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Roadside Geology of the Dempster Highway, Northwest Territories and Yukon

A traveler's guide to the Geology of Canada's most northwestern road

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YUKON GEOLOGICAL SURVEY
Yukon Energy, Mines and Resources

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CAUTIONARY NOTES

The Dempster Highway is a gravel road, quite narrow in places; and rough depending on seasonal conditions and traffic. Ensure your vehicle is suitable for the trip. Spare tires, emergency kits, extra food and additional fuel are essential when traveling in this remote area. If you are stranded it may be many hours before another vehicle passes by, so plan ahead.

Conversely, despite the lack of traffic, remember that this is a first-order highway, and drivers of large trucks treat it that way. They are not expecting to encounter pedestrians, dogs or middle-of-the-road sightseers. Thus it is important to seek pullouts or completely move your vehicle from the traveled portion of the roadway, never park along sharp or blind curves. Help after an accident on this remote road will be a long time coming. The Highway cuts across expansive wilderness. Maintain respectful and safe distances from wildlife.

The time changes from Pacific Standard Time to Mountain Standard Time as you cross the boundary from the Yukon to the Northwest Territories. Please note the time change as you make plans, particularly for the ferry crossings.

This guide is not a substitute for a road map. The road distances and outcrop access were correct as of July 2005 (northern section) and September 2006 (southern section). Each summer, however, some parts of the road are re-constructed, and various borrow (gravel) pits and quarries are opened and closed by highway maintenance crews. Furthermore, the kilometre posts (northern section) are periodically moved or replaced. As a result some distances recorded in this guide will be inexact: please check locally if certain sites are critical to your visit.

We hope you enjoy the ride!

Cover illustrations (clockwise from top): View east from the Dempster Highway to the community of Tsiigehtchic which sits on Devonian Imperial Formation; View north from the Dempster Highway to Cathedral Mountain in the Tombstone Range, Yukon; Young grizzly bear in a roadside meadow.

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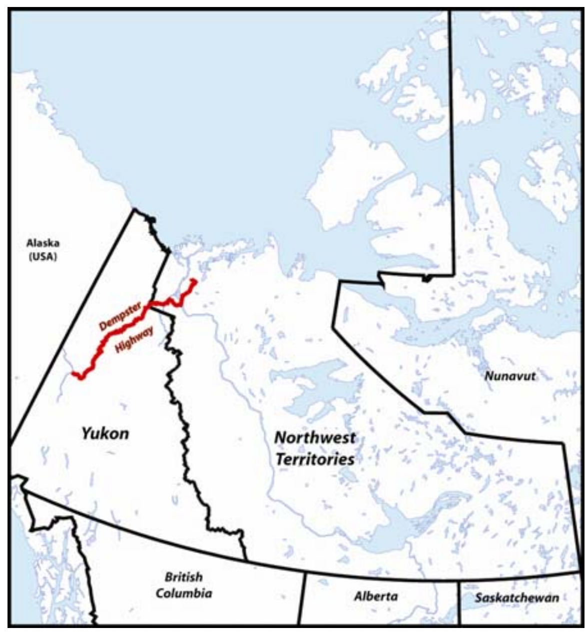


The Dempster Highway, northwestern Canada.

FOREWORD

This guidebook describes the rocks and landforms along the Dempster Highway. The southern terminus of the highway is located near Dawson City in west-central Yukon. A drive along the Dempster Highway takes you from its junction with the South Klondike Highway (Hwy 2), 717 km northeastward to Inuvik, Northwest Territories. On road maps this is Highway 8 in Northwest Territories, and Highway 5 in Yukon.

The Dempster Highway traverses diverse geological features and many contrasting landscapes. It passes rocks created hundreds of millions of years ago, mountain ranges with a complex history of continental collision, hints of the energy resources at depth, and evidence of recent glaciations.

The guide is an update and expansion of a guide produced for a fieldtrip sponsored by the Canadian Society of Petroleum Geologists (Norris et al., 1992). It also incorporates information from a guide by Tarnocai et al. (1993) and observations of the contributors in 2005 and 2006. In this guidebook you will find an introduction to the general bedrock geology, glacial history and mineral resources of the area, followed by a road log, and a glossary explaining ***geological terms (the first occurrence of the word is bold and italicized)***.

Fireweed meadow along the Dempster Highway, Yukon.

Cotton Grass meadow, Northwest Territories.

INTRODUCTION

The Dempster Highway is an all-weather highway through landscape that remains mostly wilderness. From its southern starting point (Km 0) east of Dawson City, Yukon it crosses the Arctic Circle (latitude 66°33’N) at Km 405, and passes from Yukon into Northwest Territories at Km 465. It also summits the ***continental divide*** between drainages to the Pacific and Arctic oceans (Km 82) and traverses two mountain ranges (Ogilvie and Richardson mountains) of the ***Canadian Cordillera.*** It is a spectacular landscape and your journey will be enriched if you can spare some time to enjoy it.

History of the Dempster Highway

Construction of the highway was sparked by Prime Minister Diefenbaker’s government “Roads to Resources” policy that addressed the need for access to natural resources of the north. Winter hauling of oil drilling equipment established the route through the Ogilvie Mountains to Eagle Plain. Between 1958 and 1961, about 115 km of road was completed from the southern end. Less than hoped-for results in the search for hydrocarbon exploration led to decreased government funding and sporadic construction for ten years. Gas exploration in the Mackenzie River delta and the Beaufort Sea was the impetus to complete the highway in 1979.

Highway engineers faced the challenge of ***permafrost***; most construction over ice-rich ground occurred during the winter to avoid melting. Permafrost is continuous across the landscape north of the Arctic Circle, but thinner and discontinuous in central Yukon. Along most of its length the highway sits on a 1-4 m thick gravel pad. The thickness is required to insulate the frozen substrate, because the dark road surface absorbs more summer heat than tundra vegetation. A second challenge was finding nearby deposits of road-surfacing gravel that could withstand wet weather, heavy loads, as well as provide a positive grip for rubber tires without cutting them.

The Dempster Highway is named after William John Duncan (Jack) Dempster who served with the Royal Northwest Mounted Police (RNWMP) for 37 years. He was the “Iron Man of the Trail” and led the expedition to find the remains of “The Lost Patrol” in 1911. The tragedy was the only serious mishap in the annual mid-winter dogsled excursion of the Dawson RNWMP to Fort McPherson. The excursions were run until 1921. The highway intersects the old patrol route at Chapman Lake (Km 116).

How to Get There

You can drive (or bike) the Dempster Highway from either Dawson City, Yukon or Inuvik, NWT. Dawson City is 536 km by road from Whitehorse. Inuvik is served by daily flights from Yellowknife and Whitehorse.

Kilometre (Km) 0 of the Dempster Highway is located at the bridge across the South Klondike River 45 km east of Dawson City. Signposts indicating kilometres are along the east side of the Highway. Eagle Plains Lodge (roughly halfway) is Km 369. Inuvik is Km 717.

Highway, Ferries, Travel Conditions, Services, Information

The Dempster Highway is North America’s most northern highway. It is open all year, but the Peel and Mackenzie rivers (Km 537 and 605 respectively) are uncrossable during spring thaw and fall freeze-up. From June to October, government ferries cross the Peel and Mackenzie/Arctic Red rivers on a regular schedule. From late November to April, an ice road is maintained across these rivers by the NWT Department of Transportation. Travelers are encouraged to check ferry schedules or the ice road status before beginning their journey.

Six territorial government campsites located along the highway are noted in this guide. Gas, food, and lodging are available at Dawson City, Eagle Plains Lodge, Fort McPherson and Inuvik.

Three Interpretive and Visitor Information centres that focus on the Dempster Highway are staffed from May to September. A blue building on Front Street in Dawson is dedicated to the "Road to the Western Arctic"; another centre at Km 71 (Tombstone Mountain Campground) displays local natural history; and the third centre is the Western Arctic Regional Visitor Centre in Inuvik.

Well maintained vehicle pullouts with informative signboards are currently located at:

- Km 0: landscapes, wildlife resources, services for the motorized traveler;
- Km 71: Interpretive centre - natural history displays and bulletin board of topical interest;
- Km 74: North Fork Pass viewpoint: nature of Tombstone Mountain, history of valley use;
- Km 102: Two Moose Lake: thaw Lakes and waterfowl;
- Km 259.2: Gwazhal Kak Rest area: surficial and bedrock geology, petroleum exploration;
- Km 378: Eagle River: RNWMP manhunt for the "Mad Trapper of Rat River";
- Km 405: Arctic Circle and Richardson Mountains;
- Km 465: Northwest Territories / Yukon border; and
- Km 528.5: Tetlit Gwinjik Wayside Park: viewing platform with interpretive signs.

NORTHERN CANADIAN CORDILLERA

The Dempster Highway is the most northerly road crossing the Canadian Cordillera. Current ***tectonics*** and ***seismicity*** across the northern Cordillera result from collision of the Yakutat ***terrane*** obliquely with the North American plate margin (Figure 1). The Yakutat terrane is a piece of oceanic-continental ***crust*** that has moved northwest on the Pacific Plate to collide with North America in the Alaska Trench. This collision both uplifts the crust of the St. Elias Mountains, which includes Canada's highest peak, Mount Logan, and drives upper crust of southern Yukon northeastward. This lateral motion is tracked by repeating GPS (global positioning system) measurements annually at selected bedrock sites throughout the northern Cordillera, which records an average rate of movement of about 5 mm/year. This information is significant in the effort to understand current plate tectonic motions and the origin of the Foreland Belt (Mackenzie Mountains; Figure 2) of the Cordillera. Earthquakes are indicators of current crustal deformation and indicate the location of ***faults*** in the crust. Although there is sparse distribution of seismographs in this part of the Cordillera, minor seismicity is concentrated along the Tintina Fault, and strong seismicity is detected beneath the Mackenzie and Richardson mountains (Figure 2).

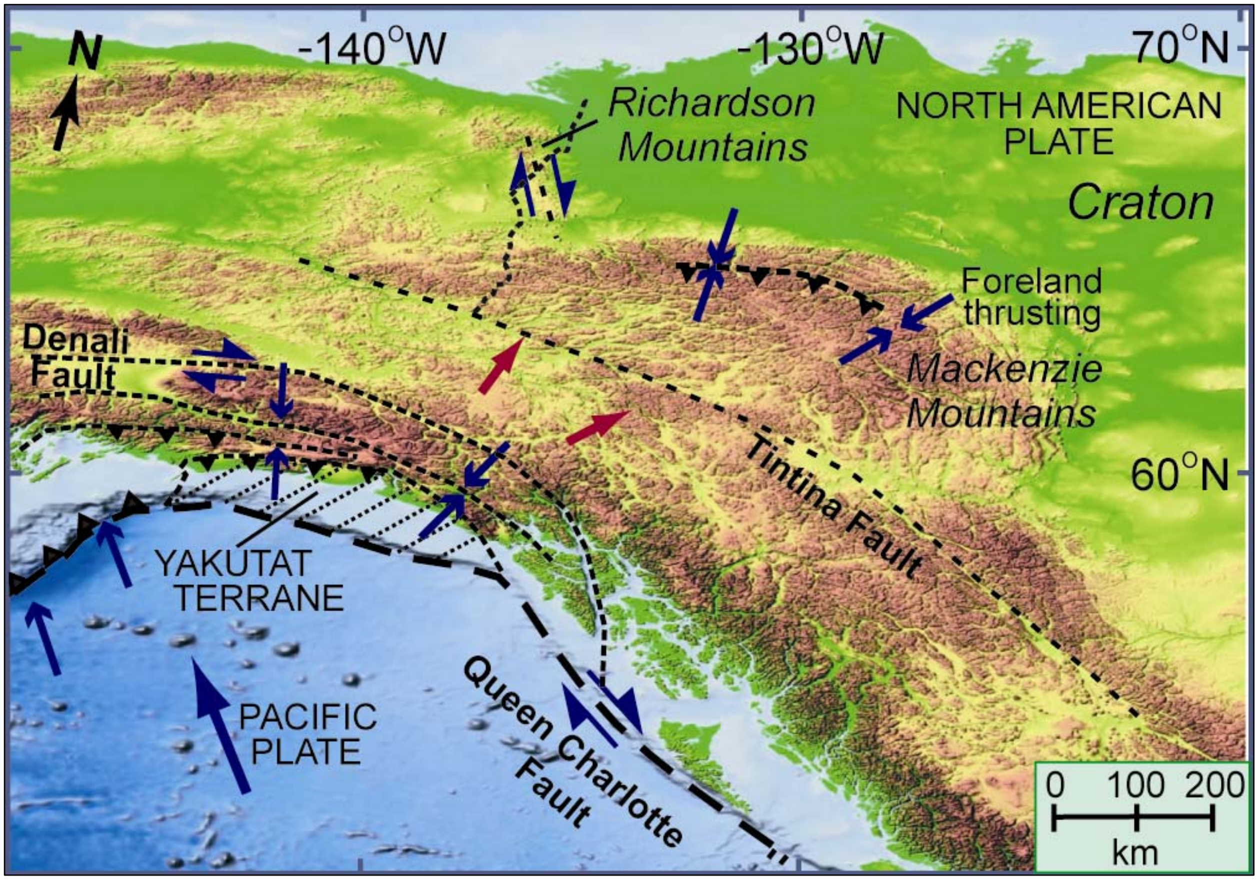


Figure 1. Current plate tectonic setting of the northern Canadian Cordillera. Dark blue arrows show relative Pacific and North America plate motion. Red arrows show the direction of movement of the northern Cordillera relative to North America motions. Broken lines represent fault systems (from Hyndman et al., 2005).

