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Wrangell-Saint Elias National Park and Preserve

Wrangell-Saint Elias National Park and Preserve (WRST) was originally proclaimed as a national monument on December 1, 1978. Two years later, on December 2, 1980, the monument was established as a national park and preserve, and a large portion of this expansive park was designated as wilderness. Wrangell-Saint Elias National Park and Preserve represents the largest area of the National Park System and encompasses 5,332,106 ha (13,175,901 acres), larger than nine states and more than twice the land area of Maryland. The park represents 3,368,263 ha (8,323,148 acres) and the preserve represents 1,963,842 ha (4,852,753 acres). Three mountain ranges, the Chugach, Saint Elias, and Wrangell, converge within the park to form what is commonly referred to as the "mountain kingdom of North America." The park includes the continent's largest assemblage of glaciers and the greatest collection of peaks above 4,570 m (15,000 ft) in elevation. Mount Saint Elias is the second highest peak in the United States standing at 5,488.8 m (18,008 ft) above sea level. Wrangell-Saint Elias National Park and Preserve was also designated a World Heritage Site on October 24, 1979.

WRST is surrounded by other federal and provincial areas both in Alaska and Canada. To the south the park is Glacier Bay National Park and Preserve (see the Southeast Alaska Network Paleontological Resource Inventory Report; Santucci and Kenworthy 2008). The Cordova District of the Chugach National Forest and the Yakutat District of the Tongass National Forest are contiguous with WRST. The Tetlin National Wildlife Refuge in Alaska, Alsek-Tatshenshini Provincial Park in British Columbia, and Kluane National Park and Game Sanctuary in the Yukon Territory are all adjacent lands to the park.

Geological Background

The geology of Wrangell-Saint Elias National Park and Preserve has been the focus of intensive research and exploration for more than a century. Although the park is expansive and quite remote, the rich mineral deposits have drawn great interest to this otherwise inaccessible wilderness. Previous geologic work and mapping has been documented in the following publications for the Wrangell Mountains and Alaska Range portion of WRST: O. Rohn (Rohn 1900), W.C. Mendenhall (Mendenhall and Schrader 1903), F.H. Moffit (Moffit 1914, 1915, 1918, 1930, 1938; Moffit and Capps 1911; Moffit and Knopf 1910; Moffit and Maddren 1909; Moffit and Mertie 1923; Moffit and Wayland 1943), S.R. Capps (Capps 1916; Moffit and Capps 1911), E.M. MacKevett, Jr. (MacKevett 1963, 1965a, 1965b, 1970a, 1970b, 1970c, 1971, 1972, 1973, 1976, 1978; MacKevett and Smith 1972a, 1972b; MacKevett et al. 1964, 1978; Winkler and MacKevett 1981), and D.H. Richter (Richter 1971a, 1971b, 1973, 1975a, 1975b, 1976; Richter and Jones 1973; Richter and Schmoll 1973; Richter and Smith 1976; Richter et al. 1973, 1979, 1989, 1993, 1994, 2000, 2006; Lowe et al. 1982). The National Park Service Geologic Resources Division held a geologic resources evaluation scoping meeting in 2004 to discuss geologic mapping and geologic resource management within the park (National Park Service 2004). A digital geologic map (GIS) and accompanying geologic resources inventory report are in progress.

The region in and around WRST is a tectonically active continental margin which represents a convergence between the North American continental plate and the Pacific oceanic plate. The southern Alaska margin of the Pacific plate is one of the most seismically active areas in the world (Wilder 2000). The prominent geologic features of WRST, including the tall mountain ranges, volcanoes, and seismic activity are related to the proximity of the plate boundary. Volcanism in the Wrangell volcanic field was initiated in the latest Oligocene or earliest Miocene. The 200 million year sequence of accreted terranes has been documented in the WRST region which yields evidence of an extremely complex geologic history (Winkler et al. 2000).

The earliest geologic and geographic surveys of Alaska were funded coincident to the acquisition of territory from Russia in 1867. Coastal surveys to identify and chart navigable waterways were the first work to be funded. The first inland surveys of the Wrangell-Saint Elias area were not funded until the 1880s. These include field work under the direction of Holt (1882), Bremner (1884), Abercrombie (1884), Allen (1885), Schwatka (1886), and glaciologist Russell (1890 and 1891). By the 1890s thousands of gold seekers were drawn to Alaska and the Yukon in Canada. Although gold was found in the WRST area, the rich copper deposits in the McCarthy area were the primary mining interest along the southern flank of the Wrangell Mountains during the 1900s. The Kennecott mines attest to the economic value of copper in the area.

The geologic map of Wrangell-Saint Elias Park and Preserve (Richter et al. 2006) recognizes a collage of seven tectonostratigraphic terranes underlying the area. Listed in order of accretion to North America (first to last), the terranes are mapped as the Windy, Peninsular, Wrangellia, Alexander, Chugach, Prince William, and Yakutat terranes. In general, these terranes were formerly situated far to the south and subsequently rafted northward where they were accreted to Alaska and the North American continent. The accreted terrane concept—critical to understanding the formation of much of the Circum-Pacific Rim geology (Jones et al., 1977, 1982, 1987; Coney et al. 1980)—was based in part on geologic mapping within WRST. This paleontological resource summary utilizes the geologic framework recognized by Richter et al. (2006). Each terrane is characterized by a distinct stratigraphy and is separated from neighboring terranes by major faults (either strike-slip or thrust). See the pamphlet associated with Richter et al. (2006) for further information on the formation and characteristics of each terrane. Winkler et al. (2000) provides a description of the terranes, geologic history, and geologic exploration in WRST. Rocks of the Wrangellia terrane have yielded fossils within WRST. Fossils have been described in rocks of the Alexander, Prince William, and Yakutat terranes outside of the park. The paleontological resources and literature for those terranes yielding significant paleontological content are summarized below. The terranes also contain significant amounts of unfossiliferous rock (which may be highly metamorphosed or igneous in origin) not mentioned here. Refer to Richter et al. (2006) and Winkler et al. (2000) for descriptions of such rocks within WRST.

Sources of Paleontological Resources

The fossils of WRST present opportunities for education, interpretation, and continued or future scientific research in the park. This summary of geologic units identified as sources of paleontological resources has been organized by terranes. This same organization is used in the section below for geologic units with potential for paleontological resources.

Nearly all the early paleontological data available for WRST were acquired during geological mapping efforts of the U.S. Geological Survey (USGS), which included active collections made from the late 1890s up into the early 1980s. Numerous USGS internal fossil reports (referred to as Evaluation and Research Reports or "E&R Reports") were made during this interval by USGS paleontologists including: G.H. Girty, T.W. Stanton, J.P. Smith, R.W. Imlay, N.J. Silberling, and D.L. Jones, as well as several non-USGS paleontologists who utilized the USGS collections (J.P. Smith and Tatsuro Matsumoto). Many of the reports were incorporated into published reports and geologic maps released by the USGS geologists.

Wrangellia Terrane

The Wrangellia terrane was established by Jones et al. (1977) and is one of the largest accreted terranes recognized in the tectonic collage that comprises much of western North America. For example, Triassic rocks of the Wrangellia terrane were originally deposited near the equator, suggesting more than 2,900 km (1,800 mi) of subsequent travel prior to accretion onto North America (Winkler et al. 2000). As originally envisioned, the terrane extends from south-central Alaska (the southern Wrangell Mountains being the type area) as far south as Vancouver Island, British Columbia. The terrane ultimately terminates at its southernmost extent in the Hell's Canyon region near the Oregon and Idaho border.

