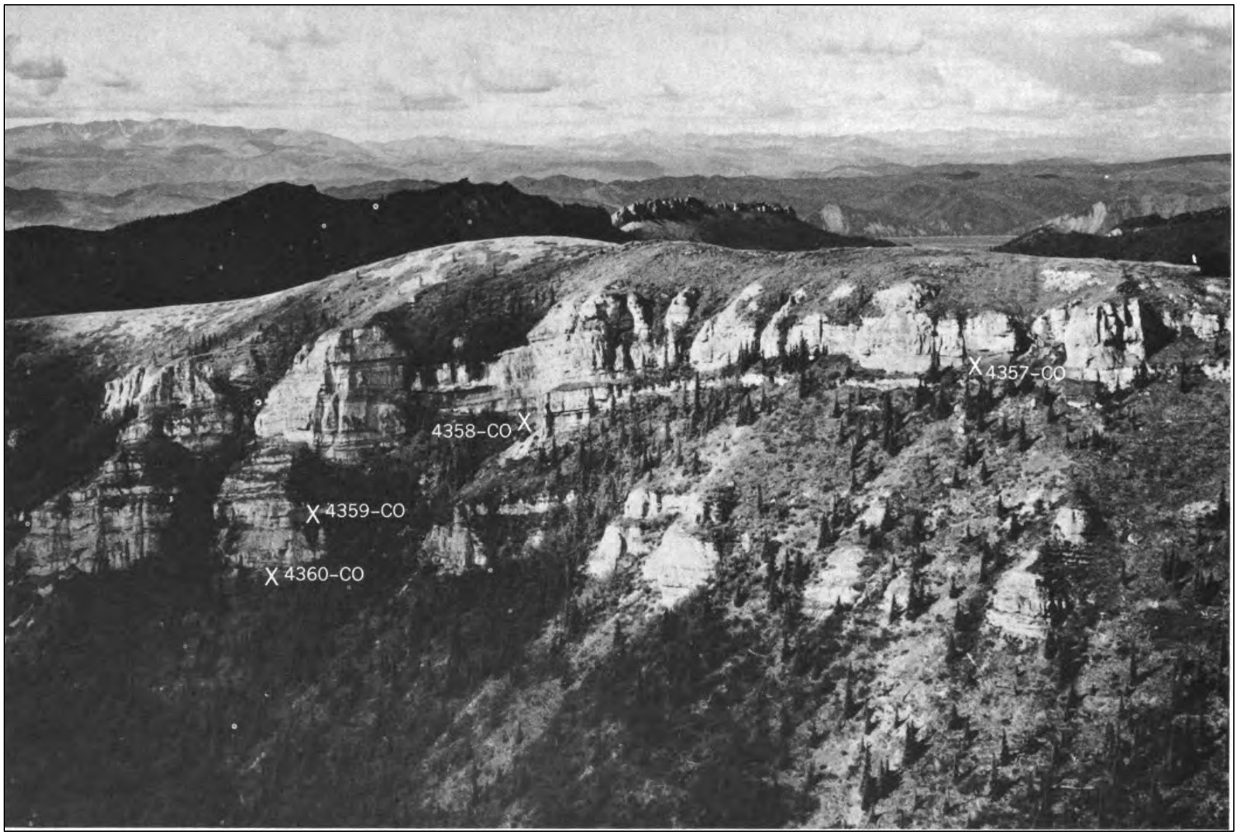


Figure 26. Upper part of the Hillard Limestone type section on cliffs 2.1 km (1.3 mi) north-northeast of Hillard Peak. The type section has a maximum thickness of 152 m (500 ft). The ridge in the middle background is Limestone Hogback. Numbers indicate fossil collection localities of Brabb (1967). Figure 6 from Brabb (1967).

Jones Ridge Formation

The Cambrian–Ordovician Jones Ridge Formation was named by Brabb (1967) after the type section exposure at Jones Ridge, in the central part of sec. 3, T. 3 N., R. 33 E. and extending across the ridge crest to the northwestern part of section 10 (Table 4; Figure 23). At the type section, the formation measures ~910 m (3,000 ft) thick and forms spectacular cliffs and jagged peaks (Brabb 1967). The formation is informally subdivided into a lower member consisting of massive, fine-grained, gray limestone and dolostone with an upper member composed of medium- to coarse-grained, pale-yellowish-brown bioclastic limestone (Brabb 1967). Stratigraphically, the Jones Ridge Formation overlies the Tindir Group and underlies a series of unnamed Ordovician-age chert, shale, and limestone.