Geological Regions and Stratigraphy

Travelers of the Dempster Highway traverse several regions where the physical character (***physiography***) of the land is shaped by its geology and glacial history. Northwestern Canada is divided into two main areas: the ***Interior Plains*** which consist of generally flat-lying sedimentary rocks or ***strata***, and the ***Foreland Belt of the Cordillera*** which includes many of the same rocks but they show cumulative effects of mountain building (***orogeny***) during the last 150 million years (***Ma***). North of the Dempster Highway, the Arctic Coastal Plain of the mainland consists of the Mackenzie Delta and Yukon Coastal Plain. South of the Dempster Highway's southern terminus lie metamorphic rocks that were added to ancient North America by plate tectonics about 180 Ma.

The Interior Plains and Cordillera are divided into physiographic regions, which are shaped by different tectonic elements. Each tectonic element has its own structural style and tectonic history as well as ***stratigraphy***. The Dempster provides access to a variety of rock units and features across several regions encountered in this order (from Dawson City):

1) Tintina Trench and the Selwyn Fold Belt (Southern Ogilvie Mountains);
2) Taiga-Nahoni Fold Belt (Northern Ogilvie Mountains);
3) Eagle Fold Belt (Eagle Plain);
4) Richardson Anticlinorium (Richardson Mountains);
5) Northern Interior Platform; and
6) Aklavik Arch Complex (Figure 3).

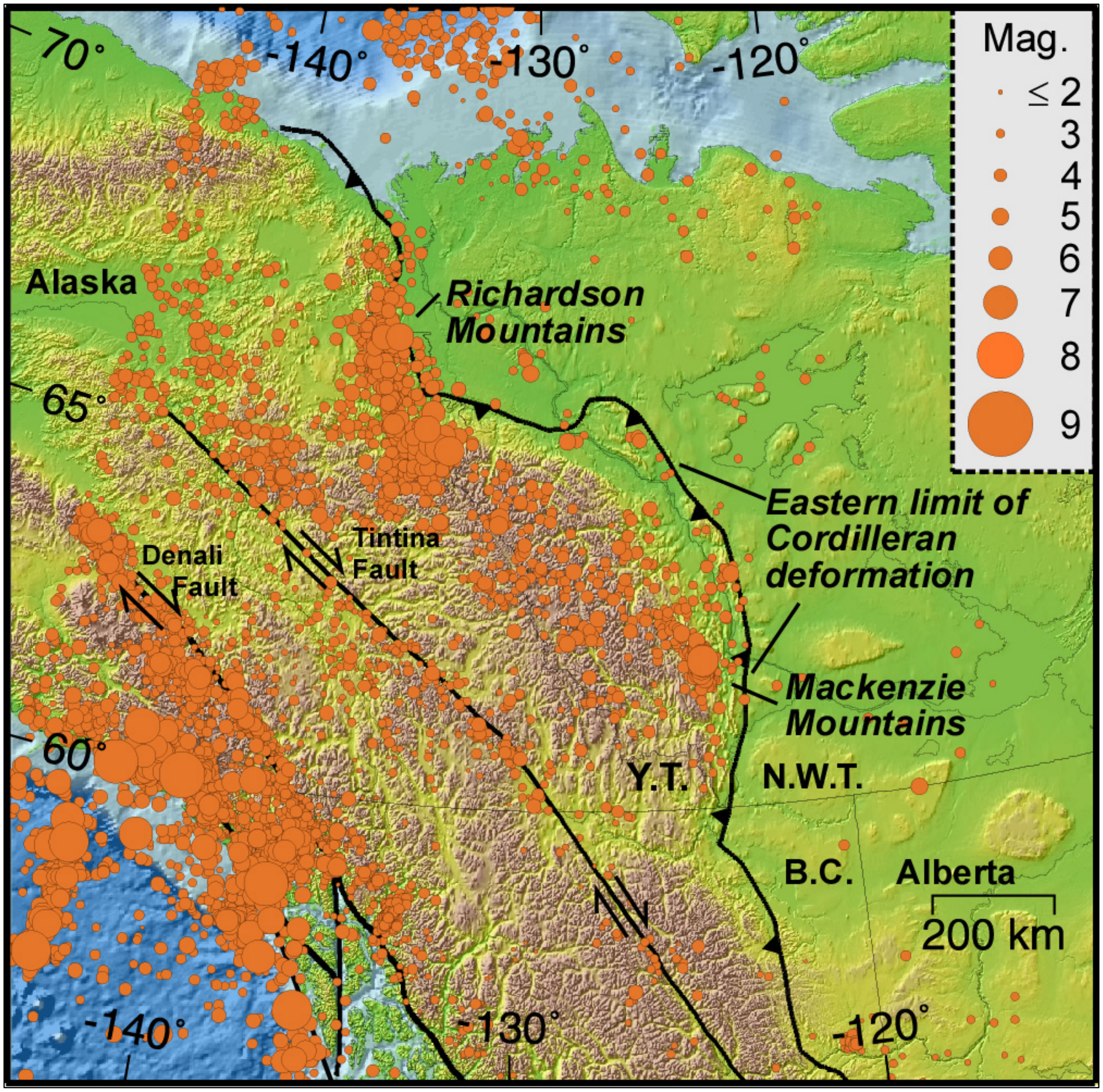


Figure 2. Seismicity of the northern Canadian Cordillera (scale is Richter; from Hyndman et al., 2005).

General Stratigraphy

The stratigraphic succession that makes up the Cordillera and Interior Plains extends as a supracrustal wedge of ***sedimentary*** rocks and sediments that thickens westward from the edge of the Canadian Shield. The wedge is up to 20 km thick and exposed by uplift in the Cordillera. The succession consists of six general stratigraphic assemblages that are separated by ***unconformities***. These assemblages (Figure 4) extend from the Proterozoic (as old as 1800 Ma) to Late Cretaceous (as young as 65 Ma). The supracrustal wedge lies on crystalline basement rocks that are thought to be the continuation of the Canadian Shield.

The Proterozoic assemblages (Wernecke Supergroup (>1800-1200 Ma), Pinguicula / Mackenzie Mountains supergroups (1200-800 Ma), and Windermere supergroups (800-543 Ma)) comprise about 60% of the sedimentary wedge. There are only a few outcrops of the Wernecke and Windermere supergroups near the Dempster Highway.

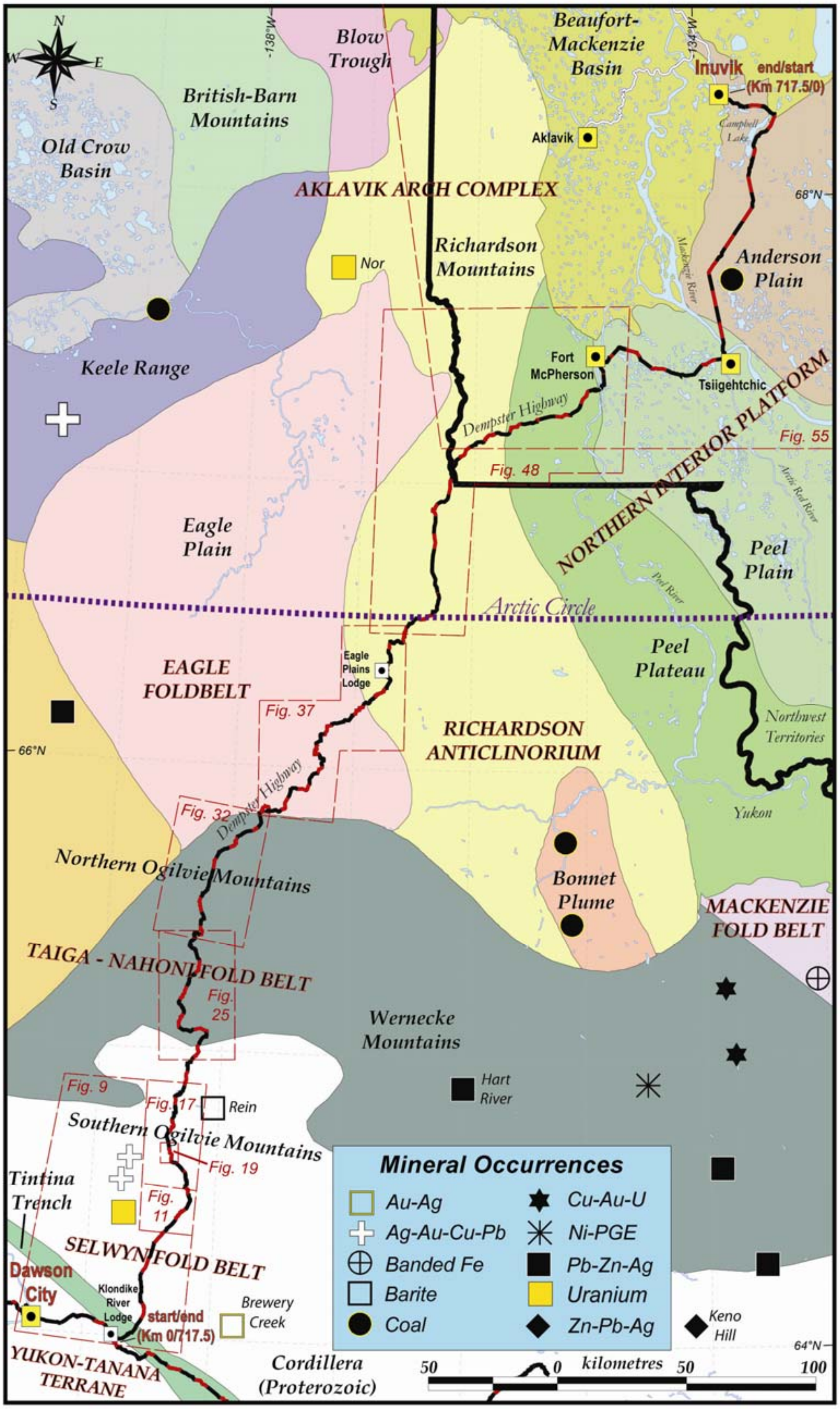
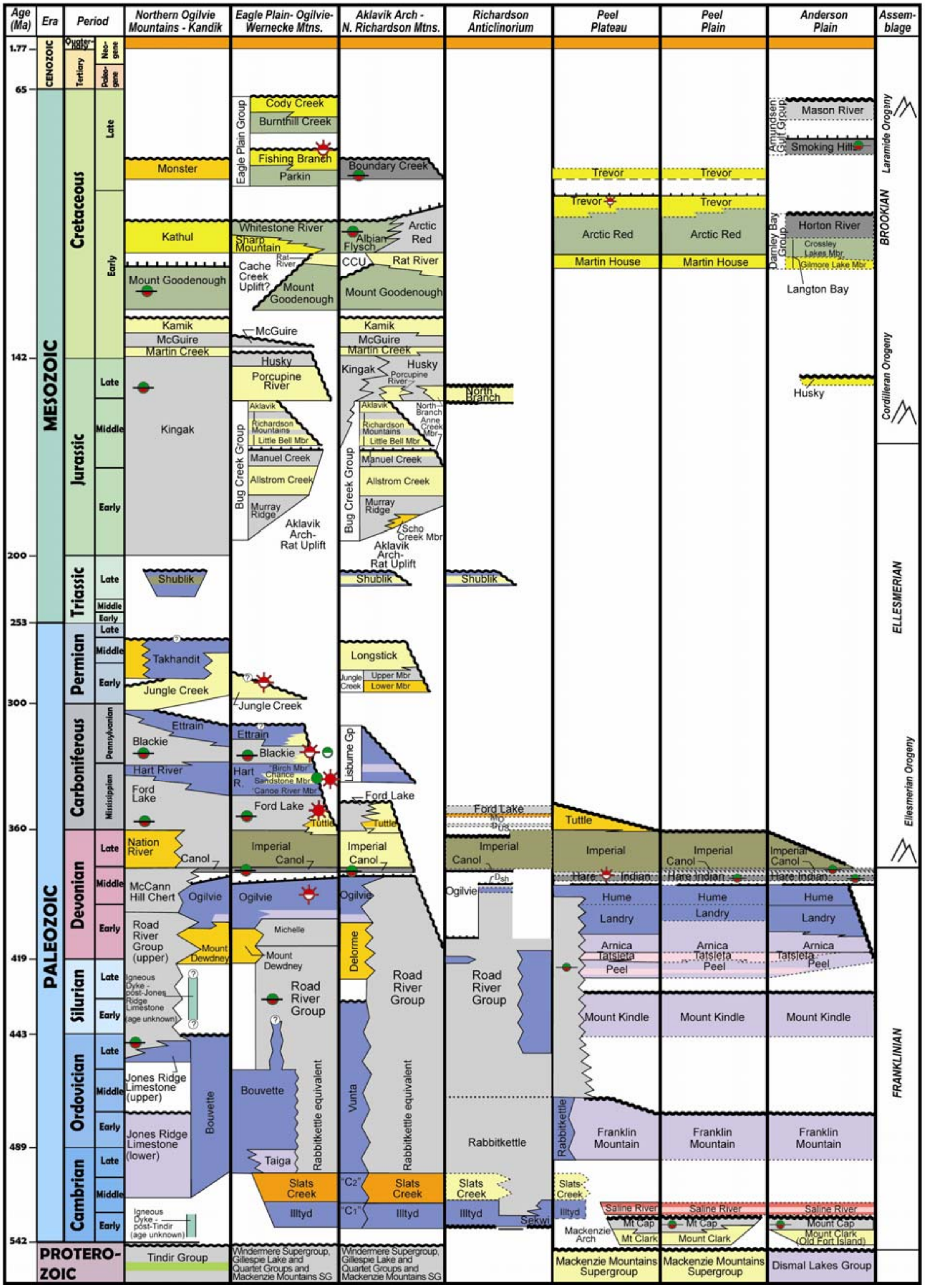


Figure 3. Hydrocarbon exploration regions (coloured areas, black labels, after Mossop et al., 2004) and key tectonic elements (all caps, red and black labels, after Norris, 1997) in the Dempster Highway region. Key mineral occurrences (from Yukon Minfile) and locations of other maps (figures) in this report are also included.