As in Richter et al. (2006), the Wrangellia terrane is subdivided into two sections within this paleontological resource summary. The first subdivision focuses on the Eastern Alaska Range and Northern Wrangell Mountains. The other subdivision focuses on the Southern Wrangell Mountains and Saint Elias Mountains.

Wrangellia Terrane (Eastern Alaska Range and Northern Wrangell Mountains)

Tetelna Volcanics (Pennsylvanian and Lower Permian)

The oldest recognized unit on the geologic map in the northern part of WRST south of the Denali Fault in the Nabesna quadrangle is the Tetelna Volcanics. The Tetelna Volcanics are well exposed north of the Nabesna Road in the Boyden Hills and on the ridge north of Natat and Caribou Creeks (Winkler et al. 2000). The unit was named by Mendenhall (1905) and consists chiefly of interbedded dark-green to purplish-gray-green volcanic flows, volcanic mud and debris avalanches, lapilli-pumice tuffs and fine- to coarse-grained volcaniclastic rocks. Thickness is greater than 1,000 m (3,300 ft), but the base is nowhere exposed. This unit conformably underlies the Mankomen Group. To the west, in the southeast part of the Mt. Hayes quadrangle the formation is considered to be Pennsylvanian in age (Richter and Dutro 1975), however the upper part of the formation in the Nabesna C-5 quadrangle contains Permian brachiopods and cephalopods (Richter 1976; Richter and Schmoll 1973). Refer to the appendix for a geologic time scale.

Schiappa et al. (2005) described and illustrated two Permian ammonoids, *Uraloceras involutum* (Vionova 1934) and *Uraloceras fedorowi* (Karpinsky 1889) from USGS locality 23431-PC in the Nabesna C-5 quadrangle in WRST. These were reported from beds described as argillite and limestone beds of early Artinskian age (284 to 276 million years ago) that are interbedded within or overlying the Tetelna volcanic and volcaniciclastic rocks. These ammonoid occurrences were briefly mentioned in Spinosa et al. (1985, 1987, 1989, 1991).

Mankomen Group (Middle Pennsylvanian to Lower Permian)

The Mankomen Formation of Mendenhall (1905) was raised in rank to Mankomen Group by Richter and Dutro (1975). The type area for the Mankomen Group is in the southeastern part of the Mt. Hayes quadrangle. Outcrops are most accessible in the Camp Creek area east of the Nabesna River with good exposures also present between Nabesna Glacier and Camp Creek (Winkler et al. 2000). Richter and Dutro (1975) recognized two new formations within the Mankomen Group. The lower Slana Spur Formation is a 1,400 m (4,550 ft) thick volcaniclastic and calcareous volcaniclastic sequence. The overlying Eagle Creek Formation 900 m (2,940 ft) thick non-volcanogenic marine argillite and limestone sequence. The Mankomen Group conformably overlies the Tetelna Volcanics and unconformably underlies the Nikolai Greenstone of Middle and (or) Late Triassic age. The Nikolai Greenstone is a non-fossiliferous, thick succession of predominantly subaerial basalt flows reaching up to 1,800 m [5,900 ft] in thickness.

Both the Slana Spur and Eagle Creek formations are fossil-rich. Fossils from the Slana Spur Formation indicate a Middle Pennsylvanian to Early Permian age, while the Eagle Creek Formation is entirely of Early Permian age. Corals were discussed from the Mankomen Group within the Nabesna quadrangle by Rowett (1971, 1975a, and 1975b). Rowett (1975a) listed the following Early Permian age corals from the Nabesna quadrangle: ?*Sochkineophyllum* sp., *Clisiophyllum* sp., ?*Clisiophyllum* sp., a polycoelid coral, *Timania* sp., *Bothrophyllum* cf. *B. pseudoconicum*, *Wentzelella* sp., *Amplexizaphrentis* sp., *Allotropiophyllum* sp., *Bothrophyllum* sp., *Durhamina alaskaensis* Rowett 1969, *Timania* cf. *T. multiseptata* Fedorowski 1965, *Auloclisia deltense* Rowett 1969, and *Sinopora minatoi* Rowett 1969. Stevens (2008) described the following Early Permian corals from the Suslota Pass area of the Nabesna quadrangle in the park: *Protolonsdaleiastraea* aff. *P. cargalensis* (*Dobrolyubova*) and *Lytvophyllum*? *hongi*.

Unnamed carbonaceous shale, *calcareous argillite*, *and chert (Middle Triassic)*

This unit consists of discontinuous, thin (less than 30 m [90 ft] thick) lenses of carbonaceous shale, calcareous argillite, and chert recognized by Richter (1976). This unit separates the upper part of the Mankomen Group (Eagle Creek Formation) from the Middle to Late Triassic age Nikolai Greenstone. This unnamed unit has yielded specimens of the flat-clam bivalve *Daonella* at several localities in the Nabesna quadrangle (see map of Richter [1976] for their location). The identified species indicate a Ladinian (late Middle Triassic) age, about 237 to 229 million years old.

Triassic limestone (Upper Triassic)
Richter et al. (2006) maps an unnamed, locally fossil-rich, thin-bedded marine limestone with interbedded argillite overlying a fossil-poor, shallow marine to intertidal cherty, massive limestone. This limestone unit immediately overlies the Nikolai Greenstone and is equivalent to Chitistone Limestone, Nizina Limestone and lower part of the Late Triassic McCarthy Formation in the southern Wrangell Mountains and Saint Elias Mountains (see description in that section below). In the Nabesna quadrangle within WRST the unnamed Triassic limestone unit contains marine invertebrates such as the bivalve *Monotis subcircularis* Gabb, the hydrozoan *Heterastridium* as well as the brachiopod *Spondylospira* (Richter 1976). Extensive faunal lists from these Upper Triassic limestones can be found in Moffit (1954).

Nutzotin Mountain Sequence (Upper Jurassic and Lower Cretaceous)
The Nutzotin Mountain Sequence was named by Berg et al. (1972) and underlies much of the area between the Denali and Totschunda faults in the Nabesna quadrangle. It is up to 3,000 m (9,800 ft) thick and is primarily composed of marine turbidite rocks with graded beds of argillite, siltstone, and graywacke sandstone (Richter 1976; Richter et al. 2006). Sparse to abundant *Buchia* bivalves are found throughout the unit and indicate an Early Cretaceous age for the top of the unit and a Late Jurassic age for deposits below. Richter and Jones (1973) provided a list of *Buchia* and other fossils found in this unit in the Nabesna A-2 quadrangle, and Berg et al. (1972) listed seven species of *Buchia* from this unit in or near the park.

Chisana Formation (Lower Cretaceous)
The Chisana Formation is a marine and subaerial volcanic and volcaniclastic unit more than 3,000 m (9,800 ft) thick. Located in the Nabesna A-2 and A-3 quadrangles, it was named by Richter and Jones (1973). The upper part of the unit is composed of volcanic flows, tuffs and clastic volcanic rocks. In some locations, lignitized wood and other carbonaceous debris are present. The lowest 600 m (2,000 ft) of the formation contains marine mudstone, argillite, graywacke, and pebble to cobble conglomerate. The argillite and greywacke are locally fossil rich (Richter et al. 2006). Inoceramid bivalves are locally abundant and a *Shasticrioceras* ammonite indicates an Early Cretaceous (Barremian) age (Richter and Jones 1973), approximately 130 to 125 million years old.

Unnamed Sedimentary Rocks (Cretaceous)
Cretaceous rocks in the Gulkana quadrangle on the southeast flank of Mount Drum are primarily siltstones and mudstones of shallow marine origin (Richter et al. 1979). The basal beds near Mount Drum in the park contain *Brewericeras hulenense* and other ammonites of the *Brewericeras hulenense* local faunizone, indicative of late early Albian age (about 110 million years old). The upper beds contain the ammonite *Puzosia alaskana* Imlay of probably the same age (Grantz et al. 1966).