Woodchopper Volcanics

The Devonian Woodchopper Volcanics was proposed by Mertie (1930) for exposures in the type locality along both banks of the Yukon River from the mouths of Woodchopper and Coal Creeks downstream for 24 km (15 mi), extending on the south bank just beyond the mouth of Thanksgiving Creek (Table 4; Figures 23 and 27). Type locality exposures have a maximum measured thickness of 2,350 m (7,700 ft) and consist of a complexly folded assemblage of basaltic greenstone, volcanic sandstone, tuff, interbedded massive limestone, and minor amounts of slate, shale, and chert (Mertie 1930; Churkin et al. 1982). The unit is well known for its spectacular pillow basalts, formed when lava extruded under water, which are well exposed along the north bank of the Yukon River at the type section. In addition to Mertie (1930), detailed geologic maps showing the aerial distribution of the formation can be found in Brabb and Churkin (1969) and Dover and Miyaoka (1988). Fossils found within the sedimentary rocks of the unit include corals (Oliver et al. 1975; Lane and Ormiston 1976), graptolites (Churkin et al. 1982), brachiopods (Rohr et al. 2008), and other megafossil groups. The vast bulk of the fossils reported to date indicate an Emsian (Late Devonian) age. However, summation of fossil evidence indicates the unit to be of Early, Middle(?), and Late(?) Devonian age (Churkin et al. 1982). Stratigraphic relationships for the Woodchopper Volcanics are enigmatic due to the formation's complex style of folding and faulting (Mertie 1930).

Figure 27. Type locality exposures of the Woodchopper Volcanics at McGregor Bluff along the southern bank of the Yukon River (NPS/JOSH SPICE).

McCann Hill Chert

The Devonian McCann Hill Chert was named by Churkin and Brabb (1965) for exposures that occur near McCann Hill along the Alaska–Yukon border. Churkin and Brabb (1965) designated the type section along the creek about 0.8 km (0.5 mi) east of Benchmark 4085 except for the uppermost 30 m (100 ft) which is exposed on the ridge crest extending north from the benchmark (Table 4; Figure 23). Exposures near the type section range in thickness from 60–240 m (200–800 ft) and consist of thin-bedded, laminated, light gray to black chert and siliceous shale with minor interbeds of siltstone (Churkin and Brabb 1965). The McCann Hill Chert unconformably overlies the Road River Formation and conformably underlies the Nation River Formation.

Nation River Formation

The Late Devonian Nation River Formation was first proposed by Brooks and Kindle (1908) to describe exposures along the Nation River in east-central Alaska. The type locality of the formation was designated by Mertie (1930) at and below the mouth of the Nation River, on the northeast bank of the Yukon River (Table 4; Figure 23). Type locality exposures measure about 1,100 m (3,700 ft) thick and consist of gray clay shale interbedded with conglomerate containing pebbles of gray, red, and green chert (Brooks and Kindle 1908; Mertie 1930). The Nation River Formation stratigraphically occurs above the McCann Hill Chert and underlies and the Ford Lake Shale (Brabb and Churkin 1969).

Ford Lake Shale

The Late Devonian to Late Mississippian Ford Lake Shale was named by Brabb (1969) after its type section exposures along the east and west banks of the Yukon River from 3.2 km (2 mi) northeast of Ford Lake in the Eagle D-1 Quadrangle, east-central Alaska (Table 4; Figure 23). The type section measures about 300 m (1,000 ft) thick along the west bank of the Yukon River near Calico Bluff, but the true thickness is complicated by several folds (Figure 28; Brabb 1969). Lithologically, the Ford Lake Shale consists of grayish-black siliceous shale and laminated grayish-black chert that stratigraphically occur between the underlying Nation River Formation and overlying Calico Bluff Formation (Brabb 1969).

Figure 28. Type section cliff exposure of the Ford Lake Shale located along the west bank of the Yukon River about 3.2 km (2 mi) northeast of Ford Lake. Cliff face is approximately 30 m (100 ft) tall and consists of laminated shale beds that are intensely folded. Figure 4 from Brabb (1969).

Calico Bluff Formation

The Middle Mississippian–Early Pennsylvanian Calico Bluff Formation was first mentioned by Brooks and Kindle (1908) to describe a heterogeneous sequence of rocks at Calico Bluff and along the Yukon River in east-central Alaska. Armstrong (1975) would later designate Calico Bluff the type locality of the formation (Table 4; Figure 23). At Calico Bluff, the formation measures approximately 460 m (1,500 ft) and predominantly consists of argillaceous brown-black shale and argillaceous lime mudstone to packstone (Figures 29–31; Armstrong 1975). The formation conformably overlies the Ford Lake Shale and unconformably underlies the Tahkandit Limestone (Brabb 1969).

Figure 29. Rhythmically layered limestone and shale (mudstone) at Calico Bluff, type locality of the Calico Bluff Formation (NPS/JOSH SPICE).