Age (Ma)
Era
Period
Northern Ogilvie Mountains - Kandik
Eagle Plain- Ogilvie-Wernecke Mtns.
Aklavik Arch - N. Richardson Mtns.
Richardson Anticlinorium
Peel Plateau
Peel Plain
Anderson Plain
Assemblage
CENOZOIC
MESOZOIC
PALEOZOIC
PROTEROZOIC
Quaternary
Tertiary
Neogene
Paleogene
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
Late
Middle
Early
1.77
65
142
200
253
300
360
419
443
489
542
Monster
Kathul
Mount Goodenough
Kamik
McGuire
Martin Creek
Kingak
Shublik
Takhandit
Jungle Creek
Ettrain
Blackie
Hart River
Ford Lake
Nation River
Canol
McCann Hill Chert
Ogilvie
Road River Group (upper)
Mount Dewdney
Igneous Dyke - post-Jones Ridge Limestone (age unknown)
Jones Ridge Limestone (upper)
Jones Ridge Limestone (lower)
Bouvette
Igneous Dyke - post-Tindir (age unknown)
Tindir Group
Eagle Plain Group
Cody Creek
Burnthill Creek
Fishing Branch
Parkin
Whitestone River
Sharp Mountain
Rat River
Cache Creek Uplift?
Mount Goodenough
McGuire
Husky
Porcupine River
Aklavik
Richardson Mountains
Little Bell Mbr
Bug Creek Group
Manuel Creek
Allstrom Creek
Murray Ridge
Aklavik Arch-Rat Uplift
Jungle Creek
Ettrain
Blackie
Hart R.
Birch Mbr
Chance Sandstone Mbr
Canoe River Mbr
Ford Lake
Tuttle
Imperial
Canol
Ogilvie
Michelle
Mount Dewdney
Road River Group
Bouvette
Rabbitkettle equivalent
Taiga
Slats Creek
Illtyd
Windermere Supergroup, Gillespie Lake and Quartet Groups and Mackenzie Mountains SG
Boundary Creek
Albian Flysch
Arctic Red
CCU
Rat River
Mount Goodenough
Kamik
McGuire
Martin Creek
Kingak
Husky
Porcupine River
Aklavik
Richardson Mountains
North Branch
Anne Creek Mbr
Little Bell Mbr
Manuel Creek
Allstrom Creek
Murray Ridge
Scho Creek Mbr
Aklavik Arch-Rat Uplift
Shublik
Longstick
Jungle Creek
Upper Mbr
Lower Mbr
Lisburne Gp
Ford Lake
Tuttle
Imperial
Canol
Ogilvie
Delorme
Road River Group
Vunta
Rabbitkettle equivalent
"C2"
"C1"
Slats Creek
Illtyd
Windermere Supergroup, Gillespie Lake and Quartet Groups and Mackenzie Mountains SG
North Branch
Shublik
Ford Lake
Imperial
Canol
Ogilvie
Road River Group
Rabbitkettle
Slats Creek
Illtyd
Sekwi
Trevor
Arctic Red
Martin House
Tuttle
Imperial
Hare Indian
Hume
Landry
Arnica
Tatsieta
Peel
Mount Kindle
Rabbitkettle
Franklin Mountain
Slats Creek
Illtyd
Saline River
Mt Cap
Mt Clark
Mackenzie Arch
Mackenzie Mountains Supergroup
Trevor
Arctic Red
Martin House
Imperial
Canol
Hare Indian
Hume
Landry
Arnica
Tatsieta
Peel
Mount Kindle
Franklin Mountain
Saline River
Mt Cap
Mount Clark
Mackenzie Mountains Supergroup
Amundsen Gulf Group
Mason River
Smoking Hills
Darnley Bay Group
Horton River
Crossley Lakes Mbr
Gilmore Lake Mbr
Langton Bay
Husky
Imperial
Canol
Hare Indian
Hume
Landry
Arnica
Tatsieta
Peel
Mount Kindle
Franklin Mountain
Saline River
Mount Cap
Mount Clark (Old Fort Island)
Dismal Lakes Group
Laramide Orogeny
BROOKIAN
Cordilleran Orogeny
ELLESMERIAN
Ellesmerian Orogeny
FRANKLINIAN

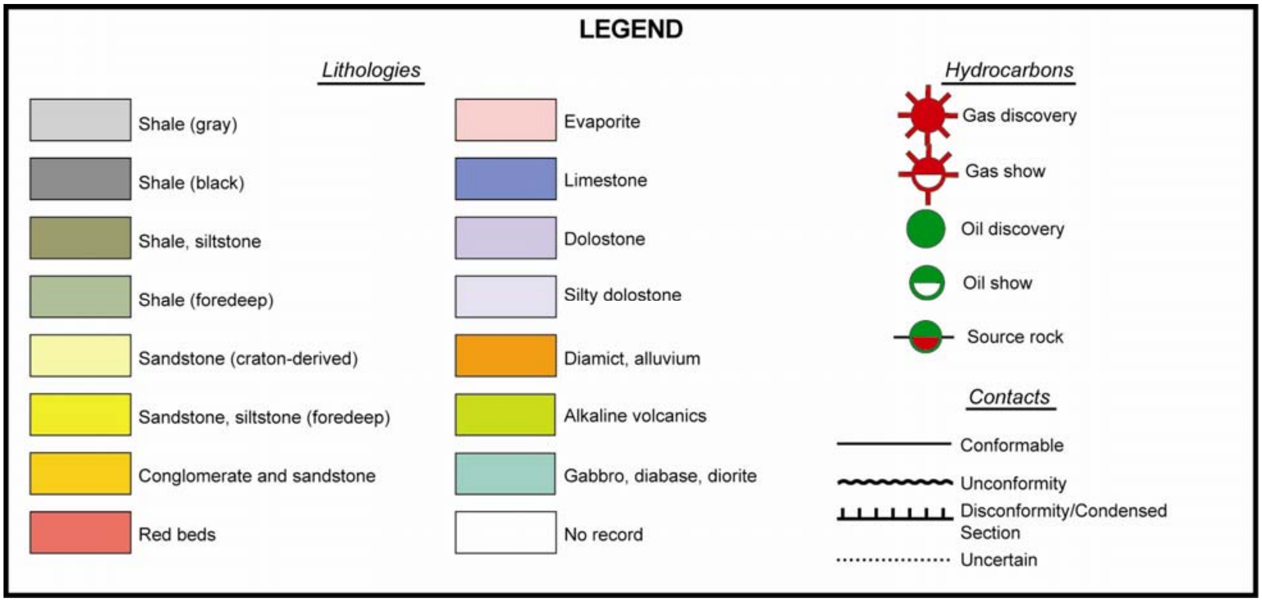


Figure 4. Schematic stratigraphy exposed in the tectonic elements of the Dempster Highway region. Northern Ogilvies after: Dixon (1992, 1998), Gabrielse and Yorath (1991), Morrow (1999), Norris (1997), and Pugh (1983); Eagle Plain-Ogilvie-Wernecke Mountains after: Dixon (1992, 1998), Gabrielse and Yorath (1991), Morrow (1999), Norris (1997), Osadetz et al. (2005), and Pugh (1993); Aklavil Arch-Northern Richardson Mountains, Richardson Anticlinorium after: Dixon (1992, 1998), Gabrielse and Yorath (1991), Morrow (1999), Norris (1997), and Pugh (1993); Peel Plateau after: Cook and MacLean (2004), Dixon (1999), Dixon and Stasiuk (1998), Morrow (1991, 1999), and Pugh (1993); Peel Plain after: Cook and MacLean (2004), Dixon (1999), Dixon and Stasiuk (1998), Morrow (1991, 1999), and Pugh (1993); Anderson Plain after: Cook and MacLean (2004), Dixon (1999), Morrow (1991, 1999), and Pugh (1983, 1993).

TIME SCALES IN GEOLOGY TALES

The stock-in-trade of most geologists is elucidating the order of geological events. To help them, a well established sequence of eras, periods and smaller divisions form the Geological Time Scale. Boundaries of geological time periods are based upon stratigraphic position of age-characteristic fossils (increasingly refined using microfossils) and cross-referenced with numeric dates derived from the decay of radioactive elements in minerals that crystallized during cooling (igneous rocks) or changed ambient conditions (exposure to sunlight, for example). The vertical axis of Figure 4 (Table of Formations) depicts both geological time periods and their approximate age. On the page-size geological maps in this guidebook only the numerical span of rock units in millions of years (***Ma***) is shown, highlighting their relative age.

Between rocks and the unconsolidated deposits overlying them is both a large span of time, but also a different scale of time. Rocks in the Dempster Highway region range from 80 to 1800 Ma, but the geologic events they record is selective (largely because preservation is favoured by rapid underwater burial in basins and troughs. In contrast the glacial and ***colluvial*** deposits are positive topographic features ranging from several million to about ten thousand years (**ka**) old; collectively they are called Neogene (Figure 4). The moraine and till veneers of the last Ice Age that are roadside companions from Km 0 to 140 undoubtedly had different configurations during earlier glaciations, but only the last two; the ***Reid*** (300-200 ka) and the ***McConnell*** (25-12 ka) can be distinguished today. Another contrast is their preservation: most rock exposures will change little during a human lifetime while some glacial and fluvial components of the landscape may be radically altered in this short span of geologic time.

The overlying Franklinian assemblage (543-400 Ma) is mainly a ***passive continental margin*** succession deposited along the edge of ancestral North America. These rocks were deposited on a broad, shallow-water platform, and in an adjacent deeper water basin. The Ellesmerian assemblage (400-135 Ma) is characterized by the influx of fine sediments shed from newly uplifted source areas to the north (the Ellesmerian Orogeny) and block-faulting and local ***erosion*** of basinal Franklinian assemblage in the south and east. The youngest assemblage (135 Ma to present; Brookian Assemblage on Figure 4) represents the Cordilleran orogeny in which sediments were derived from uplift and erosion of the preceding assemblages to the south and southwest.

Tintina Trench and Selwyn Fold Belt

The southern terminus of the Dempster Highway lies in the Tintina Trench, an extensive (1000 km long) valley feature that marks the position of Tintina Fault, a dextral (right-lateral) ***transcurrent fault***. Vastly different geological provinces are separated by the fault. To the south lies the Yukon-Tanana Terrane consisting of ***metamorphic*** and ***igneous intrusive*** rocks, juxtaposed with the Selwyn Fold Belt (dominantly ***sedimentary*** rocks) to the north (Figure 3). The fault extends vertically to the base of the crust; along its trace the crushed rocks have dropped into a ***graben*** and are overlain by younger sediments (including coal) and, in a few places, by lava flows. Offset of older rocks exposed on both sides of the fault indicate at least 425 km of right-lateral displacement: those around Dawson today were adjacent to the Ross River area about 100 Ma before present. Tintina Fault is the northeastern-most, and oldest, of the great faults that cut northwesterly through the northern Cordillera.

The Selwyn Fold Belt in the Dempster Highway area of the Southern Ogilvie Mountains exposes deformed sedimentary rocks of the Windermere Supergroup, Franklinian and Ellesmerian assemblages, intruded by 92 Ma igneous intrusions. Most of Franklinian strata were deposited in a regional deep-water feature called the Selwyn Basin (Figure 5; note that the Richardson Mountains contain related deep-water strata). These and the overlying Ellesmerian strata comprise three different stratigraphic successions that have been telescoped together by north-directed ***thrust faults***: the Dawson, Tombstone and Robert Service thrusts (Figure 5). The Tombstone thrust and strata above and below it are intruded by cylindrical intrusions from 0.2 to 10 km diameter; it is a type of granite exposed in towers and precipitous cliffs that give the area its name. North of Dawson fault the Franklinian assemblage consists of mostly shallow water ***carbonate*** rocks. Several kilometres east and west of the Dempster Highway the carbonate has been arched and eroded, exposing underlying Proterozoic strata (Wernecke and Pinguicula supergroups). In contrast, the Dempster Highway passes through the Taiga Valley which is a structural low (hollow) underlain by black ***siliciclastic*** rocks of the Ellesmerian assemblage.