Nonmarine Sedimentary Rocks (Cretaceous)
Richter (1976) mapped this unit in the Nabesna quadrangle. The unit consists of nonmarine conglomerate, sandstone, siltstone, and mudstone and includes volcanic ash and carbonaceous material (Richter 1976; Richter et al. 2006). Exceptionally well preserved fossil leaves and other plant material are locally abundant and have been found in the park in Erickson Gulch, south of Cathendra Creek (Richter 1976).

Fiorillo et al. (2010) reported on the first occurrence of dinosaurs from WRST. Small theropod and ornithopod undertrack impressions are preserved within a yet unnamed nonmarine Cretaceous-aged sedimentary sequence from within the park. The track producing unit is identified within the Wrangellia terrane and consist of intraformational conglomerates, fine to medium grained light colored sandstones and medium gray shales of Late Cretaceous age (Fiorillo et al. 2010). Fossil horsetails, ferns and gymnosperm wood are also reported to be abundant in within the track-bearing unit.

Wrangellia Terrane (Southern Wrangell Mountains and Saint Elias Mountains)

The Southern Wrangell Mountains and Saint Elias Mountains preserve important Late Paleozoic and Mesozoic paleontological localities. The Middle and Upper Triassic succession of the southern Wrangell Mountains provides the association of Nikolai Greenstone, Chitistone Limestone, Nizina Limestone, and McCarthy Formation. This association forms the characteristic key stratigraphic sequence defining the Wrangellia terrane along much of the western margin of North America (Jones et al. 1977). These units have been the subject of stratigraphic and paleontologic studies by Rohn (1900), Mendenhall and Schrader (1903), Martin (1916, 1926), Smith (1927), Silberling (1963, 1985), Silberling and Tozer (1968), Silberling et al. (1997), Armstrong et al. (1969), Armstrong and MacKevett (1982), Grant-Mackie and Silberling (1990), as well as numerous other publications by F.H. Moffit and E.M MacKevett, Jr.

Unnamed marble unit (Pennsylvanian-Permian)

Richter et al. (2006) maps an unnamed marble unit in the Wrangellia terrane. They note the unit is regionally metamorphosed and locally contains poorly preserved Permian or Early Pennsylvanian-aged fossils.

Strelna Metamorphics (Upper Mississippian-Lower Pennsylvanian)

The oldest rocks to yield fossils in this region belong to the Strelna Metamorphics of Plafker et al. (1989) which consist of schist and slate associated locally with altered limestone, tuff, and basalt flows (Richter et al. 2006). The Strelna Metamorphics are defined as the metamorphosed part of the now-abandoned Strelna Formation nomenclature of Moffit and Mertie (1923) and Moffit (1938). This unit is exposed mainly in along the southern Wrangellia terrane margin between Chitina and Border Ranges faults east of Taral fault and in thin fault-bounded sheets between Taral fault and the Richardson Highway. The metamorphic assemblage includes greenschist, marble, schistose marble, quartzo-feldspathic-mica schist, and micaceous quartz schist.

Fossils within the unit suggest a range of ages. Megafossil collections (consisting primarily of bryozoans, brachiopods and gastropods) made in the early part of the 20th century were considered by G.H. Girty to indicate a Late Mississippian age (Moffit and Mertie 1923; Moffit 1938), while conodonts from the unit are indicative of an Early Pennsylvanian age (Plafker et al. 1985a). Subsequent restudy of the putative Mississippian age megafossil collections indicated an Early Permian age (MacKevett 1978) and were thought to rather represent a metamorphosed equivalent of the Skolai Group. However, the Early Pennsylvanian strata which yielded the conodonts referred to above also contain metamorphosed megafossils. A careful re-evaluation of these metamorphosed megafossil collections seems to be in order.

Skolai Group (Pennsylvanian-Lower Permian)

The Skolai Goup was established by Smith and MacKevett (1970) for a thick sequence of low-grade metamorphic rocks in the southern Wrangell Mountains which consist of lava flows and overlying volcaniclastic and sedimentary rocks, all of marine origin. In its type area, the group is more than 2,400 m (8,000 ft) thick, and was divided into two formations: the Station Creek Formation overlain by the Hasen Creek Formation. The Skolai Group was believed to be largely or entirely Early Permian in age by Smith and MacKevett (1970), but MacKevett (1976) suggested the fauna indicated an age ranging from Pennsylvanian to Early Permian. Within WRST, the Hasen Creek Formation is fossiliferous. The Station Creek Formation is not yet known to preserve fossils within WRST and is described in the "Potential Sources of Paleontological Resources" section.

Skolai Group: Hasen Creek Formation (Lower Permian)

The Hasen Creek Formation was proposed by Smith and MacKevett (1970) as the upper part of the Skolai Group. The formation consists of a heterogeneous mixture of thin-bedded chert, black shale, sandstone, carbonaceous bioclastic limestone and minor conglomerate. Only a minor amount of volcanic material was noted by the authors within the formation. The formation is thickest near Skolai Creek, where it reaches nearly 270 m (900 ft) in thickness, excluding the Golden Horn Limestone Lentil.

Lengthy faunal lists from this fossil-rich formation can be found in Smith and MacKevett (1970) and Moffit (1938). A number of USGS E&R reports (many unpublished) also exist from this formation. Extensive megafossil collections were made by the USGS and are now deposited in the National Museum of Natural History (Smithsonian Institution) in Washington, D.C. The following taxa are reported by Smith and MacKevett (1970) as present in the Hasen Creek Formation: the brachiopods *Spiriferella* sp., *Horridonia* sp., *Liostella* sp., "*Spirifer*" sp., *Anidanthus*? sp., cf. *Chaoiella*? sp, *Odontospirifer* sp., *Neospirifer* sp., *Choristites*? sp., bryozans, crinoid columnals, and the gastropod *Straparollus* (*Euomphalus*). This assemblage suggests an Early Permian age.

Grant (1971) described and illustrated several brachiopods from the USGS locality 7109-PC from the Skolai Pass area which he assigned to *Camerisma* (*Callaiapsida*) *artica* (Holtedahl 1911). This species was originally described by Holtedahl from the Early Permian on Novaya Zemlya in northern Russia, and was assigned by Grant (1971) to his new subgenus *Camerisma*.

Stevens (2008) described and illustrated the following rugose corals from the Hasen Creek Formation: *Pararachnastraea* aff. *P. gracilis* Dobrolyubova 1941, *Iskutella gunningi* Fedorowski, Bamber and Stevens 2007, *Protowentzelella cystosa* Dobrolyuboa 1936, *Lytvophyllum*? *hongi* Wilson 1982, and a species of unclear taxonomic assignment (incertae sedis). In his broad treatment of Alaskan Permian-age corals, Rowett (1975a) listed the following taxa from the Hasen Creek Formation in WRST: ?*Lophophyllidium* sp., *Bothrophyllum* cf. *B. permicum* Fedorowski 1965, *Bothrophyllum* cf. *B. baeri* Stuckenberg 1895, metriophyllid coral, indet., ?*Stereocorphya* sp., *Cladoconus* sp., *Plerophyllum* sp., *Stereostylus* sp., ?*Stereostylus* sp., *Clisiophyllum* sp., ?*Verbeekiella* sp., *Michelinia* sp., *Lophophyllidium* cf. *L. solidum* Ross and Ross 1962, and *Caninophyllum* sp. Rowett (1975b) also provided an overview of the stratigraphic distribution of Alaskan Permian corals from the Hasen Creek Formation, similar but shorter than in Rowett (1975a).