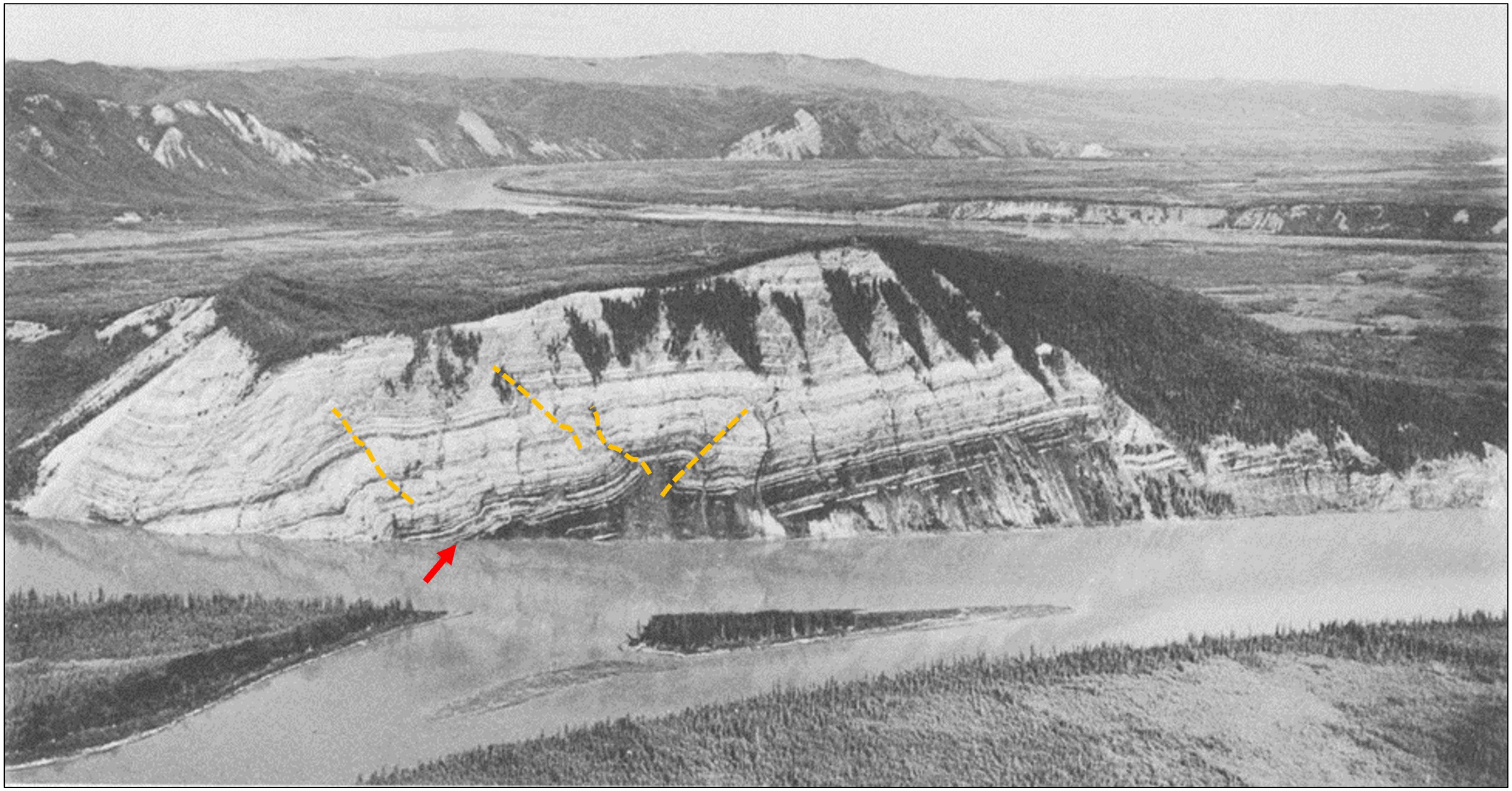


Figure 30. Type locality cliff exposures of the Calico Bluff Formation at Calico Bluff, where interlayers of shale (mudstone) and limestone are folded and faulted (orange dashed lines show fault offsets). Red arrow points to the basal contact with the underlying Ford Lake Shale. Figure modified from Figure 2 in Brabb (1969).

Figure 31. A canoe and paddlers against the backdrop of Calico Bluff (NPS/STEPHEN LIAS).

Tahkandit Limestone

The early Permian Tahkandit Limestone was first named by Spurr (1898) after the Nation River (the Alaska Native name for which is the Tahkandit) to describe a series of exposures along the upper reaches of the Yukon River in east-central Alaska. The type section of the limestone was designated by Mertie (1930) and revised by Brabb and Grant (1971) to include two sections: 1) an inconspicuous exposure along a narrow slough of the Yukon River in the northwest corner of sec. 17, T. 4 N., R. 30 E., lat. 65°10.8′ N., long. 141°41.9′ W. in the Charlie River A-2 Quadrangle; and 2) a prominent limestone cliff located several hundred meters or feet south of the Nation River mouth on the western bank of the Yukon River (Table 4; Figures 23, 32, and 33). Exposures at the type section measure about 105 m (345 ft) thick and are subdivided into a lower unit composed of glauconitic, fossiliferous sandstone and chert-pebble conglomerate, and an upper unit composed of massive, pale-orange bioclastic limestone (Figure 32; Brabb and Grant 1971). The Tahkandit Limestone unconformably overlies the Nation River Formation and underlies the Glenn Shale with uncertain relation (Brabb and Grant 1971).