Taiga-Nahoni Fold Belt

The Dempster Highway winds through the Northern Ogilvie Mountains (which contains the Taiga and Nahoni ranges; Figure 3). The complex orientation of folded strata in this region of the Cordillera is one of the best examples of fold trains or linkages in North America. Fold “bundles” are west-trending in Taiga Ranges and north-trending in Nahoni Ranges along a 375 km stretch. These disparate fold orientations meet at the headwaters of the Ogilvie River at a point

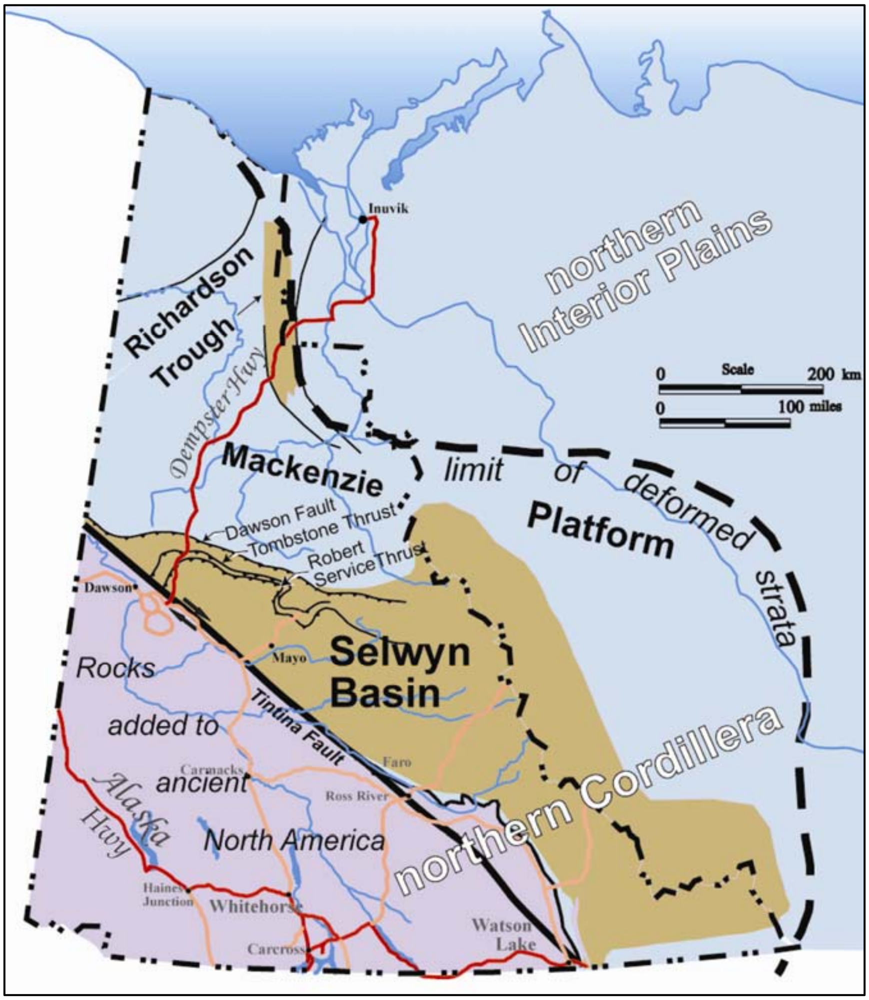


Figure 5. Paleozoic depositional features in northern Yukon and selected faults. Small teeth on the fault line indicate the side which is thrust over the other. Arrows give the relative sense of movement on the Tintina Fault.

called the Ogilvie Deflection. This deflection wraps around Eagle Plain. Resistant Devonian Ogilvie Formation limestone forms the mountain front of the Taiga Ranges and outlines fold patterns.

The exposed stratigraphic succession spans 1700 Ma from the Wernecke Supergroup to Late Cretaceous Monster Formation (Figure 4). The oldest sediments represent deposition in an intracratonic basin. Unconformably overlying carbonate units of the Pinguicula Supergroup suggest periodic shallow marine conditions.

Episodes of extension beginning around 780 Ma and local volcanism led to continental rifting about 600 Ma, succeeded by a thick package of siliciclastics and carbonate units of the Windermere Supergroup.

An unconformity separates the Proterozoic succession from the overlying Paleozoic rocks. Early Paleozoic paleogeography was complex. A crustal block called the Yukon Stable Block became separated from North America by basins called the Richardson Trough and Selwyn Basin. Shallow water carbonates were deposited during the Cambrian and Ordovician and were replaced by deep-water deposits such as chert and black shale as sea level rose through the Middle Ordovician to Middle Devonian. An extensional phase occurred in the Late

Devonian and is marked by deposition of conglomerate, sandstone, and shale in grabens.

Carboniferous to Triassic sediments indicate an emergent southern landmass during deposition of the Keno Hill Quartzite. In the late Early Jurassic (about 185 Ma) the beginning of the Cordilleran Orogeny resulted in deposition of Jurassic shale and siltstone, then Late Jurassic to mid-Cretaceous turbiditic sandstone and shale that are now preserved in the Monster, Kandik and Eagle Plain basins.

Eagle Fold Belt

The Eagle Fold Belt lies west of the Richardson Anticlinorium and south of the Aklavik Arch Complex and is coincident with the Eagle Plain (Figure 3). Several generations of structures indicate a complex history of deformation events related to Early Tertiary mountain building. The belt mainly involves Cretaceous siliciclastic rocks of the Eagle Plain Group that are widespread at surface in this region (Figure 4). Hydrocarbon reservoirs are in both structural traps, as well as stratigraphic relationships such as unconformities that truncate upper Devonian through Lower Cretaceous formations. Porous Carboniferous sandstone at this unconformity was discovered in 1960 to contain oil in southern Eagle Plains. This area remains underexplored for oil and gas in sub-unconformity, stratigraphic, and structural traps.

Richardson Anticlinorium

The Richardson Anticlinorium is a broad, north-trending, ***anticline*** separating the Northern Interior Platform from the Eagle Fold Belt. It is bound by the Trevor Fault to the east and Deception Fault to the west. This structure coincides in position with the Paleozoic Richardson Trough, a deep water basin that accumulated shale and slope-debris breccias composed of carbonate ***clasts*** shed from the flanking carbonate banks of the Interior and Eagle platforms. In the core of the ***anticlinorium*** the oldest rocks of the Wernecke Supergroup are unconformably overlain by Cambrian limestone, suggesting the removal of about 10 km of Precambrian strata (Figure 4). The anticlinorium contains the Richardson Fault Array, a set of steeply dipping, north-trending faults. Strands of the array show dextral (right-hand) displacements up to 40 km in Devonian age and older rocks; Carboniferous and younger formations lack horizontal displacement across faults. The anticlinorium formed during the Cordilleran Orogeny, from Late Cretaceous to early Tertiary east-west convergence. Seismicity is strong in the Richardson Mountains and there has been a concentration of earthquakes over the east flank of the anticlinorium (Figure 3).

Northern Interior Platform

Between Inuvik and the Richardson Mountains, the Dempster crosses Anderson Plain, Peel Plain, and Peel Plateau that lie in the Interior Platform (Figure 3). These areas are continuous with each other, with the Arctic Red River separating Anderson and Peel plains, and Peel River forms the boundary between Peel Plain and Peel Plateau. Flat-lying strata of the Interior Platform consist of the supracrustal wedge, mainly with exposures along river cuts or in borrow pits. These are mainly siliciclastic sediments of the Devonian Imperial Formation and Cretaceous Arctic Red Formation (Figure 4). The western boundary of this region is the front of the Richardson Mountains.

Aklavik Arch Complex

The Aklavik Arch Complex is a series of uplifted and depressed crustal blocks arranged right-hand en echelon (staggered) and separated by northeasterly trending vertical faults. The complex extends from east of Mackenzie Delta to the Keele Range near the Yukon-Alaska boundary. Its northeast extremity is called Campbell Uplift, which is exposed near Inuvik (Figure 3). Many unconformities occur through the succession of the arch complex, suggesting prolonged, intermittent tectonic activity. At Campbell Uplift, nearly flat-lying Paleozoic carbonate rocks overlie deformed Proterozoic siliciclastic and carbonate rocks. In the Aklavik Range of Richardson Mountains, Permian rocks lie with ***angular unconformity*** upon Lower Devonian or older Road River Group, and elsewhere in the complex, Permian rocks lie on Upper Devonian Imperial Formation (Figure 4). Both relationships are expressions of the Ellesmerian Orogeny. There are additional unconformities at the base of the Jurassic, lower Cretaceous, and upper Eocene successions which also indicate uplift and of the Arch.

GLACIAL HISTORY

The Dempster Highway traverses glaciated and unglaciated landscapes. The limited amount of ice during the glaciations is a result of the region's overall aridity (lack of precipitation). The areas not covered by ice formed the eastern edge of Beringia (Figure 6). Beringia was a cold, dry and windy subcontinent that joined Alaska to far-east Russia across a lowland where the Bering Strait is today. Beringia was cut off from southern Eurasia and southern North America by continental ice. Two distinct glaciated landscapes are present along the Dempster Highway and are associated with the Cordilleran (from the south) and Laurentide (from the east) ice sheets.

The Cordilleran Ice Sheet covered most of central and southern Yukon and advanced westward and northwestward, at least four times during the Quaternary Period, from 2.5 Ma to about 11 thousand years (***ka***) ago. Deposits of the last two glaciations, the ***Reid*** (300-125 ka), and the ***McConnell*** (25-11 ka) are well defined, but older glacial deposits are collectively referred to as "pre-Reid". They filled the Tintina Trench near the southern terminus of the Dempster Highway with more than 200 m of ***glacial drift***. During each of the Quaternary glaciations ice formed in the Ogilvie Mountains. The extent of ice produced has varied between glaciations, whereby the McConnell limit (last ice age) is significantly less than the Reid limit (second to last ice age). During the Reid glaciation, ice lobes from high in the Southern Ogilvie Mountains advanced down the North Klondike eroding this river valley almost to its present level; other lobes advanced northward toward the Taiga Valley. The most recent McConnell glaciation consisted only of shorter glaciers which barely reached the end of their tributary valleys. See Table 1 for a summary of glacial effects in the Dempster area.

Before the Ice Age about 3 million years ago, the Southern Ogilvie Mountains lay near the head of a vast south flowing drainage system. Rivers probably flowed southeast along Tintina Trench and in the current Yukon River channel, but in the opposite direction. This system drained southward to the Gulf of Alaska (Figure 7). The first glaciation drastically changed this drainage pattern when ice lobes from the Coast Range and the Cassiar Mountains blocked the southerly exit. The blocked drainage caused a large glacial lake to