Skolai Group: Hasen Creek Formation: Golden Horn Limestone Lentil (Lower Permian)
The Golden Horn Limestone Lentil, named by Smith and MacKevett (1970), is nearly 240 m (800 ft) thick at its thickest exposures. Richter et al. (2006) map this unit as the "Limestone of Hasen Creek Fromation." It is a distinctive, cliff-forming "purer", massive limestone subunit, commonly forming the uppermost unit within the Hasen Creek. The lentil consists of marine bioclastic grainstone and packstone, with suborndinate wackestone and calcite cemented arkoses. The limestone of Hasen Creek Formation contains abundant fossils. The following megafauna taxa are reported by Smith and MacKevett (1970) as present in this unit: the brachiopods *Spiriferella* sp., *Horridonia* sp., cf. *Chaoiella* sp., *Cleiothyridina* sp., *Rhynchopora* sp., *Neospirifer* sp., bryozoans, and crinoid columnals. An Early Permian age is indicated by this fauna. Rowett (1975a) in his extensive review of Alaskan Permian corals listed the following taxa from the Golden Horn Limestone Lentil of the Hasen Creek Formation: *Lophophyllidium* aff. *L. vidriensis* Ross and Ross, 1962, and *Stereocorypha* cf. *S. spissata* Moore and Jeffords, 1945. Extensive megafossil collections were made by the USGS and are now deposited in the National Museum of Natural History (Smithsonian Institution) in Washington, D.C.

Unnamed Siltstone, Shale and Chert (Triassic)
Underlying the Nikolai Greenstone in the northeastern part of the McCarthy quadrangle (MacKevett 1978) and in the Nabesna Quadrangle (Richter 1973) is a thin unit of *Daonella*-bearing siltstone and shale. These bivalves indicate a Middle Triassic age for this unit (MacKevett 1978). Fossils from this unit in WRST include *Daonella frami* Kitti, *D. degeeri* Boehm, and *D. cf. D. subquadrata* Yabe and Shimizu.

Chitistone Limestone (Upper Triassic)
The Chitistone Limestone overlies the Nikolai Greenstone in the McCarthy quadrangle and is primarily composed of olive gray limestone up to 600 m (2,000 ft) thick with beds 0.5 m to 7 m (1.6 ft to 23 ft) thick. Richter et al. (2006) mapped this formation together with the younger Nizina Limestone. The lower 100 m (330 ft) of this unit contains few fossils and is indicative of an intertidal to supratidal environment (MacKevett 1978). Stromatolites and algal-mat fragments are documented in the lower portion of the

Chitistone Limestone (Winkler et al. 2000). Above that interval, fossils become more abundant as the unit represents neritic depths, meaning a shallow coastal marine environment from low tide to a depth of about 200 m (660 ft). Bottom dwelling organisms are represented by isolated gastropods and ostreid pelecypods. Ammonites, mostly arcestids and haloritids, associated with the shells of halobiid bivalves are also found in this part of the section. A fauna comprised of bivalves *Tropites* cf. *T. welleri* Smith, *Arcestes*, and *Halobia* cf. *H. superba* Mojsisovics was collected about 160 m (530 ft) above the base of the Chitistone at Green Butte and is indicative of a late Carnian age (about 229 to 217 million years ago).

By far the most fossiliferous rocks of the Chitistone-Nizina succession are found at the transition between these two formations (Armstrong et al. 1969). At this horizon in the Green Butte section, several beds contain highly diverse, partly silicified concentrations of megafossils that represent a latest Carnian or earliest Norian age (about 217 million years ago) (Silberling and Tozer 1968). Collections from this locality include about 70 distinct taxa of marine invertebrates, including fragments of corals and spongiomorphs, a few ammonites, nautiloids, and coleoids, crinoid columnals, echinoid spines, and calcareous worm tubes. These fossils occur as tightly packed aggregates of delicate shells, both broken and unbroken, mixed with many fragments of corals and spongiomorphs. Caruthers and Stanley (2008) reported more than 20 species of scleractinian corals from this unit, indicating an age near the Carnian-Norian stage boundary. A detailed overview of the megafauna from this interval can be found in Stanley et al. (2008). In addition, gastropods are particularly diverse and well represented in the uppermost beds (of early Norian age) of the Chitistone Limestone (USGS Mesozoic locality M1708 in WRST); discussion of this gastropod fauna can be found in Blodgett and Frýda (2001) and Blodgett et al. (2001, 2005). Extensive megafossil collections were made by the USGS from this unit and are now deposited in the USGS storage facility at the Denver Federal Center in Lakewood, Colorado.

Nizina Limestone (Upper Triassic)

The Nizina Limestone overlies the Chitistone Limestone in the McCarthy quadrangle and consists of up to 500 m (1,600 ft) of limestone with subordinate chert lenses and nodules and rare grains of dolomite (MacKevett 1978). Richter et al. (2006) mapped this formation together with the Chitistone Limestone. Characteristic beds of the Nizina Limestone range from 0.1 to 1 m (0.3 ft to 3.3 ft) in thickness and are darker gray than the Chitistone Limestone. The Nizina Limestone contains a similar fauna to the Chitisone, and is particularly abundant in the basal part. In the higher parts of the Nizina, megafossils are not uncommon, though rarely well preserved. Brachiopods, gastropods, ammonites, and bivalves are present. Among the bivalves, *Halobia* are well represented, as are bottom-dwelling forms *Gryphaea* (Armstrong et al. 1969). Near the top of the Nizina, a poorly preserved ammonite fauna includes the distinctive genus *Pterotoceras*, indicating the early middle Norian Stage of the Triassic (about 210 million years old) for the top of the unit. A partial mandible with teeth of an ichthyosaur was collected from the Nizina Limestone in the Hidden Creek area of WRST by David Whistler in 1963. The specimen is in the collections of the University of California Museum of Paleontology (UCMP 113569). Extensive megafossil collections were made by the USGS from this unit and are now deposited in the USGS storage facility at the Denver Federal Center in Lakewood, Colorado.

McCarthy Formation (Upper Triassic and Lower Jurassic)

The McCarthy Formation is characterized by spiculite, impure chert, and limestone (Richter et al. 2006). The McCarthy Formation has been divided into an upper and lower member (MacKevett 1978). The lower member is up to 300 m (980 ft) in thickness and consists of interbedded shale and chert near the base, overlain by impure limestone, and in the higher parts it is composed of intercalated shale and chert with subordinate limestone (MacKevett 1971). Fossils are locally abundant (Richter et al. 2006). Bivalves of the genus *Monotis* are abundant and widespread in the lower to middle part of the lower member and indicate the late Norian Stage of the Triassic (about 206 million years ago). Grant-Mackie and Silberling (1990) reported on *Monotis* bivalves from several localities in this unit in WRST, including the type locality for *Monotis alaskana* Smith 1927. The upper member of the McCarthy consists of up to 600 m (2,000 ft) of impure calcareous organic chert and spiculite with subordinate shale and impure limestone. A considerable fauna of ammonites and bivalves has been recovered from this member. These include

Crucilobiceras sp., *Paracoroniceras*? sp., *Arnioceras* cf. *A. semicostatum* (Young and Bird), *Uptonia*? sp., *Belemnite*, *Lima* sp., "*Entolium*" *semiplicatum* (Hyatt), *Camptonectes*? sp., *Oxytoma*? sp., *Weyla* sp., *Chlamys*? sp., and *Cardinia* sp. (MacKevett, 1971). These fossils indicate Early Jurassic ages from the Hettangian to Pliensbachian stages (200 to 183 million years ago) for the upper part of this member. The lower part is unfossiliferous. Witmer et al. (2007) reported the ammonites *Dubariceras freboldi*, *Dommergues* and *D. silviesi* Mouterde, indicative of late Early Pliensbachian age (about 190 million years ago). Witmer et al. (2007) also reported the bivalve *Otapiria tailleuri* Imlay for the first time from the Wrangell Mountains. Imlay (1981) listed 14 species of Early Jurassic ammonites from this unit in WRST. Extensive megafossil collections were made by the USGS from this unit and are now deposited in the USGS storage facility at the Denver Federal Center in Lakewood, Colorado.