Figure 32. Type section exposure of the Tahkandit Limestone along the west bank of the Yukon River, YUCH (NPS/JOSH SPICE). Cliff section is about 105 m (345 ft) thick and predominantly consists of lenticular, massive limestone.

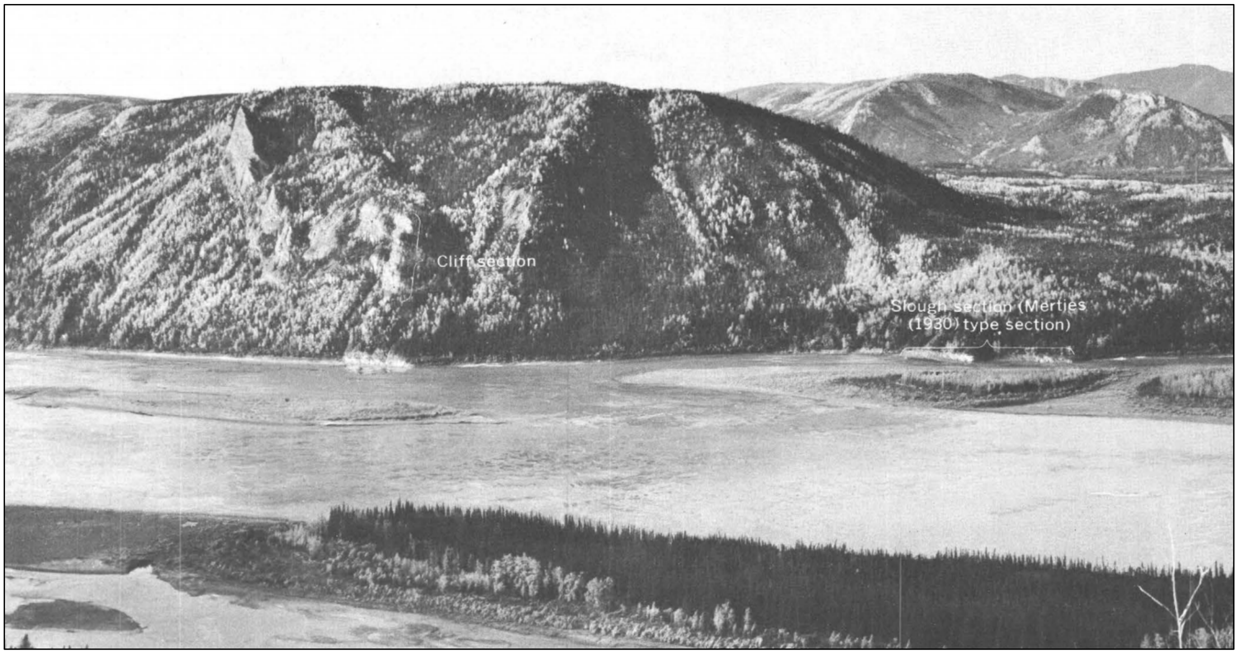


Figure 33. Southwest view of the composite type section locations of the Tahkandit Limestone. Cliff section of Brabb and Grant (1971) located to the left of the figure. Slough section of Mertie (1930) located to the right of the figure. Figure 2 from Brabb and Grant (1971).

Glenn Shale

The Middle Triassic to Early Cretaceous Glenn Shale was named by Brabb (1969) to describe extensive shale exposures along Glenn Creek to the headwaters of the Black River near the Alaska–Yukon border. Brabb (1969) described the type section of the formation as extending from its basal fault contact in the NW/4 sec. 24, T. 5 N., R. 26 E. to its upper contact with the Keenan Quartzite in NW/4 sec. 12, T. 5 N., R. 26 E., in the Charley River B-3 Quadrangle (Table 4; Figure 23). The type section has an estimated thickness of 1,524 m (5,000 ft) and consists of grayish-black, fissile, carbonaceous shale, grayish-black, massive argillite and siltstone, with a conspicuous dark-gray basal limestone (Brabb 1969). Stratigraphically, the Glenn Shale unconformably overlies the Tahkandit Limestone or Step Conglomerate and conformably underlies the Keenan Quartzite (Brabb 1969).

Kandik Group

The Early Cretaceous Kandik Group was originally referred to as the Kandik Formation by Mertie (1930) and Brabb (1961) before Brabb (1969) raised the unit to group status and subdivided the interval into the Keenan Quartzite, Biederman Argillite, and Kathul Graywacke. The type locality of the Kandik Group is in the vicinity of the Kandik River and along the valley of the Yukon River from the mouth of Glenn Creek to the top of Biederman Bluff (Table 4; Figure 23; Brabb 1969). The group stratigraphically overlies the Glenn Shale and unconformably underlies an unnamed sequence of nonmarine sandstone, mudstone, and conglomerate of Late Cretaceous–Cenozoic-age (Brabb 1969).