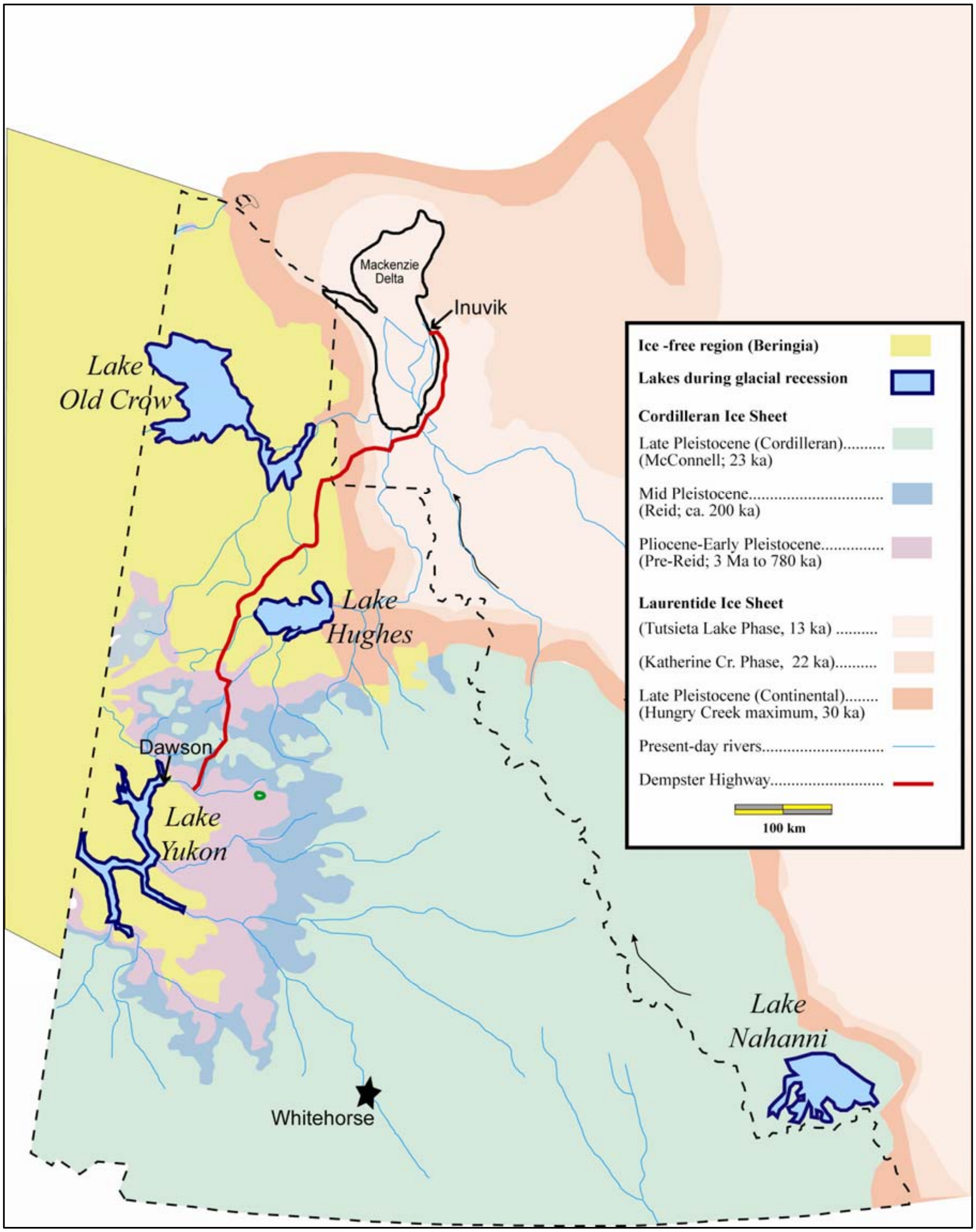


Figure 6. Regions covered by ice during McConnell, Reid, pre-Reid (maximum extent) and Katherine glaciations (modified after reduction from Duk-Rodkin, 1999).

develop in central Yukon, which eventually found a new outlet to the northwest near Dawson City (Figure 6). This outlet entered into an older west draining stream now referred to as the Kwikpak River, which flowed across Beringia to the Beaufort Sea.

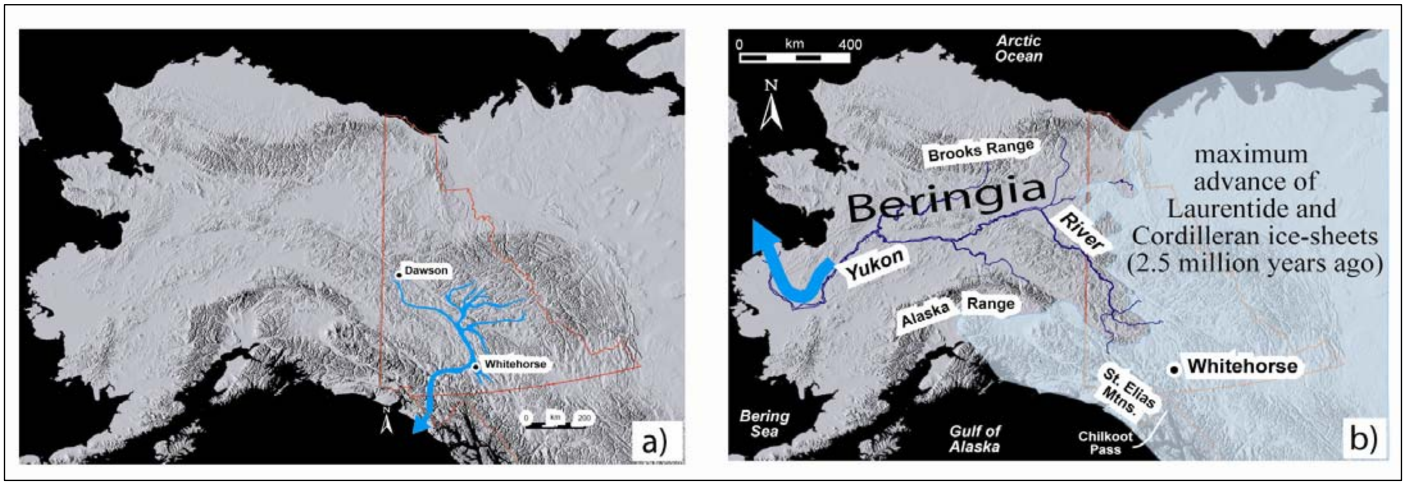


Figure 7. Major drainage pattern for central Yukon: a) before glaciation, and b) after glaciation.

Although it is unclear when during the ice age this massive shift in drainage first established, the reversal is appreciated in viewing the landscape west of Dawson, where the mighty Yukon River down-cuts large bluffs and entrenched meanders that were once the headwater of a smaller stream.

The Laurentide Ice Sheet covered the Interior Plains, east of the Richardson Mountain divide, and reached its maximum extent around 30 ka. At least two more advances occurred later in the glaciation prior to 10.6 ka years ago. The Inuvik area was glaciated around 30 ka; this part of the ice sheet extended across the Yukon Coastal Plain northwest to Herschel Island and into the Richardson Mountains up to about 900 m elevation. A lobe of this ice sheet also extended southwest into Bonnet Plume Basin (Figure 3) and diverted the drainage of the upper Peel River northward along the Eagle River drainage channel. As Laurentide ice flowed up against the Richardson Mountains it blocked McDougall Pass and dammed the previously eastward course of the Porcupine River to the Mackenzie Delta.

MINERAL AND HYDROCARBON RESOURCES

Northwestern Canada has excellent potential for minerals and hydrocarbon resources (Figure 3). Dempster Highway construction was initiated to access prospective hydrocarbon resources of Eagle Plain, and its completion was spurred by exploration activity targeting the petroleum potential of the Mackenzie Delta and Beaufort Sea. Mining is an important component of Yukon's economy (such as the famous Klondike gold rush that established Dawson City), and there is renewed interest in hydrocarbon resources. In NWT, both mining (including new diamond discoveries) and hydrocarbon production (like Canada's fourth largest producing oil field at Norman Wells and promising oil and gas resources of the Beaufort-Mackenzie Region and Mackenzie Valley) are significant economic contributors.

Geological Region	Laurentide Ice	Cordilleran Ice	Unglaciated
Southern Ogilvie Mtns.		**X**	
Northern Ogilvie Mtns.			**X**
Eagle Plain	**X**		**X**
Richardson Mountains			**X**
Peel Plateau	**X**		
Peel & Anderson plains	**X**		
Beaufort-Mackenzie Basin	**X**		

Table 1. Glacial effects in regions near the Dempster Highway.

ROAD LOG

Introductory Notes

This guide begins at the southern terminus of the Dempster Highway, 45 km east of Dawson City, Yukon. Cumulative distance from Km 0 are listed first; these correspond to km posts on the Dempster Highway in Yukon. These posts are sparse, or not maintained in the NWT, so distances from the NWT/YT border are also included. The numbers in square brackets are the distance from Inuvik, NWT.

Geology Stops

GEOLOGY STOPS (or Geo-STOPS on maps provided) are sites selected for rewarding visits by amateur geologists and rockhounds. The criteria are: well-exposed rock, interesting minerals or fossils or significance in the geological history. In addition these places permit safe exit from the highway and parking, are relatively free of natural hazards, and provide recreational opportunities. However, be aware of your surroundings and use caution at all times.

These stops are at:

- Km 74: North Fork Pass view point and roadcut of black chert (Road River Group; Ordovician age). A side road 300 m north is the trailhead for Goldensides Mountain, slate of Hyland Group (Latest Proterozic to Middle Cambrian);

- Km 96: Palsa bog (permafrost melting since about 1960). Examine thick peat of the tundra;
- Km 143: Wernecke Supergroup: Quartet sandstone and intrusive hematite-rich breccia (mid-Proterozoic);
- Km 153: Windy Pass. Short walk to examine Bouvette dolostone (Cambrian to Lower Devonian);
- Km 210: Fossils in black shale: Michelle Formation (Lower Devonian);
- Km 253: Sandstone of Fishing Branch Formation, Eagle Plain Group (Lower Cretaceous);
- Km 348: Siliceous limestone of Hart River Formation (Lower Carboniferous);
- Km 369: Eagle Plains Lodge: Sandstone of Tuttle Formation (Lower Carboniferous) near the campsite and quarry across the Highway;
- Km 396: Fossils in Ford Lake Shale (Lower Carboniferous);
- Km 446: Graptolite fossils in Road River Formation (Ordovician to Lower Devonian);
- Km 485: Deformed (folded) Devonian Imperial Formation in Vittrekwa Pass;
- Km 537: Sedimentary rocks and fossils along eastern bank of Peel River ;
- Km 609: Tsiigehtchic quarry. Sedimentary structures and fossilized plant remains (Upper Devonian);
- Km 693: *Tithegeh Chi'vitail* Park. Fossiliferous Devonian limestone; and
- Km 710: Paleozoic carbonate with abundant fossils (crinoids, brachiopods, corals).

Hiking Access

Some designated trails provide HIKING ACCESS to notable rock or glacial features. The trail heads for these are at:

- Km 58: Grizzly Lake trail and viewpoint;
- Km 72: (Tombstone campground) North Fork River and Canyon hike;
- Km 74: Goldensides Mountain; and
- Km 82: Angelcomb Mountain.

The recreational traveler will find easy access for alpine hiking, particularly near the Highway summits at North Fork Pass (Km 72-82), Windy Pass (Km 152-154), Wright Pass (Km 451) and Vittrekwa Pass (Km 511). Please treat the fragile vegetation with care.

North Klondike River Valley to Continental Divide (Km 0 to 82)

The Dempster Highway follows the North Klondike River valley in the Southern Ogilvie Mountains and diverges from it to the continental divide at North Fork Pass (Km 82). Below treeline, the highway passes through a spruce, aspen, cottonwood, and birch forest and eventually passes into alpine tundra.

The first 10 km of the Dempster Highway crosses the ***outwash*** plain of Reid and pre-Reid glaciations. It then passes through hummocky and disordered moraine and mountainside colluvium until it descends to the valley floor around Km 60.

Km 0 [717.5 km]: Start of the Dempster Highway

At Km 670 of the Klondike Highway is the southern terminus of the Dempster Highway, beside the Klondike River Lodge (gas, meals, accommodation).

The Klondike Highway continues 45 km west to Dawson City. The geology along it and in the Dawson area is in the process of being compiled by the Yukon Geological Survey (check with the Survey for more information on this project).

A large and informative signboard is set up near the T-junction - a good place for your first photographs (Figure 8).

Km 0.2 [717.3 km]: Bridge across the Klondike River

Km 0-4.0 [717.5-713.5 km]: The buried Tintina valley

The ***strike-slip*** fault here is the oldest of three prominent northwest trending strike-slip faults in Yukon. The southwestern side of Tintina Fault has moved 425 km in the last 90 million years, but has minor and irregular seismicity today. The linear valley extends from Watson Lake in southeast Yukon, to Alaska, north of Circle. Where crossed by the Dempster Highway the valley is muted by glacial drift from Quaternary glaciations. The terminal ***moraine*** (farthest point reached by the alpine glaciers from valleys of the Ogilvie Mountains) from the Reid glaciation (300-125 ka) is about Km 8 on the Dempster Highway (Figure 9).

Figure 8. Welcoming signs at the southern terminus of the Dempster Highway (Km 0).