Lubbe Creek Formation (Lower Jurassic)
The Lubbe Creek Formation consists of up to 100 m (330 ft) of impure spiculite and subordinate amounts of coquina (MacKevett 1969). Richter et al. (2006) mapped Lubbe Creek Formation together with the Nizina Mountain and Root Glacier formations. It constitutes an excellent marker horizon, forming bold outcrops, and containing abundant fossils, including the diagnostic pecten (scallop) *Weyla durfrenoyi* D'Orbigny. This unit also contains the bivalves *Gryphaea* sp., *Ostrea* sp., *Camptonectes* sp., *Chlamys* sp., *Liostrea* sp., the ammonites *Arieticeras* sp. and *Prodactylioceras* sp., and brachiopods. *Arieticeras* suggests a late Pliensbachian age (about 184 million years ago) for the lower part of the unit and the *Weyla durfrenoyi* indicates a Toarcian age (between 183 and 176 million years ago) for the upper part of the formation.

Nizina Mountain Formation (Middle to Upper Jurassic)
This formation consists of up to 400 m (1,300 ft) of fine-grained to very fine-grained graywacke that is associated with sparsely distributed shaly partings and a few limy lenses and concretions (MacKevett 1969). Richter et al. (2006) mapped the Nizina Mountain Formation together with the underlying Lubbe Creek Formation and overlying Root Glacier formations. This unit contains a large fossil fauna chiefly consisting of belemnites, pectinids, and poorly preserved ammonites. Fossils from the formation identified by R. W. Imlay include the ammonites *Parareineckeia* cf. *P. hickersmensis* Imlay, *P.* cf. *P. shelikofana* (Imlay), *Cobbanites* cf. *C. talkeetnanus* Imlay, *Cranocephlites* cf. *C. costidensus* Imlay, *C.* cf. *C. pompeckji* (Madsen), *Arctocephalites*? sp., the bivalves *Inoceramus* cf. *I. ambiguus* Eichwald, *Plesiopecten*? sp., *Camptomtes* sp., *Oxytoma* sp., *Entolium* sp., *Thracia* sp., *Coelastarte* sp., *Pleuromya* sp., *Liostrea* sp., *Quenstedtia*? sp., and undetermined belemnites, aptychus, fish scales, and a crustacean appendage. These fossils indicate a Bathonian to Callovian age for the unit, about 168 to 161 million years old.

Root Glacier Formation (Upper Jurassic)
This formation ranges from about 400 m to 1,300 m (1,300 ft to 4,300 ft) in thickness and consists mainly of diverse clastic rocks—chiefly mudstone and siltstone—and less abundant graywacke, arenite, and shale (MacKevett 1969). This unit also contains some limy beds, lenses, and concretions. A conglomerate interval less than 70 m (230 ft) in thickness is also present and is comprised of well-indurated pebble and cobble conglomerate and coarse-grained and very coarse-grained arenite. Richter et al. (2006) mapped the Root Glacier Formation together with the underlying Lubbe Creek and Nizina Mountain formations. Fossils in this unit include *Buchia* bivalves, belemnites, ammonites, and wood fragments that are indicative of a late Oxfordian to Kimmeridgian age (about 161 to 151 million years old). Fossils identified by R. W. Imlay include: the bivalves *Lima* sp., *Camptomtes* sp., *Ctenostreon* sp., *Buchia rugosa* (Fischer), *B. concentrica* (Sowerby), *B. mosquensis* (von Buch), the ammonites *Phylloceras* sp., *Partschiceras* sp., *Amoeboceras* (*Priondoceras*) sp., the gastropod "*Turbo*" sp., and belemnite *Cylindroteuthis* sp.

Kotsina Conglomerate (Middle to Upper Jurassic)
The Kotsina Conglomerate is a thick-bedded, well-rounded, pebble-and-cobble conglomerate that contains boulders in some beds (Grantz et al. 1966). The matrix is lithic or feldspathic sandstone or in some places a dark, hard lutite (clastic sedimentary rock composed of clay size grains). The formation contains interbeds and lenses of sandstone, and lutite that commonly are carbonaceous and contain plant

scraps. Grantz et al. (1966) stated that the only fossils found in the Kotsina Conglomerate are plant scraps in the lutite layers, and older Late Triassic mollusks found in limestone clasts eroded and redeposited as part of the Kotsina Conglomerate. The conglomerate clasts are principally dark rocks and of local origin, mostly altered volcanic rocks and Triassic limestone, argillite, and chert. Richter et al. (2006) stated that fossils were absent from the Kotsina Conglomerate.

Berg Creek Formation (Lower Cretaceous)
The Berg Creek Formation is a distinctive bioclastic sandstone unit that is up to 250 m (820 ft) thick which in places forms a bold outcrop. The unit consists of impure bioclastic sandstone that with thick to medium beds and cross bedded in places. Richter et al. (2006) mapped the Berg Creek Formation together with the Kennicott, and Kuskulana Pass formations. Inoceramid bivalve fragments are abundant and in some places dominate the clasts. The unit probably represents nearshore bars or shoals in a transgressive marine setting (MacKevett et al. 1978). Fossils found in this unit in WRST include the bivalves Inoceramus and Pinna, belemnites and the ammonite *Simberskites*. The ammonite and belemnites indicate a Hauterivian age (approximately 134 to 130 million years old) and possibly a Barremian age as well (130 to 125 million years old).

Kuskulana Pass Formation (Lower Cretaceous)
The Kuskulana Pass Formation is about 300 m (980 ft) in thickness and consists of thin bedded, fine grained sandstone, siltstone and shale, and represents rapid, shallow water marine deposition (MacKevett et al. 1978). Richter et al. (2006) mapped the Kuskulana Pass Formation together with the Berg Creek and Kennicott formations. It contains a sparse ammonite and bivalve fauna in WRST including *Acrioceras* and *Syncyclonema*. The former is indicative of a Barremian age (approximately 130 to 125 million years old). The belemnite *Acroteuthis* is also known from this unit (Winkler and MacKevett 1981).

Kennicott Formation (Lower Cretaceous)
The Kennicott Formation is widely distributed throughout the McCarthy quadrangle and is well exposed at its type locality and elsewhere in the southern part of the C-6 quadrangle and in the A-4 quadrangle north of the Chitina River in the park (Jones and MacKevett 1969). The Kennicott Formation ranges from 10 m up to 375 m (33 ft up to 1,230 ft) in thickness. The formation generally consists of shallow marine sediments: a basal unit of sandstone and conglomerate as much as 30 m (100 ft) thick and an overlying unit of fine siltstone, shale, and sandstone as much as 100 m (330 ft) thick. Richter et al. (2006) mapped the Kennicott Formation together with the Berg Creek and Kuskulana Pass formations. This unit is very fossiliferous and contains ammonites and bivalves of biostratigraphic significance. It can be subdivided into two well-defined faunal zones of early Albian age (about 110 million years old), a lower *Mofitites robustus* zone and an upper *Brewericeras hulenense* zone. Both the upper and lower units are rich in molluscan fossils including the bivalve *Aucellina*. The basal rocks of the lower unit commonly also contain fossil wood and plant debris, and the shales and siltstones of the upper unit are locally rich in radiolarians and foraminifers (Jones and MacKevett 1969).