Keenan Quartzite

The Early Cretaceous Keenan Quartzite was named by Brabb (1969) after Keenan Creek, a tributary of Glenn Creek in the Charley River B-3 Quadrangle, east-central Alaska. Brabb (1969) designated the type section of the quartzite along the west bank of the Yukon River 0.8 km (0.5 mi) downstream from the mouth of Glenn Creek (Table 4; Figure 23). The type section consists of about 46 m (150 ft) of light- to dark-gray, fine-grained, massive quartzite that underlies the tightly folded strata of the Biederman Argillite and overlies the Glenn Shale (Brabb 1969; Johnsson 2000).

Biederman Argillite

The Early Cretaceous Biederman Argillite was named by Brabb (1969) after its excellent type section exposure at Biederman Bluff on the northwest bank of the Yukon River in the Charley River B-4 Quadrangle, Alaska (Table 4; Figure 23). The type section extends from the banks of the river to the top of the bluff in the NW/4 sec. 32 T. 7 N., R. 25 E. and consists of about 300 m (1,000 ft) of thin-bedded, dark-gray or grayish-black argillite with rhythmic interbeds of siltstone, sandstone, and quartzite (Figures 34 and 35; Brabb 1969). A supplemental reference section is located 0.4 km (0.25 mi) downstream from the mouth of Glenn Creek to 1.6 km (1.0 mi) southeast of benchmark 3122 on Kathul Mountain (Brabb 1969). The Biederman Argillite stratigraphically occurs between the overlying Kathul Graywacke and underlying Keenan Quartzite.

Figure 34. Type section exposure of Biederman Argillite at Biederman Bluff along the northwest bank of the Yukon River, approximately 6.4 km (4 mi) downriver from the mouth of the Kandik River, YUCH (NPS/JOSH SPICE). Bluff exposures are about 300 m (1,000 ft) thick.