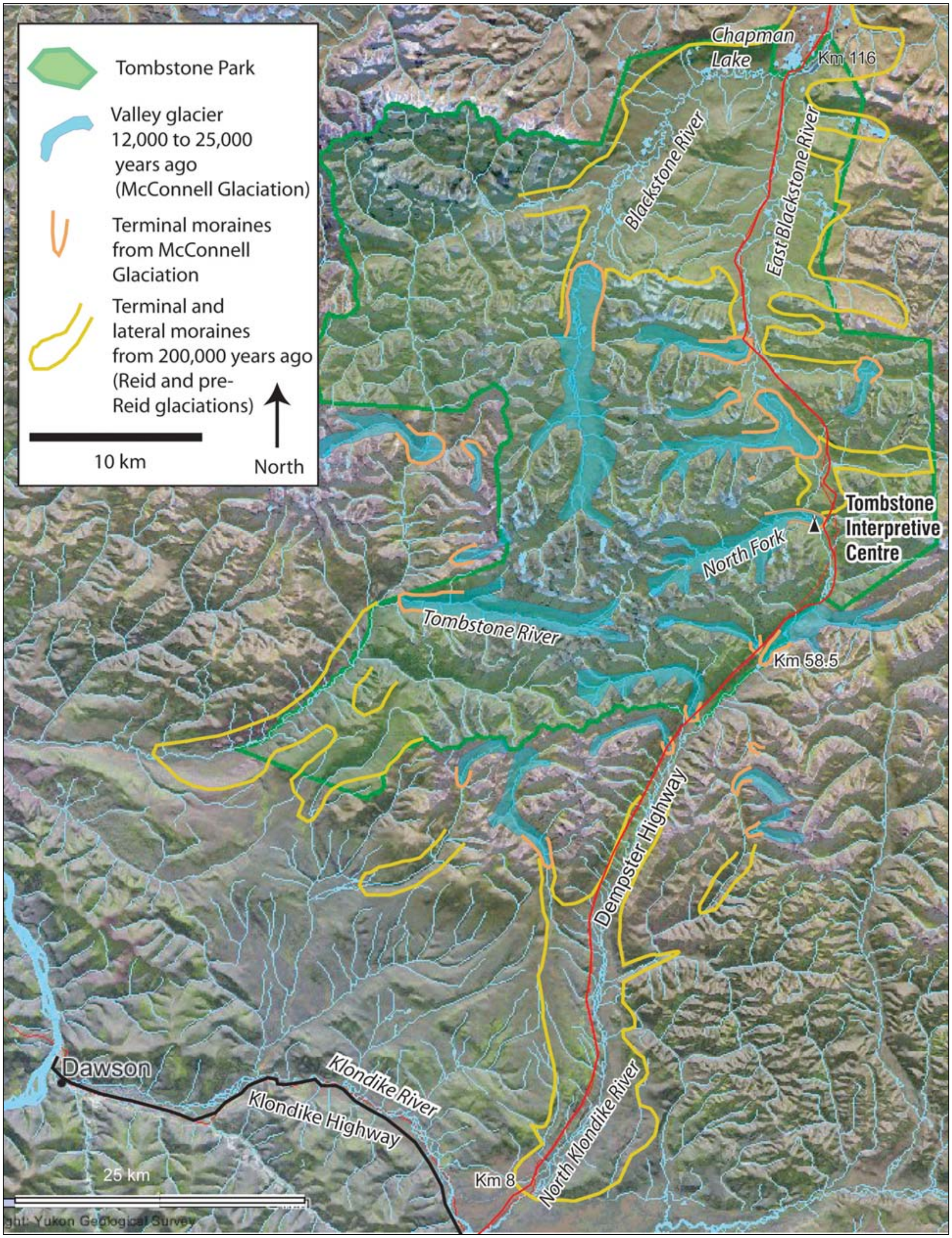


Figure 9. Distribution of glacial features in the Southern Ogilvie Mountains (after Duk-Rodkin, 1996).

Km 5.8 [711.7 km]: End of pavement, gravel surface begins

Km 6.5 [711.0 km]: North Fork ditch

Here the highway diagonally crosses a 4 m wide ditch with a service road along the north side. This canal was dug around 1910 to divert water from the tributaries of the Klondike River to a hydroelectric power plant. Although the electricity primarily powered the gold-mining dredges, the North Fork power plant was also the main source of power for Dawson, with interruptions during deep cold and spring breakup, until 1966. After 1966 the city relied on diesel-powered generators for electricity until 2004, when an electricity line was built to the power dam on the Mayo River, about 200 km to the southeast.

Km 7.9 [709.6 km]: Access to former Brewery Creek mine

The road extends 30 km east to an open-pit mine that operated profitably between 1997 and 2001. More than 8.5 million grams (266,000 oz.) of gold was recovered by dripping cyanide solution (heap-leach process) through carefully prepared beds of pulverized rock. The mine is now decommissioned: open cuts are filled in, re-contoured and revegetated. The former leach pads have been neutralized and are monitored.

Km 10.5 [707 km]: View to Antimony Mountain

This triangular peak, 30 km to the northeast, is your first glimpse of the Southern Ogilvie Mountains. Its summit (2040 m) is at the centre of an igneous intrusion of the same age and rock types as Tombstone Mountain. A quartz vein containing the antimony-bearing mineral stibnite (in some areas of the world this mineral is used as a hardening alloy for lead) occurs high on the west flank of the mountain, and several copper-gold prospects are in the surrounding area.

Km 16.0 [701.5 km]: Abundant moraines

Sand and gravel deposits in a series of borrow pits on the west side of the highway around Km 16 were used to build the 3.0 m thick roadbed so that underlying ice-rich ground (permafrost) would not melt. Glaciers advancing out of the many U-shaped valleys in the Ogilvie Mountains left these deposits during the Quaternary glaciations that began about 3 million years ago.

While glaciers have been common in the Ogilvie Mountains, much of nearby western Yukon and central Alaska have remained ice-free during the Ice Ages. This area was a windy, treeless subcontinent called Beringia that was cut off from mid-latitude North America by huge ice sheets for long periods of time. The Dawson area remained ice free and was home to numerous species of now extinct mammals, such as wooly mammoth, Yukon horse and steppe bison.

GEOLOGICAL SYNOPSIS OF SOUTHERN OGILVIE MOUNTAINS (FROM TINTINA TRENCH TO TOMBSTONE CAMPGROUND - KM 0 TO 69)

The southern end of the Dempster Highway crosses a major geological boundary - the Tintina Fault. From Watson Lake in the southeast to Dawson in the northwest, this fault is at the bottom of a deep valley or narrow trench. Unfortunately here the valley is completely buried by glacial and ***colluvial*** sediments. On the Tintina Fault the southwest side moved northwest, at least 425 km in the last 100 million years. In this part of the Yukon the fault separates rocks deposited on ancestral North America (north side) from geological ***terranes*** accreted to it (including the Klondike area, to the south).

From its southern terminus to about Km 20, the Dempster Highway is built upon ***Reid*** moraine on the valley floor of the North Klondike River. It is a deposit of the second last glaciation - a long tongue of ice that extended from the high land around Tombstone Mountain. Ridges on either side of the valley were probably ice-free (part of Beringia). Thus the upper slopes of the mountains are characterized by ***colluvium***, frost-fractured rubble, ***cryoplanation*** terraces and pillar-like outcrops (***tors***).

The lower slopes traversed by the Dempster Highway comprise glacier-scoured bedrock ridges poking through a veneer of till and ***glaciofluvial*** sand and gravel. Relatively clean rock is exposed in several borrow pits (Km 23 and Km 30). The slate and metamorphosed sandstone represent the Narchilla and Yusezyu formations of the Hyland Group, of Neoproterozoic to Cambrian (600 to 525 Ma) age. This unit represents deeper water equivalents of the Windermere Supergroup which was deposited as a *clastic wedge* on the ragged rifted margin of ancestral North America. After the supercontinent Rodinia broke up or rifted apart, these were some of the earliest sediments deposited.

The Hyland Group (named after a river north of Watson Lake) is the initial deposit of a deep-water succession that in Early Paleozoic time extended across what is now central Yukon in a feature called Selwyn Basin (figures 5, 7). Moving up the section, dark coloured sediments are collectively referred to as the Road River Group (Cambrian to Middle Devonian age; 525 to 390 Ma). The Mackenzie Platform lies to the north of Selwyn Basin. The platform is characterized by Early Paleozoic light-coloured carbonate rocks (although Road River Group is also present there as a thin stratigraphic unit that represents a short period of sea-level rise).

The Southern Ogilvie Mountains contain three west-trending belts that are each bounded along the north edge by a regional-scale fault. From south to north these are the Robert Service Thrust, the Tombstone Thrust and the Dawson Fault (figures 5, 11, 19). None are abrupt, in-your-face geological boundaries: their recognition requires familiarity with the lithologic variation in units which look similar but differ in age by several hundred million years. For example, the Robert Service Thrust angles across the face of Logger Mountain (east of the Highway at Km 44) but its trace is the subtle distinction between sandstone (above the thrust) and sandy shale (below). Where it crosses the North Klondike River valley the Robert Service Thrust is buried by gravel near Benson Creek.

GEOLOGICAL SYNOPSIS OF SOUTHERN OGILVIE MOUNTAINS (FROM TINTINA TRENCH TO TOMBSTONE CAMPGROUND - KM 0 TO 69) - continued

Along this segment of the Dempster Highway most sedimentary layers are tilted southward, so a northward journey passes outcrops of successively older rocks; this is what geologists call "going down-section". By driving northward from Benson Creek you will see in the Tombstone thrust sheet (named after the thrust fault at its base) a section of Jurassic shale (called the Lower Schist) underlain by Permian red and green slate (Mount Christie Formation), and then Lower Carboniferous metamorphosed sandstone (Keno Hill Quartzite; named at Keno City about 200 km east where it hosts significant silver-lead-bearing veins; Figure 11). These strata were deposited in a shallow sea that succeeded the deep-water Selwyn Basin and ended when the margin was uplifted by mountain-building (the Cordilleran orogeny, beginning in Middle Jurassic time).

The Keno Hill Quartzite was intruded by a layer-parallel mafic intrusion (called a diorite sill) about 225 million years ago. The sedimentary succession enclosing the sill was later tightly folded and imbricated by internal thrust faults. As a result the diorite is now exposed in long lenses visible on the mountain side as irregular cliff bands.

The north edge (i.e., at the base) of the Keno Hill Quartzite is the Tombstone Thrust. Its trace is high on the mountains directly south of the interpretive centre (Figure 11). This thrust juxtaposes 340 Ma quartzite over 150 Ma shale. The latter is the uppermost member of the next succession - the Dawson thrust sheet - which is the subject of another sidebar.

How does Tombstone Mountain fit into this tale of deformed sediments? Like a bull into the china shop! Tombstone intrusion is the largest of five sub-circular ***plutons*** in a 30 km-long northwest trend. Each pluton punched through the sedimentary rocks, leaving steep, sheared margins and a fringe of heat-altered rock. The plutons cooled about 90 million years ago: they are the same age as plutons north of Fairbanks, Alaska which gave rise to large gold deposits, although only small gold deposits have been found in the Tombstone area. The reason may be the depth of erosion: more than three kilometres of the top of these plutons have been removed.

Km 23.1 [694.4 km]: Slate and glacial till

Borrow pit on west side of highway exposes a face of steeply dipping, yellowish-orange weathering, greenish grey slate (Narchilla Formation of the Hyland Group). The north side of the outcrop is sharply overlain by grey, boulder-rich moraine (Figure 10).

Km 24.1 [693.5]: Glacier Creek (culvert)

During the 20th century the ice accumulations along some streams and some slopes were traditionally known as "glaciers"; today, they are called "icings". In early summer they can be seen here and also at kms 32.5, 33.9 and 34.4. These ice accumulations result from continued flow of groundwater through the winter months, and this builds as overlapping layers of ice on the surface. A thick icing can take much of the summer to melt. In large braided river channels (such as the North Fork of the Klondike River about 3 km upstream from the Tombstone campground) these icings are called ***aufeis***. During dry summers the steady melt of these ice accumulations provides reliable moisture for plants and fish fry in pools along river banks.

Figure 10. Golden coloured slate sharply overlain by glacial till (Km 23.1).

Km 28.6 [688.9 km]: Benson Creek (culvert)

This is one of many streams that drain eastward from the North Klondike Range. A well-appointed tourist accommodation - the last on the highway until Eagle Plains Lodge - has an entrance at Km 29.5.

Km 30.0 [687.5 km]: Sandstone in borrow pit

The outcrop consists of quartz sandstone and granule to pebble conglomerate (600 million years old) called the Hyland Group. These were the first sediments to pour into an ocean basin formed as the supercontinent Rodinia broke up, creating a ragged western edge of the continent we now call North America. Elsewhere in the Ogilvie Mountains, sandstone and granule layers are hundreds of metres thick; these layers have been uplifted during mountain building, and thrust over younger rocks along thrust faults.

The sandstone is metamorphosed so that quartz and lithic (shale and siltstone) pieces are barely visible: closely spaced quartz veins cut through the sandstone. Sandy layers overlie thin-bedded ***phyllitic*** siltstone and mudstone, which are warped and crumpled beneath the more competent sandstone layers.

Km 51.8 [665.7 km]: Wolf Creek (culvert)

The borrow pit north of the stream is used for road fill.

TOMBSTONE: YUKON'S FOURTH TERRITORIAL PARK

Ddhal Ch'el means "among the sharp, ragged rocky mountains" to the Tukudh Gwich'in, the mountain people of the upper Porcupine River country. This area was special because it was their hunting grounds for the caribou herds that roamed the Blackstone uplands. In late summer the Tr'ondëk Hwëch'in people traditionally came here to hunt, dry meat, and pick berries.

Small veins of silver, gold and antimony minerals were mined in this area during the early 1900s. Although prospectors located many showings since that time, 1976 was a big year: in response to rising uranium prices, increased exploration was done in the area and a large low-grade uraninite deposit was identified southwest of Tombstone Mountain, and bedded barite was located in the Earn Group (8 km east of Km 102). The uranium claims were relinquished to ease the creation of the park, and the Rein barite property (outside the park) is covered by claims in good standing.

These mineral interests and increased access following completion of the Dempster Highway spurred the Tr'ondek Hwech'in First Nation to negotiate for a large area to protect wildlife habitat. The government acted too late: before the area was withdrawn from staking in 1997 a promising gold showing was found by prospectors in the Cloudy Range. The land claim includes an agreement between the Yukon Government and the First Nation to jointly manage the Tombstone-Blackstone area and a territorial park was announced in 1999. The steering committee for the park continues to wrestle with management of the 500 m wide corridor of the Dempster Highway in how to reduce the impact of increasing numbers of tourist hikers and back-country users. Subsistence hunting is allowed throughout the area but as traffic increases, the game species move away and are less easily accessed.