Moonshine Creek Formation (Mid to Upper Cretaceous)
This thick, marine, dominantly siltstone and sandstone sequence is well exposed along Moonshine Creek in the McCarthy C-4 quadrangle of WRST, which was designated as the type area for the formation (Jones and MacKevett 1969). The formation ranges from tens of meters to 1,100 m (3,600 ft) in thickness and consists dominantly of siltstone and sandstone with minor conglomerates (MacKevett, 1978). The formation probably was deposited in a restricted, rapidly sinking basin. Richter et al. (2006) mapped the Moonshine Creek Formation together with the MacColl Ridge, Chititu, and Schulze formations. The Moonshine Creek Formation contains abundant ammonites, gastropods and bivalves, mainly *Inoceramus*, which define three faunal zones ranging in age from the late Albian to late Cenomanian stages (together spanning the time between 112 and 94 million years ago). These include the late Albian zone of *Desmoceras* (*Pseudouhligella*) *dawsoni*, the early Cenomanian zone of *Desmoceras* (*Pseudouhligella*) *japonicum*, and a late Cenomanian *Inoceramus* sp. zone. A few ammonites of possible middle Albian age also have been found near the base of the formation (Jones and MacKevett 1969). Matsumoto (1959)

described seventeen species of ammonites from this unit in the McCarthy C-4 quadrangle, naming four new species and one new genus from material collected in the WRST by USGS scientists.

Schulze Formation (Upper Cretaceous)

The Schulze Formation is a thin sequence probably ranging from 30 m to 75 m (100 ft to 250 ft) in thickness of dominantly siliceous, marine rocks. The unit is limited in distribution and is best exposed in the north-central part of the McCarthy B-5 quadrangle, but is also known from the A-4, B-4, C5, and C-6 quadrangles in WRST (Jones and MacKevett 1969; MacKevett 1978). This unit is composed of finely laminated and platy porcellanite that consists dominantly of chalcedony and grades into impure chert. Richter et al. (2006) mapped the Schulze Formation together with the Moonshine Creek, MacColl Ridge, and Chititu formations. Fossils in the Schulze Formation are mainly scraps of Inoceramus bivalves and microfossils, including calcareous tests of foraminifers and siliceous tests of radiolarians. *Desmoceras* (*Pseudouhligella*) ammonites are common, and several relatively undistorted specimens from the upper part of the formation have been identified as *Desmoceras* (*Pseudouhligella*) *japonicum* of Cenomanian age (approximately 100 to 94 million years old) (Jones and MacKevett 1969).

Chititu Formation (Upper Cretaceous)

The Chititu Formation is a thick sequence of up to 1,700 m (5,600 ft) of dark-gray to black marine mudstone and shale that is widely distributed in the McCarthy A-4, B-4, B-5, and B-6 quadrangles in WRST (Jones and MacKevett 1969). Richter et al. (2006) mapped the Chititu Formation together with the Moonshine Creek, MacColl Ridge, and Schulze formations. The Chititu Formation contains minor amounts of porcellanite, impure chert, and fine-grained sandstone, and uncommon thin beds and lenses of impure limestone. Calcareous concretions are locally abundant and are fossiliferous. Fossils in the Chititu Formation consist mainly of *Inoceramus* bivalves and less common ammonites. Microfossils, mostly radiolarians, are abundant in some of the silica-rich pelites and less common in the other beds. The macrofossils indicate that the formation is mainly Late Cretaceous, with an age span extending from at least Cenomanian to Late Campanian (about 100 to 71 million years old) (Jones and MacKevett 1969). Matsumoto (1959) lists nine species of ammonites and two species of inoceramid bivalves from this unit.

MacColl Ridge Formation (Upper Cretaceous)

The MacColl Ridge Formation is an approximately 770 m (2,500 ft) thick, coarse sandstone sequence well exposed on MacColl Ridge in the McCarthy A-4 quadrangle as well as some areas of the B-4 and B-5 quadrangles in WRST (Jones and MacKevett 1969). Richter et al. (2006) mapped the MacColl Ridge Formation together with the Moonshine Creek, Chititu, and Schulze formations. The MacColl Ridge Formation consists dominantly of coarse grained sandstone with lesser amounts of granule to pebble conglomerate and fine-grained sandstone and siltstone. This unit is considered to be of Late Cretaceous (late Campanian or Maastrichtian, approximately 76 to 65.5 million years ago) age based on its overlying relationship to the Chititu Formation. The only fossils that have been found in this formation are poorly preserved plant remains, fragments of inoceramid bivalves, and possibly reworked fragments of unidentifiable ammonites (Jones and MacKevett 1969).

Alexander Terrane

Kaskawulsh Group of Kindle (1953) (Devonian, Mississippian, Pennsylvanian and older)

Rocks attributed to the Alexander terrane have been recognized in WRST and mapped as the Kaskawulsh Group of Kindle (1953) by Richter et al. (2006). These rocks are a metamorphosed marine sequence of marble, schist, and phyllite; minor metamorphosed tuff, flows, breccia, and metamorphosed conglomerate (Richter et al. 2006). The Kaskawulsh Group rocks are exposed in the eastern portion of the park between Klutlan, Barnard, and Walsh glaciers, along with a small exposure east of the Hubbard Glacier (Winkler et al. 2000). None of the Alexander terrane rocks within WRST have yielded any abundance of fossils nor has formal stratigraphic nomenclature been applied to them. These rocks are metamorphosed, and much more altered than presumably equivalent rocks of the Kaskawulsh Group recognized in northwest British Columbia and southwest Yukon Territory. Poorly preserved tabulate horn corals tentatively assigned as Devonian in age occur in marble along the Klutlan Glacier. They are the only fossils known in the Kaskawulsh Group in Alaska (Winkler et al. 2000). Alexander terrane rocks of Southeast Alaska are for the most part not metamorphosed and contain a rich array of fossil faunas of Paleozoic and Mesozoic (Triassic) age. It should be noted that some geologists have even questioned the assignment of some rocks to the Alexander terrane in WRST. Future study should help resolve this issue, and much may depend on the results of micropaleontological analysis, due to the high metamorphic grade of these rocks.

Yakutat Terrane

As mapped by Richter et al. (2006), the Yakutat terrane encompasses a variety of sedimentary, metamorphic and igneous rocks. Of the seven terranes that underly WRST, the Yakutat was the last to be accreted (Winkler et al. 2000). Fossiliferous sedimentary rocks within the terrane are found in the Kulthieth, Poul Creek, and Yakataga formations.

Yakataga Formation (Miocene through Pleistocene)

The Yakataga Formation comprises mudstone, siltstone, sandstone, and diamictite in a glacially-influenced continental slope deposit (Richter et al. 2006). Fossils are "abundant" in the Yakataga Formation (Richter et al. 2006). Eyles et al. (1992) described trace fossils and foraminifera from the formation. Kanno (1971) reported on the extensive molluscan fauna from this unit. Addicott et al. (1978) illustrated upper Miocene to Pliocene sections of this unit in the Chaix and Samovar Hills areas of the park and listed two dozen species of bivalves and gastropods as well as barnacles and scaphopods. Marincovich (1990) and Oleinik and Marincovich (2003) discussed molluscan taxa from this unit and their paleoclimatic significance. Lagoe (1983) and Zellers (1990) reported on extensive foraminiferal assemblages from the Yakataga Formation on the coast, west of the park at Yakataga Reef. Richter and et al. (2006) tentatively indicate the Yakatage extends into the Holocene.

Wrangell Volcanic Field

The Wrangell Volcanic Field is not considered a terrane, but a "province" (Richter et al. 2006). Deposits associated with volcanoes throughout the Wrangell and St. Elias mountains are included in this field. The fossil-rich Frederika Formation represents older sedimentary rocks found in the province.