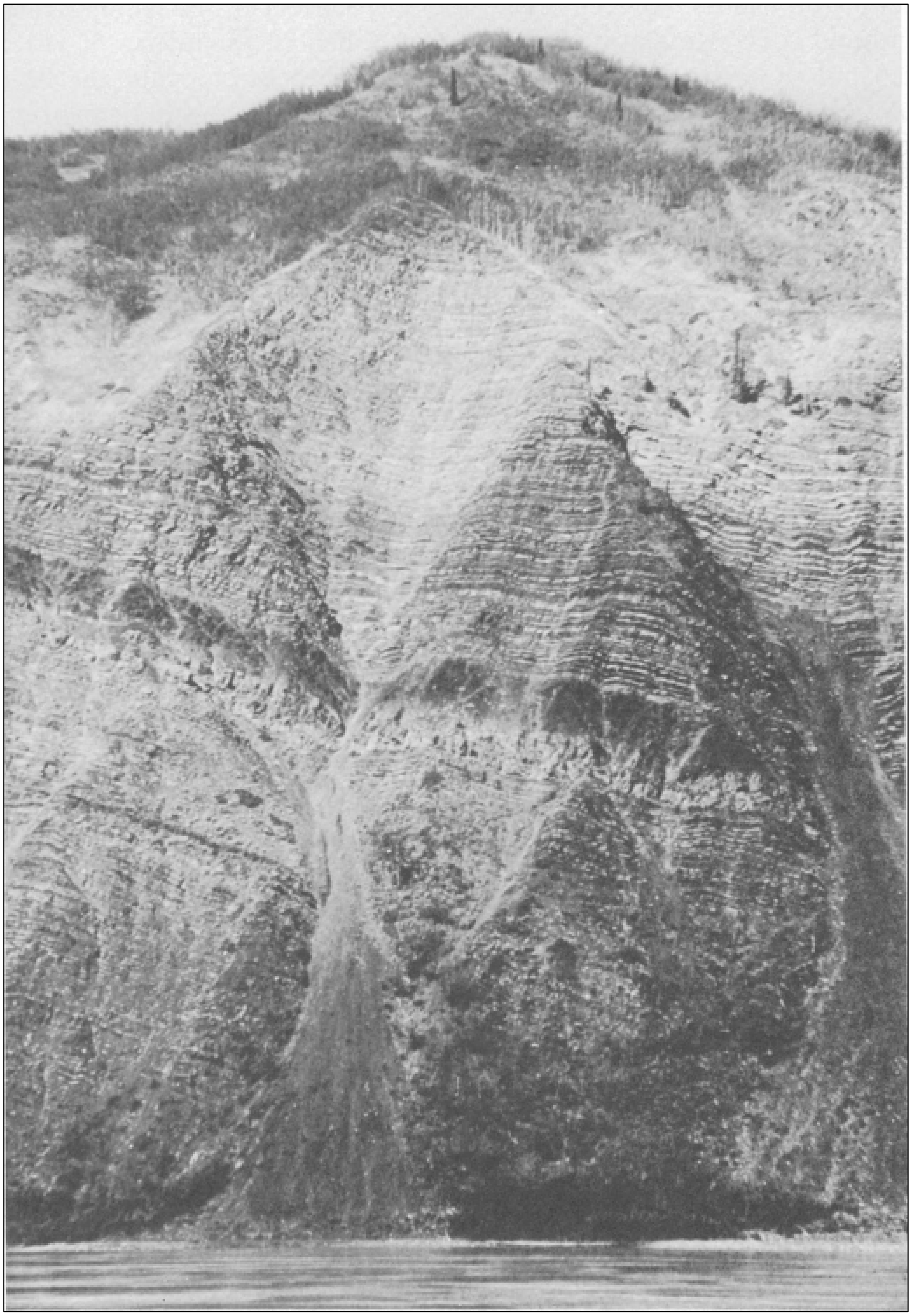


Figure 35. Type section exposure of the Biederman Argillite at Biederman Bluff. The cliff exposure rises about 300 m (1,000 ft) above the river and consists of argillite with rhythmically interbedded siltstone and sandstone. Figure 7 from Brabb (1969).

Kathul Graywacke

The Early Cretaceous Kathul Graywacke is the uppermost formation of the Kandik Group proposed by Brabb (1969). The formation is named after its type section exposure that extends from the middle to upper south slopes of Kathul Mountain, north of the Yukon River in the Charley B-3 Quadrangle, Alaska (Table 4; Figures 23, 36, and 37; Brabb 1969). At the type section the Kathul Graywacke consists of about 460 m (1,500 ft) of massive to thin-bedded, greenish-gray pebble-conglomerate and sandstone that grade upward into thin beds of dark gray or grayish-black siltstone and argillite (Brabb 1969). The Kathul Graywacke unconformably overlies the Biederman Argillite and unconformably underlies an unnamed sequence of nonmarine sandstone, mudstone, and conglomerate of Late Cretaceous–Cenozoic age (Brabb 1969).

Figure 36. Kathul Mountain located north of the Yukon River, YUCH (NPS/JOSH SPICE). The middle to upper slopes of the mountain consist of pebble-conglomerate, sandstone, siltstone, and argillite of the Kathul Graywacke type section.