The Tombstone Park covers more than 2000 km^2 of the southern Ogilvie Mountains and Taiga valley (figures 11, 12). It contains a variety of virtually undisturbed ecosystems, from arctic tundra to boreal forest, as well as fascinating landforms. Park facilities are minimal: some trails near the road are built, pit toilets provided, and in summer the campground and natural history interpretive centre are open. It truly fits the last stanza of Robert Service's poem, *The Spell of the Yukon*:

"It's the great, big, broad land 'way up yonder,
It's the forests where silence has lease;
It's the beauty that thrills me with wonder,
It's the stillness that fills me with peace."

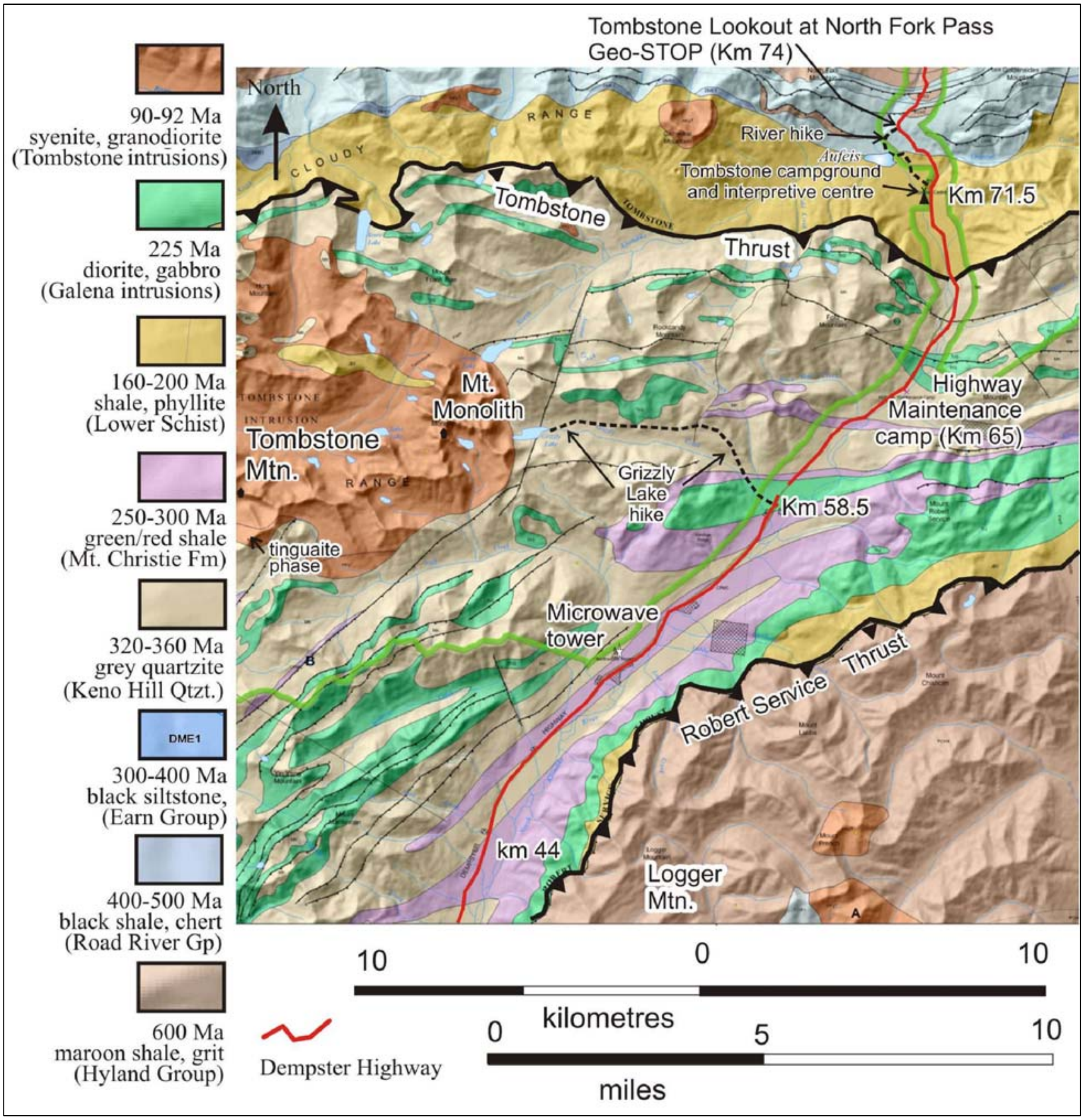


Figure 11. General bedrock units in the southern Ogilvie Mountains near the Dempster Highway. The green outline is the park boundary. Adapted from the Tombstone Park geology map (unpublished) by Yukon Geological Survey.

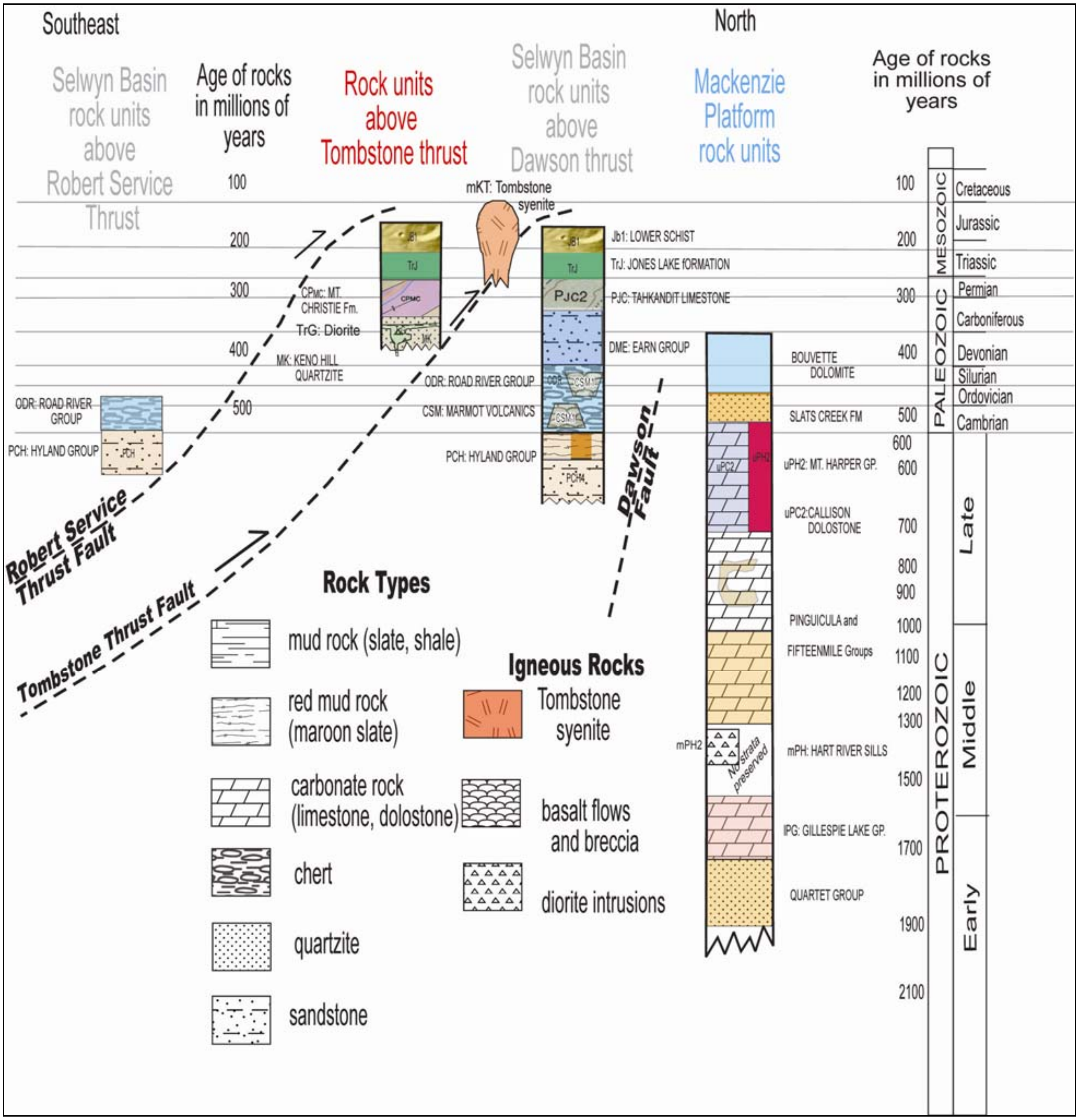


Figure 12. Schematic stratigraphy and structural relationships of thrust sheets in Southern Ogilvie Mountains. Dawson Fault is considered the Paleozoic shelf-basin boundary, re-activated as a Mesozoic thrust.

Km 53.6 [663.9 km]: Sideroad to microwave tower

A steep one-lane track leads west of the highway upslope to the installation with limited parking. Although views are limited it is a good site to begin an off-trail mountain hike into the Cloudy Range to the west. Furthermore, the gravel foundation outside the security fencing contains stream cobbles of grey ***tinguaite***, an unusual igneous rock that was an intermediate phase in the Tombstone intrusion that outcrops 10 km west of here. This gravel was almost certainly trucked from the glacial moraine quarried beside Wolf Creek. Look for cloudy white polygonal crystals of ***pseudoleucite***, an intergrowth of ***nepheline*** and ***alkali-feldspar***.

Km 58.5 [659.0 km] HIKING ACCESS: Grizzly Lake trail and view point

A parking lot located in a retired borrow pit is the trailhead for a 9 km hiking trail (8 hours one way). This is the most popular overnight trip in the park. The first 3 km of the trail leads to a spectacular alpine viewpoint (2 hours return).

Km 62.0 [655.5 km]: View east and west to Keno Hill Quartzite

The flanking slopes (Mount Cairnes to west; Mount Robert Service to the east) expose the Keno Hill Quartzite, a resistant rock prone to frost fracture. Most of the slope is therefore ***quartzite*** rubble, with cliff bands of Triassic ***diorite*** that intruded between the quartzite layers (Figure 13).

Km 65.0 [652.5 km]: Highway maintenance camp

This is the first of three permanent facilities for workers of the Yukon Government Transportation Maintenance Branch. Emergency assistance is available here.

Km 66.0 [651.5]: North Klondike River (bridge)

The west abutment of the bridge contains boulders of Keno Hill Quartzite - one of the best road-accessible places to see a fresh rock of this unit. Note the intense quartz veining. The quartzite deformed in a brittle manner, and silica-rich fluid likely derived from metamorphism precipitated white quartz in veins.

Figure 13. Skyline west of Dempster Highway near Km 62 consists of thick beds of Keno Hill Quartzite.

Km 69.0 [648.5 km]: Stabilized Rock Glacier

The bowl-shaped hollow in the mountainside east of the valley contains a lobate mound of rock rubble. The rock mass advanced downslope out of the cirque by individual rock fragments tumbling down the steep front face. The outer zone adjacent to the highway is older and separated by a depression from an inner younger zone with preserved ridges. Both zones contain lichen-covered blocks - it appears to be no longer active.

Km 70.0 [647.5 km]: Tombstone Thrust

Although buried beneath this point and blocky rubble on the mountainside, this is the projected location of a south-dipping thrust fault plane. The Keno Hill Quartzite on the higher slopes of the mountain was shoved northward over younger (Jurassic) shale (Figure 14).

Km 71.5 [646.0 km] Tombstone Mountain Campground, Dempster Interpretive Centre, and River hike

The Campground and Interpretation Centre are built on moraine from a glacier that extended down the North Fork of the Klondike River and coarse gravel from Charcoal Creek which bounds the parking area. Slopes rising south of this point are mostly quartzite (Keno Hill Quartzite, Carboniferous), with cliffs formed by thin wedges of igneous intrusive rock called diorite. Slopes to the north consist of much older dark grey shale and chert (Road River Group, Ordovician). Rounded white boulders in the area are glacial ***erratics*** of intrusive ***syenite*** which comes from the core of the Tombstone Range, 15 km up the valley to the west.

HIKING ACCESS: River hike

A straight section of old road heading northwest between the campsites is the start of a hiking trail (4 km return; easy) along the North Klondike River to aufeis and a meltwater canyon with black siltstone and chert (Road River Group).