Frederika Formation (Lower Miocene to Middle Miocene)

The only Cenozoic-aged unit currently known to preserve fossils within the park is the Frederika Formation. The Frederika Formation is composed of up to 600 m (2,000 ft) of terrestrial volcaniclastic sediments that appear to have been deposited over several million years during the early to mid-Miocene. They are associated with the extensive volcanic deposits of the Wrangell Volcanic Field (Richter et al. 2006). Paleontological resources are abundant and include a wide variety of very well-preserved paleobotanical specimens such as the angiosperms *Betula*, *Acer*, and *Alnus*. A variety of conifers are also represented, including *Metasequoia* (MacKevett 1970a; Fremd et al. 2003). The unit appears to represent broadly variable depositional environments indicated by paleosols, coal beds, lacustrine deposits, silty tuffaceous sandstones and other tephra-rich materials. Fish remains have also been noted from this formation in an internal USGS report written by E.W. Berry on Feb. 6, 1928 regarding the fossil flora. The occurrence of fish in the unit has not yet been reported in published literature.

Potential Sources of Paleontological Resources

Fossils have not yet been documented from the following rock units within WRST. However, these units are known to preserve fossils in areas outside the boundaries of the park and preserve. Future field investigations within the park and preserve may recover fossils from these units. As outlined above, the geologic units with potential for paleontological resources are organized by terranes.

Peninsular Terrane

The Peninsular terrane is exposed west of the Copper River. The Talkeetna Formation (Early Jurassic) represents rocks which are known to be fossiliferous in localities outside of WRST, but fossils have not yet been identified in the park.

Talkeetna Formation (Lower Jurassic)

This formation is represented by only a few outcrops on the westernmost boundary of WRST. A series of primarily andesite lavas, tuffs, and volcaniclastic debris-flows and turbidite deposits comprise the Talkeetna Formtion (Clift et al. 2005; Richter et al. 2006). Clift et al. (2005) indicated that plant fossils are found in this unit in the Sheep Mountain area west of WRST in Matanuska Valley. These Early Jurassic plant localities were subject of a published paper (Knowlton 1916), an abstract (Sunderlin 2007), and were also described in detail in Martin (1926). Fossils have not yet been described in the Talkeenta Formation of WRST. Talkeetna Formation fossils are common in parks of the Southwest Alaska Network (Kenworthy and Santucci 2003).

Chugach Terrane

The Chugach terrane is exposed west of the Copper River. The Valdez Group (Upper Cretaceous) represents rocks which are known to be fossiliferous in localities outside of WRST, but fossils have not yet been identified in the park.

Valdez Group (Upper Cretaceous)

The Valdez Group is mainly composed of magmatic arc-derived flysch and metamorphosed marine volcanic rocks that were accreted to the continent by early Paleocene time. Jones and Clark (1973) discussed this band of deep water rocks along the southern margin of Alaska and listed fossils from within these rocks. Fossils are rare and are currently known only from areas outside of WRST. They include the bivalve species *Inoceramus kusiroensis* (Nagao and Matsumoto) and *I. concentrica* (Ulrich), which indicate a latest Cretaceous (Maastrichtian Stage; about 70.6 to 65.5 million years ago) age. Richter et al. (2006) noted abundant, slightly deformed radiolarian microfossils from the McHugh Complex, a “chaotic assemblage of oceanic rocks” mapped as part of the Valdez Group.

Wrangellia Terrane

As described above in the “Sources of Paleontological Resources” section, the Wrangellia terrane is one of the largest accreted terranes in western North America (Jones et al. 1977; Coney et al. 1980). All of the paleontological resources thus found within WRST are preserved in rocks associated with the Wrangellia terrane. In the Southern Wrangell Mountains and Saint Elias Mountains section of the terrane, fossils are also known from the Station Creek Formation of the Skolai Group. However fossils have not yet been documented from these units within the park and preserve.

Wrangellia Terrane (Southern Wrangell Mountains and Saint Elias Mountains)

Skolai Group (Pennsylvanian-Lower Permian)

As described above in the “Sources of Paleontological Resources” section, the Skolai Goup was established by Smith and MacKevett (1970) for a thick sequence of low-grade metamorphic rocks in the southern Wrangell Mountains which consist of lava flows and overlying volcaniclastic and sedimentary rocks, all of marine origin. In its type area, the group is divided into two formations: the Station Creek Formation overlain by the Hasen Creek Formation. The Hasen Creek Formation is known to preserve fossils within WRST and is described above. The older Station Creek Formation is not yet known to preserve fossils within WRST.

Skolai Group: Station Creek Formation (Pennsylvanian-Lower Permian)

The formation was divided by Smith and MacKevett (1970) into two informal members, a lower volcanic flow member (approximately 1,200 m or 4,000 ft thick at its type locality) and an upper volcaniclastic member (reaching up to 760 m or 2,500 ft thick). No fossils were reported from the Station Creek Formation by Smith and MacKevett (1970). However, according to Smith and MacKevett (1970) its age was considered to be Permian (?) based on its proximity and structural continuity with fossiliferous overlying rocks of the Hasen Creek Formation and on differences in structural grade with underlying rocks that are largely or entirely of Mississippian age. MacKevett (1976) revised the age of the Station Creek Formation to Pennsylvanian and Early Permian because the unit is broadly correlative stratigraphically and lithologically with Middle Pennsylvanian to Early Permian Slana Spur Formation of the Mankomen Group to the north (Richter and Dutro 1975).

Prince William Terrane

Orca Group (lower Paleocene to lower Eocene)

Sedimentary rocks of the Prince William terrane have been assigned to the Orca Group (Richter et al. 2006). Dumoulin (1987) discussed the Orca Group, which consists predominantly of flysch deposits, with subordinate intercalations of mafic intrusive and volcanic rocks. It is part of a Paleogene accretionary belt that extends through Prince William Sound to the Kodiak Islands to the west and probably underlies much of the contiguous continental shelf. This unit occurs to the southwest of WRST and might occur in the park.

While Richter et al. (2006) note that the formation is "locally fossil rich," fossils are for the most part, scarce in the Orca Group.Megafossils are very rare, and those that have been found generally not age-diagnostic. Sparse microfossils, including foraminifers, radiolarians, diatoms, silicoflagellates, coccoliths, dinoflagellates, and palynomorphs occur in hemipelagic and pelagic layers in the turbidite sequence and in volcanogenic, calcareous, and concretionary 1ayers associated with the basalts (Plafker et al. 1985b).

Yakutat Terrane

As mapped by Richter et al. (2006), the Yakutat terrane encompasses a variety of sedimentary, metamorphic and igneous rocks. Of the seven terranes that underly WRST, the Yakutat was the last to be accreted (Winkler et al. 2000). Fossiliferous sedimentary rocks within the terrane are found in the Kulthieth, Poul Creek, and Yakataga formations.

Kulthieth Formation (Paleocene to lower Eocene)

The Kulthieth Formation is part of a belt of Paleogene sedimentary and volcanic rocks that fringes the margin of the Gulf of Alaska from the vicinity of Yakutat Bay westward to the Trinity Islands (Addicott and Plafker 1971). This unit is present in the Bering Glacier and Mt. St Elias quadrangles. The sequence consists predominantly of uniformly bedded, light-gray to greenish-gray, hard, arkosic sandstone, pebbly sandstone, and sandy pebble conglomerate. Interbedded with the coarse clastic rocks are subordinate amounts of fossil leaf-bearing calcareous sandstone, siltstone, and thin beds of sheared bituminous coal. The fossil leaves are of subtropical affinity and can be locally abundant (Richter et al. 2006). In addition, sparse warm-water marine mollusks are known from the Kulthieth Formation (Richter et al. 2006). Although the mollusks are of Eocene to Oligocene age, Addicott and Plafker (1971) reported the gastropod *Turritella merriami brevitabulata* Merriam and Turner along with other mollusks from a massive sandstone near the base of unit, indicating the Upper Paleocene "Meganos Stage" of the Pacific Coast of the conterminous United States. The fossils provided the first evidence for strata of this age in the Gulf of Alaska Tertiary province. Early Eocene-age mollusks include *Turritella buwaldana* Dickerson and several bivalves reported in a USGS E&R report by Addicott (1970).