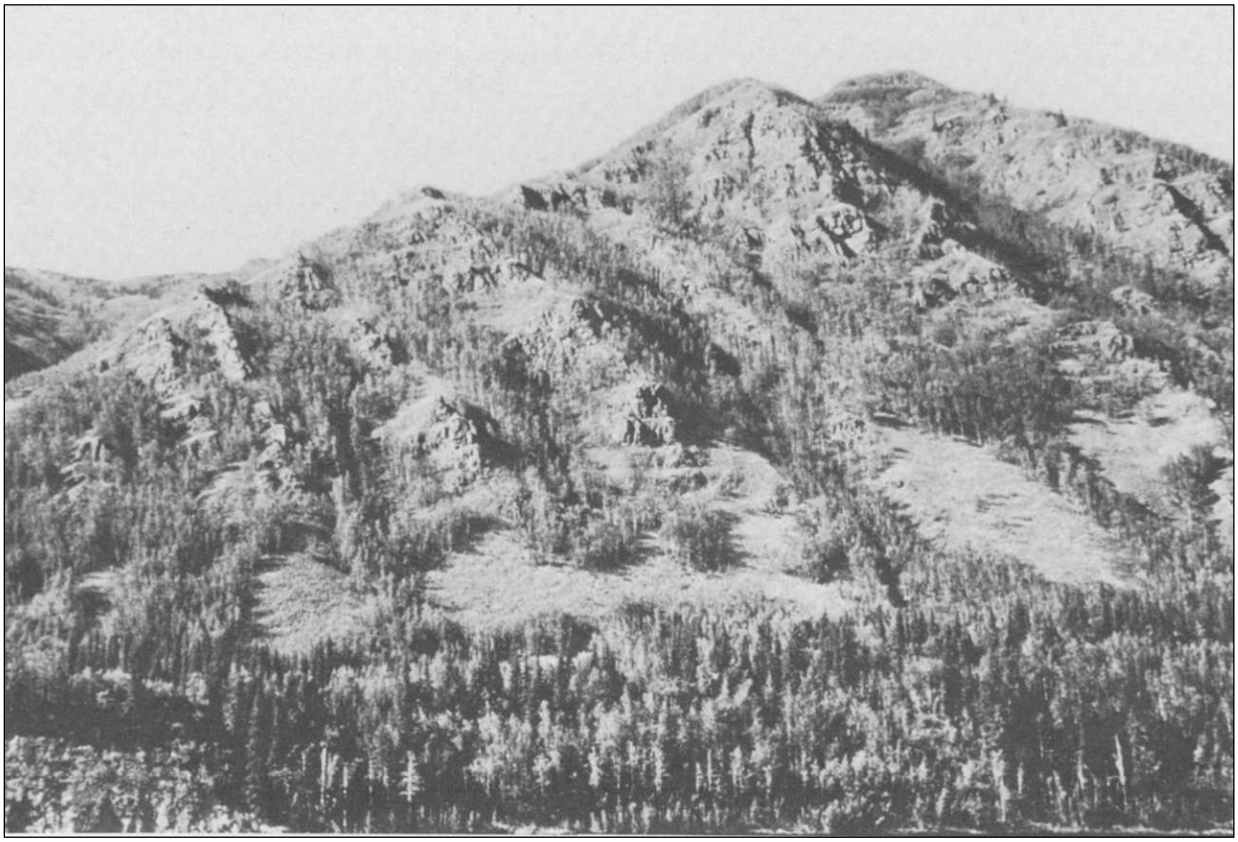


Figure 37. Type section of the Kathul Graywacke on Kathul Mountain. Blocky outcrops located between the middle grassy slopes and the peak of the mountain consist of conglomerates and sandstone of the Kathul Graywacke. Type section exposures measure about 460 m (1,500 ft) thick. Figure 9 from Brabb (1969).

Recommendations

1) The NPS Geologic Resources Division should work with park and network staff to increase their awareness and understanding about the scientific, historic and geologic heritage significance of geologic stratotypes (type sections/localities/areas, reference sections, lithodemes). *Stratotypes represent unique geologic exposures and should be considered extremely important to protect for the advancement of the scientific community for future generations*.
2) Once the CAKN Geologic Type Section Inventory report is finalized, the NPS Geologic Resources Division should schedule a briefing for the staff of the CAKN and respective network parks.
3) The Miocene–Holocene Wrangell Lava was originally described by Mendenhall (1905) for a series of lava flows that form the entire western part of the Wrangell Mountains. Several maps of WRST show the unit is widely distributed throughout the park (MacKevett 1970a, 1970b, 1972; Richter 1976; MacKevett et al. 1978; Winkler and MacKevett 1981; Richter et al. 2006). However, no formal stratotype for the Wrangell Lava has been designated. Therefore, we recommend a formal type section be designated in order to A) provide a standard reference for scientific research; B) educate park staff and visitors about the geoheritage significance of the unit; and C) help safeguard the exposure.
4) The Jurassic Kotsina Conglomerate was named by Rohn (1900) for exposures that occur along Kotsina River, a tributary to the Chitina River in WRST. However, no formal stratotype for the Kotsina Conglomerate has been designated. Therefore, we recommend a formal type section be designated in order to A) provide a standard reference for scientific research; B) educate park staff and visitors about the geoheritage significance of the unit; and C) help safeguard the exposure.
5) The Triassic Kuskulana Formation (not to be confused with the younger Kuskulana Pass Formation) was named by Rohn (1900) for exposures along the valley of the Kuskulana River in WRST. However, no formal stratotype for the Kuskulana Formation has been designated. Therefore, we recommend a formal type section be designated in order to A) provide a standard reference for scientific research; B) educate park staff and visitors about the geoheritage significance of the unit; and C) help safeguard the exposure.
6) The Jurassic–Cretaceous Yakutat Group was first mentioned by Russell (1891) as the "Yakutat system" for exposures about Yakutat Bay and westward along the foot of St. Elias Mountain to Icy Bay, Alaska. However, no formal stratotype for the Yakutat Group has been designated in this structurally complex sequence with mélange facies. Therefore, we recommend a formal type section be designated in order to A) provide a standard reference for scientific research; B) educate park staff and visitors about the geoheritage significance of the unit; and C) help safeguard the exposure.
7) The NPS Geologic Resources Division should work with park and network staff to ensure they are aware of the location of stratotypes in park areas. This information would be important to ensure that proposed park activities or development would not adversely impact

the stability and condition of these geologic exposures. Preservation of stratotypes should not limit availability for future scientific research but help safeguard these exposures from infrastructural development.

8) 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.
9) From the assessment in (8), 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.
10) 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.
11) The NPS Geologic Resources Division should ensure the park-specific Geologic Type Section Inventory Reports are widely distributed and available online.
12) 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.
13) The NPS Geologic Resources Division should work with park and network staff to obtain good photographs of each geologic type section within the parks. In some cases, where there may be active geologic processes (rock falls, landslides, coastal erosion, etc.), the use of photogrammetry may be considered for monitoring of geologic type sections. GPS locations should also be recorded and kept in a database when the photographs are taken.
14) The NPS Geologic Resources Division should work with park and network staff to consider the collection and curation of geologic samples 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.
15) 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.
16) 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 CAKN Parks

DENA

- GMAP 4837: Clautice, K. H., R. J. Newberry, R. B. Blodgett, T. K. Bundtzen, B. G. Gage, E. E. Harris, S. A. Liss, M. L. Miller, R. R. Reifenstuhl, A. H. Clough, and D. S. Pinney. 2001. Bedrock geologic map of the Chulitna region, southcentral Alaska. Alaska Division of Geological and Geophysical Surveys, Fairbanks, Alaska. Report of Investigations 2001-1A. Scale 1:63,360. Available at: https://dggs.alaska.gov/pubs/id/2768 (accessed January 20, 2022).
- GMAP 4852: Pinney, D. S. 2001. Surficial geologic map of the Chulitna region, southcentral Alaska. Alaska Division of Geological and Geophysical Surveys, Fairbanks, Alaska. Report of Investigations 2001-1C. Scale 1:63,360. Available at: https://dggs.alaska.gov/pubs/id/3313 (accessed January 20, 2022).
- GMAP 4853: Pinney, D. S. 2001. Engineering geologic map of the Chulitna region, southcentral Alaska. Alaska Division of Geological and Geophysical Surveys, Fairbanks, Alaska. Report of Investigations 2001-1D. Scale 1:63,360. Available at: https://dggs.alaska.gov/pubs/id/3314 (accessed January 20, 2022).
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Appendix B: Geologic Time Scale

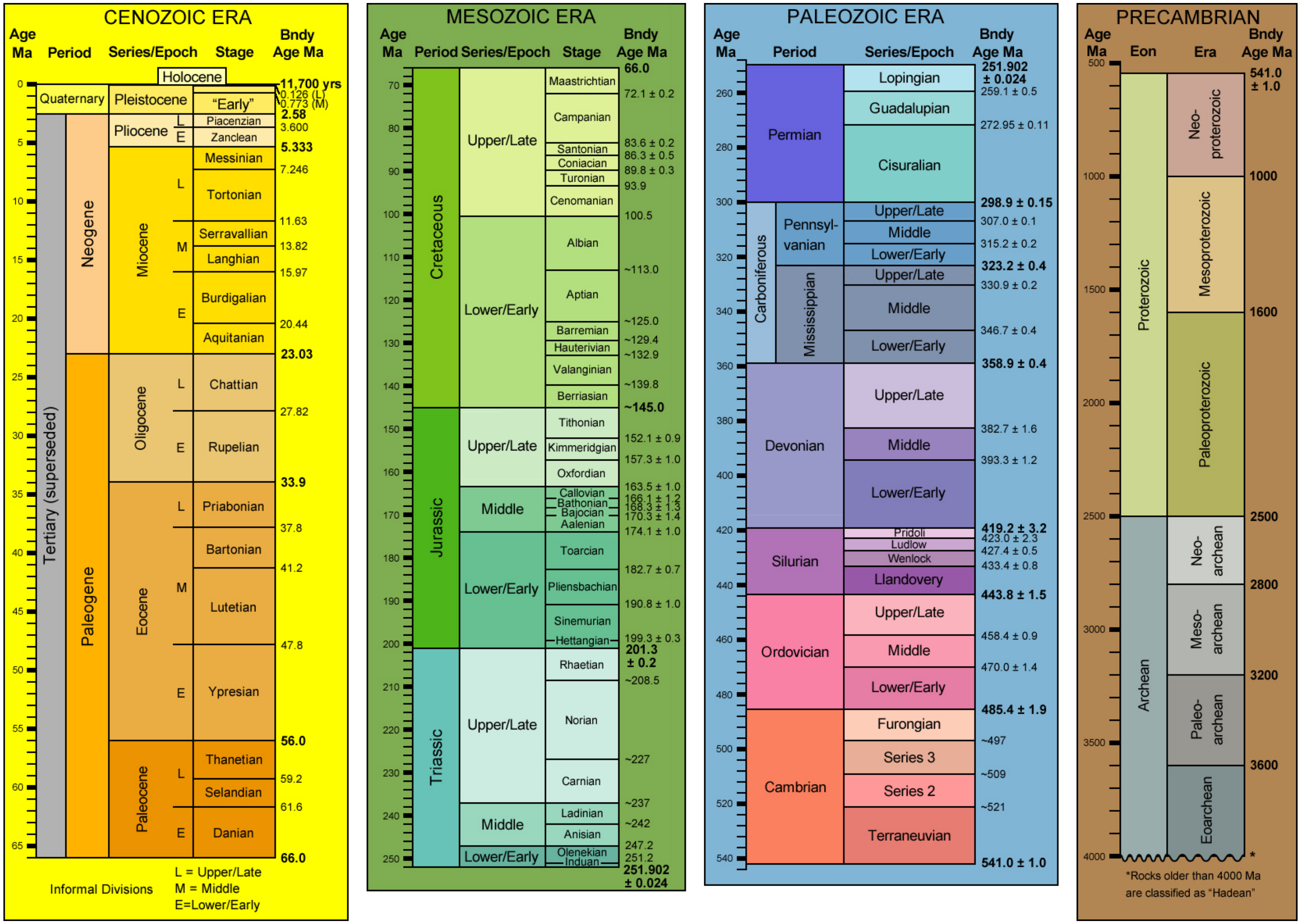

Figure B1. Geologic Time Scale. **Ma**=Millions of years old. **Bndy Age**=Boundary Age. Layout after 1999 Geological Society of America Time Scale (https://www.geosociety.org/documents/gsa/timescale/timescl-1999.pdf). Dates after Gradstein et al. (2020).

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