Poul Creek Formation (upper Eocene through lower Miocene)
The Poul Creek Formation contains marine siltstone, claystone, sandstone, and conglomerate, as well as minor basaltic tuff (Richter et al. 2006). The unit locally contains the mineral glauconite. Strata of this unit provide a record of Eocene to Miocene sedimentation on the Yakutat microplate as it was transported and subducted beneath the Alaskan continental margin. The Poul Creek is the best known Paleogene marine unit in southern Alaska and is known to contain over 100 species of molluscks (Marincovich and McCoy 1984). This unit is present in the Bering Glacier and Mt. St Elias quadrangles in the WRST area. Mollusks of this unit were documented by Kanno (1971) and many others. Mollusks from the Poul Creek provide much information regarding paleoclimate as the formation spans the transition from global "greenhouse" climates of the early Cenozoic to "icehouse" climates of the later Cenozoic. Oleinik and Marincovich (2003) discussed molluscan taxa from this unit and their paleoclimatic significance.

Park Collections

According to the WRST Park Curator Mary Cook (pers. comm. 2010) the park collection includes a variety of paleontological specimens. Most of these fossil specimens are maintained at the University of Alaska Museum in Fairbanks, Alaska. The earliest paleontological collections date to September1928 and represent fossils collected by employees of the Kennecott Copper Corporation. The park archives indicate the specimens were identified by Fred H. Moffitt and include a possible Cretaceous belemnite and a Triassic pecten. The belemnite was collected from glacial moraine just above Powder House on the Erie Trail. The source of the specimen is believed to be originally from some Cretaceous marine rocks north of the Erie Mine. The Triassic pecten was identified by Moffitt as *Pseudomonotis subcircularis* from a shale unit in the McCarthy Formation.

A small collection of Mesozoic marine invertebrate fossils were made by Gary Kline in 1970. Permian brachiopods were collected by Kline from the Bond Creek area near Nebesna and east of Nabesna Glacier in WRST.The brachiopods from the east of Nabesna Glacier were discovered in a tan colored limestone unit which is overlain by a volcanic sequence. Kline collected some possible Triassic bivalves, *Monotis* and *Halobia*, from a thin-bedded limestone located on a ridge were drainage on the west intersects Cooper Creek near Cooper Pass. Kline also made a collection of Lower Cretaceous ammonoids, belemnites and bivalves from some shale and limestone beds along the north-facing slope of Chathenda Creek, about 3 km (2 mi) upstream.

In August 1972, Earl Redman collected Permian echinoids and crinoids from the west side of a ridge between Nabesna Glacier and a glacier near Nikonda Creek. Redman suggests these fossils were possibly obtained from a unit in the Mankomen Group. Redman collected some bryozoans and crinoids from a Permian Limestone in WRST in August 1974. The crinoid columnals were identified by Harvell Strimple (Univeristy of Iowa) as *Platyplatium monstrum*. These fossils were collected from the float below a Permian limestone unit near the ridge between Nikonda and the west fork of Bond Creek.

A fragment of the Triassic ammonite *Michelinoceras* (Sweet 1964) was collected by Don Henn in 1974 from WRST. The specimen was located near the Nizina River between McCarthy and Chitina. In 1979 Dan Fair collected Permian ammonoids from the Eagle Creek Formation of the Mankomen Group at a locality in the Wrangell Mountains. Although these specimens are included in the NPS collections for WRST, the locality these ammonoids were collected may in fact be outside the boundary of WRST.

Lower Permian bryozoans and crinoids stems were collected from the Hansen Creek Formation by Bruce Panuska from WRST in 1980. The fossils were collected along Skolai Creek in the Wrangell Mountains. One specimen of the brachiopod tentatively identified as *Linoproductus* was collected by Bob Gaddis in 1969. The specimen was found below the terminus of Russell Glacier in the Moraine Creek area of WRST.

In 1992, WRST Geologist Danny Rosenkrans collected a large specimen of fossiliferous rock from the Bonanza Creek area of the park. The bivalve-rich (*Buchia*) rock was from the Lower Cretaceous Chisana Formation (Richter and Jones 1973).

A specimen of the decapod *Hoploparia* was collected by Jeffrey Trop (Kent State University) in 1995. The specimen was identified Rodney Feldman as a moderate sized nephropid with a smooth carapace and well developed cervical and antennar grooves. The specimen was collected from a Cretaceous (Late Albian – Late Cenomanian) open marine shelf facies from the Moonshine Creek Formation in Contact Gulch of the Wrangell Mountains.

In addition to the University of Alaska Museum (Fairbanks), several other outside repositories maintain fossil collections from WRST. These include the University of California Museum of Paleontology (Berkeley, UCMP); Kent State University; the U.S. Geological Survey (Denver, USGS); and the Smithsonian Institution National Museum of Natural History (Washington, D.C). In the 1990s, UCMP became the repository for most of the USGS Mesozoic fossil collections which were originally stored at Menlo Park. Additional USGS paleontology collections are maintained in Denver, including the complete USGS Triassic invertebrate paleontology collection. The Smithsonian maintains the USGS Permian-Carboniferous (Mississippian and Pennsylvanian) fossil collections as well as many Jurassic and Cretaceous fossils collected by the USGS in Alaska.

Paleontological Resource Management, Preliminary Recommendations

- The National Park Service Geologic Resources Division coordinated a geologic resource scoping meeting for the Central Alaska Inventory and Monitoring Network, including WRST, between February 24 and 26, 2004. The participants of the scoping meeting developed a series of recommendations for future work. Recommendations relative to paleontology included additional information, site location, development of interpretive materials, and incorporation of paleontological information into a geographic information system (GIS) (National Park Service 2004).
- The park should consider future field inventories for paleontological resources to more fully document in situ occurrences of fossils. Further systematic exploration of WRST outcrops would likely reveal numerous new fossil localities. Partnering with other institutions may be of interest.
- The park may consider a formal site documentation and condition assessment for significant fossil localities. Monitoring of significant sites should be undertaken at least once a year in the future. A Geologic Resource Monitoring Manual by the Geological Society of America and NPS Geologic Resources Division includes a section on paleontological resource monitoring (Santucci et al. 2009).
- Park staff should be encouraged to observe exposed sedimentary rocks and associated eroded deposits for fossil material while conducting their usual duties. Staff should photodocument and monitor any occurrences of paleontological resources that may be observed in situ. Fossils and their associated geologic context (surrounding rock) should be documented but left in place unless they are subject to imminent degradation by accelerated natural processes or direct human impacts. When opportunities arise to observe paleontological resources in the field and take part in paleontological field studies with trained paleontologists, park staff should take advantage of them.
- Fossils found in a cultural context should be documented as other fossils, but will also require the input of an archeologist. Any fossil with cultural context may be culturally sensitive as well (e.g. subject to NAGPRA) and should be regarded as such until otherwise established. The Geologic Resources Division can coordinate additional documentation/research of such material.

- Future archeological excavations or infrastructure developments should consider scheduling site monitoring by a trained paleontologist in order to document and protect fossil resources.
- Contact the NPS Geologic Resources Division for paleontological resource management assistance.

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