Km 72.0-74.0 [645.5 to 643.5 km]: North Fork Pass

The highway climbs to North Fork Pass (Figure 15). Rocky knobs to either side consist of dark grey chert and slate of the

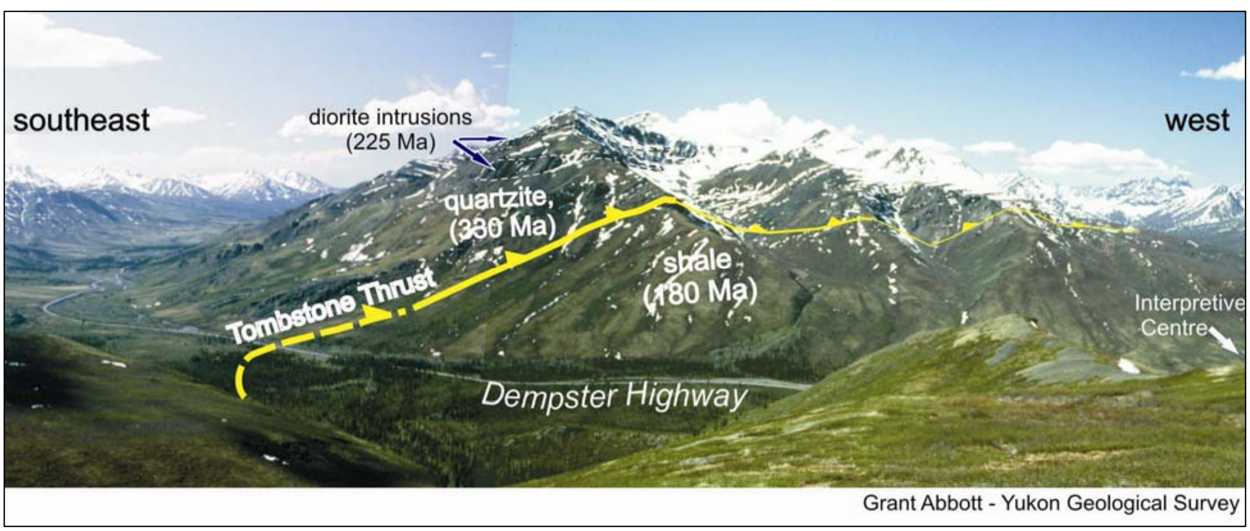


Figure 14. The mountain south of the Interpretive Centre reveals Jurassic shale in the lower slopes, and Carboniferous quartzite on top. Between these formations lies the Tombstone Thrust, a fault that was active in Late Jurassic or Early Cretaceous time.

Figure 15. View northward at North Fork Pass. The highway lookout is at the left end of the diagonal beige streak (road embankment). In the middle ground is the braided bed of the North Klondike River, where aufeis typically forms in winter. Mountains flanking the pass are underlain by Hyland Group; Angelcomb Mountain in the background is volcanic breccia.

Road River Group. This section of the highway is re-surfaced with trucked-in gravel because the chert caused so many flat tires in the early days.

The chert can be chipped to a cutting edge, and several of the outcrops contain chert flakes where stone-age hunters prepared their tools while watching for game.

Km 74.0 [643.5 km] GEOLOGY STOP: Tombstone Mountain Lookout

The highest point in the area is Tombstone Mountain (2500 m), which lies at the head of the North Klondike River, about 20 km away (Figure 16). The jagged skyline results from long, steep fractures in the resistant syenite and ***granodiorite*** rock, which cooled 92 million years ago. Ridges north of the North Klondike River consist of Windermere Supergroup and Road River Group. Black, resistant ribs are Middle Ordovician chert of the Road River Group (200 m thick total) which to the east, intersect the nearest ridge and are thrust over younger shale. Beneath the Road River strata lie maroon ***argillite*** and gritty quartz feldspar sandstone of the Windermere Supergroup. Paleocurrent indicators and a coarsening southward pattern suggest a source to the south. Clast composition is granitic. In the next set of ridges to the north the Windermere-Road River succession structurally overlies Cambrian and Ordovician basaltic volcanics. The contact is called the North Fork Thrust, and is one of several internal repetitions of the stratigraphy within the Dawson thrust sheet. Cathedral Mountain in the Cloudy Range to the north has a plug of syenite, but is predominantly made of Road River Group shale and chert.

Figure 16. The highest point in the area (2500 m / 8200 feet) is Tombstone Mountain, which lies at the head of the North Fork of the Klondike River about 20 km in the distance. It is a prominent landmark from every direction and has reverted to its traditional name (Mt. Campbell, the name on the old signpost, is not used). The jagged skyline results from long, steep fractures in the resistant igneous intrusive rock, which cooled 92 million years ago.

Boulders protecting the parking lot were moved down the valley by the glacier, and then from nearby by the Department of Highways. Although displaced, they offer clean examples of the regional rock types. Most are examples of ***amphibole-pyroxene*** syenite and ***hornblende*** (see ***amphibole***) quartz ***monzonite***. Now, cautiously cross the Highway to examine the roadcut across from the parking area. It is black chert of the Road River Group and contains radiolarians (microscopic marine organisms with silica skeletons) of mid-Ordovician age.

From the viewpoint northward the road continues through a different landscape: long smooth slopes of tundra. Although you can see a long way into the distance, traveling through such terrain is difficult because the ground is very uneven and bushes (dwarf birch, willow and other shrubs) are matted and dense.

Km 74.3 [643.2 km] HIKING ACCESS: Goldensides Mountain

About 300 m north of the Tombstone Lookout, a sideroad east of the highway goes uphill about 1 km to a microwave installation. This is a public road although the turnaround and parking space is limited at the fence. A large Yukon Government /Tr'ondek Hwech'in First Nation sign welcomes you to the area and a trekkers' register box marks the unimproved trailhead (Figure 17).

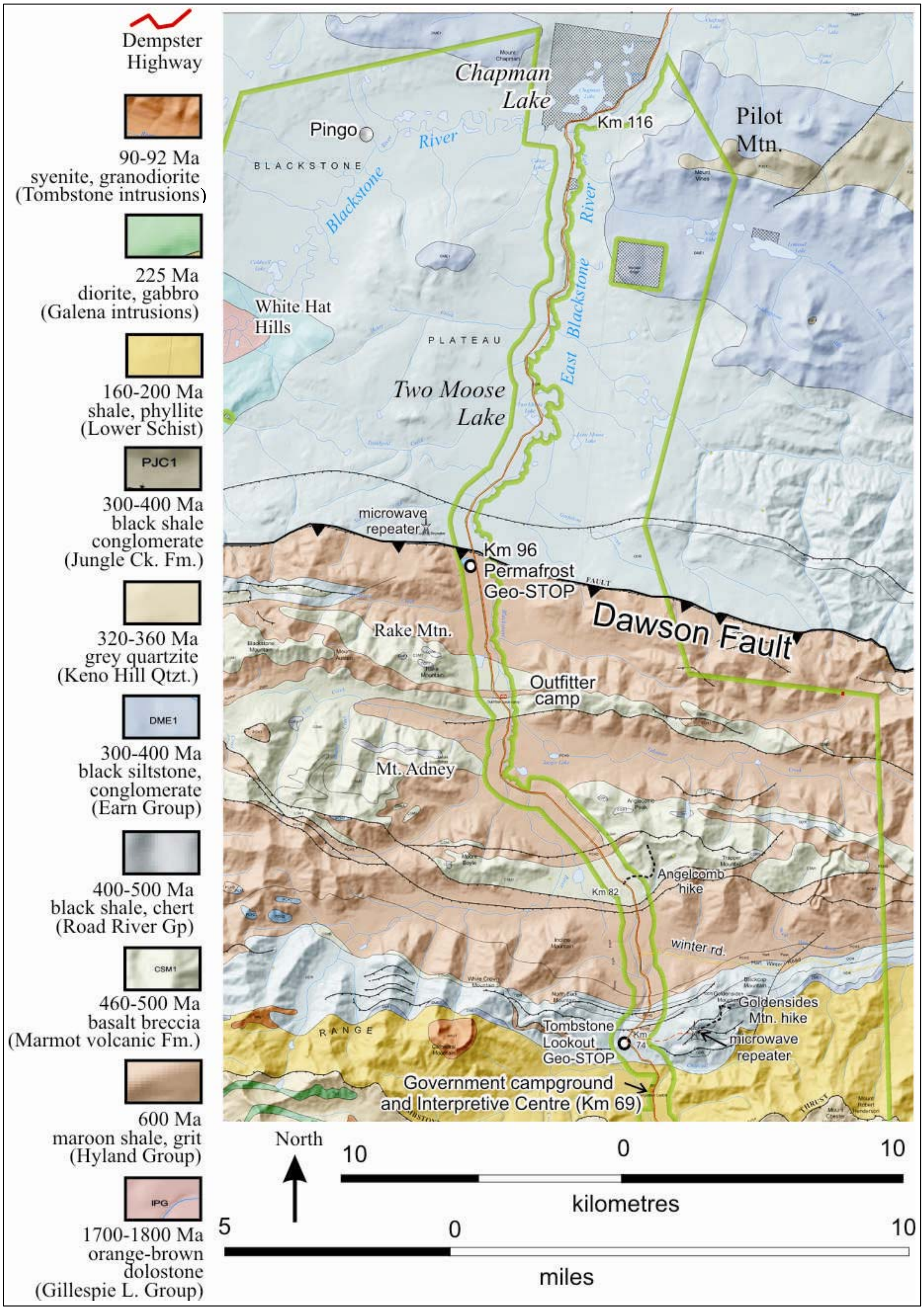


Figure 17. General bedrock units in the southern Ogilvie Mountains near the Dempster Highway. The green outline is the park boundary; hachured areas are titled First Nation's land selections. Adapted from the Tombstone Park geology map (unpublished) by Yukon Geological Survey.

It is about 400 m walk to the base of the mountain, a slope of dwarf birch (buckbrush) and willow, sphagnum, and grass tussocks. Higher slopes are brown weathering, metamorphosed mudstone (slate). The golden colour comes from abundant brownish yellow planar surfaces of Early to Middle Cambrian Narchilla Formation (Hyland Group) slate. Black lichen covers other rock types such as granule and quartz sandstone. The top (about a 3 hour scramble) is 1830 m above the parking lot. There are great views west to Tombstone Mountain and other peaks surrounding lower and upper North Fork valleys.

Km 77.0 [640.5 km]: Lil Creek Canyon

A steep-sided draw on the west side of the road contrasts with smooth rolling slopes here. This canyon was cut during and after the McConnell glaciation (ended about 12 ka) when a glacier extended from the head of the East Blackstone River and blocked northward drainage in this area. Meltwater from the valley to the east (Hart Pass) was diverted southward, cutting this channel down to the Klondike River.

Good exposures in the canyon are accessible from the road crossing. They include thick sandstone units representing sediment gravity flow deposits into a deep marine basin. These beds fine upwards to fine-grained sandstone and maroon shale.

Km 81.0 [636.5 km]: Junction with Winter Road to Hart River

This dirt track leads eastward through valleys. It becomes impassable beyond the large stream or snow filled ditch after about one km. Originally it was a 'winter road' for hauling mining equipment and a 20-person camp to a copper-zinc-silver occurrence near Hart River, about 70 km northeast of here. The minerals were found by a trapper in the 1930s, and their extent explored in the early 1970s, 1990s and since 2004. Each fall the road is used by hunters on all-terrain vehicles, and in springtime snowmobilers take tours into the mountains.

Km 82.0 [635.5 km] HIKING ACCESS: Continental Divide; Angelcomb Mountain

This is the highest point on the Dempster Highway at 1325 m. Southward drainage is to the Klondike River which joins the Yukon River at Dawson and continues 2300 km to the North Pacific Ocean near Bering Strait. Northward the East Blackstone River cuts through the Ogilvie Mountains to join the eastward-flowing Peel River and then the Mackenzie River which flows into the Arctic Ocean, 550 km distant.

At the crest of this rise is a short access road eastward to a quarry in shale that is periodically used for road construction. On weekends when the quarry is not active it is a good place from which to hike the slopes of Angelcomb Mountain and a well-constructed trail begins at the southeast edge. The ridge immediately east of the highway is called Angelcomb Peak, a reference to the scattered rock exposures that punctuate its slopes and skyline. The rocks are mostly volcanic breccia and conglomerate of exclusively volcanic pebbles and boulders (Marmot Volcanics; Figure 18). Only the valleys contained glaciers during the last ice age.

Downslope from the highway (west side) you can discern a line of willow shrubs that mark the old roadbed. The highway was shifted several times before relocation to a better crossing of the upper Blackstone River.

Figure 18. Large clast in volcanic breccia that makes up Angelcomb Peak (km 80.3).

Continental Divide to Northern Ogilvie Mountains (Km 82 to 130)

North of this point the highway skirts the well defined edge of a large terminal moraine left by a valley glacier that extended out of the Cloudy Range to the west (Figure 19). At the height of the last glaciation about 22,000 years ago the ice filled the North Fork Pass and spilled north and south in this valley. When the ice melted, it left a basin of disordered, hummocky terrain, dotted with ponds and small lakes, flanked by relatively smooth-topped moraine benches. White boulders, conspicuous beside the Highway near here, are part of the moraine. These glacial erratics are syenite or quartz monzonite eroded from an intrusion.

The Dempster Highway follows the broad valley of the East Blackstone River through the Southern Ogilvie Mountains. This region, locally called the Blackstone Uplands, is covered by tundra underlain by permafrost, in contrast to the forested Klondike River valley. Near Chapman Lake (Km 116) extensive moraine from the Reid glaciation dominates the landscape.

Km 89.0 [628.5 km]: East Blackstone River (culvert)

Near the headwaters, this river consists of two streams. The highway follows the river for 40 km and its volume grows with the addition of every side-valley tributary.

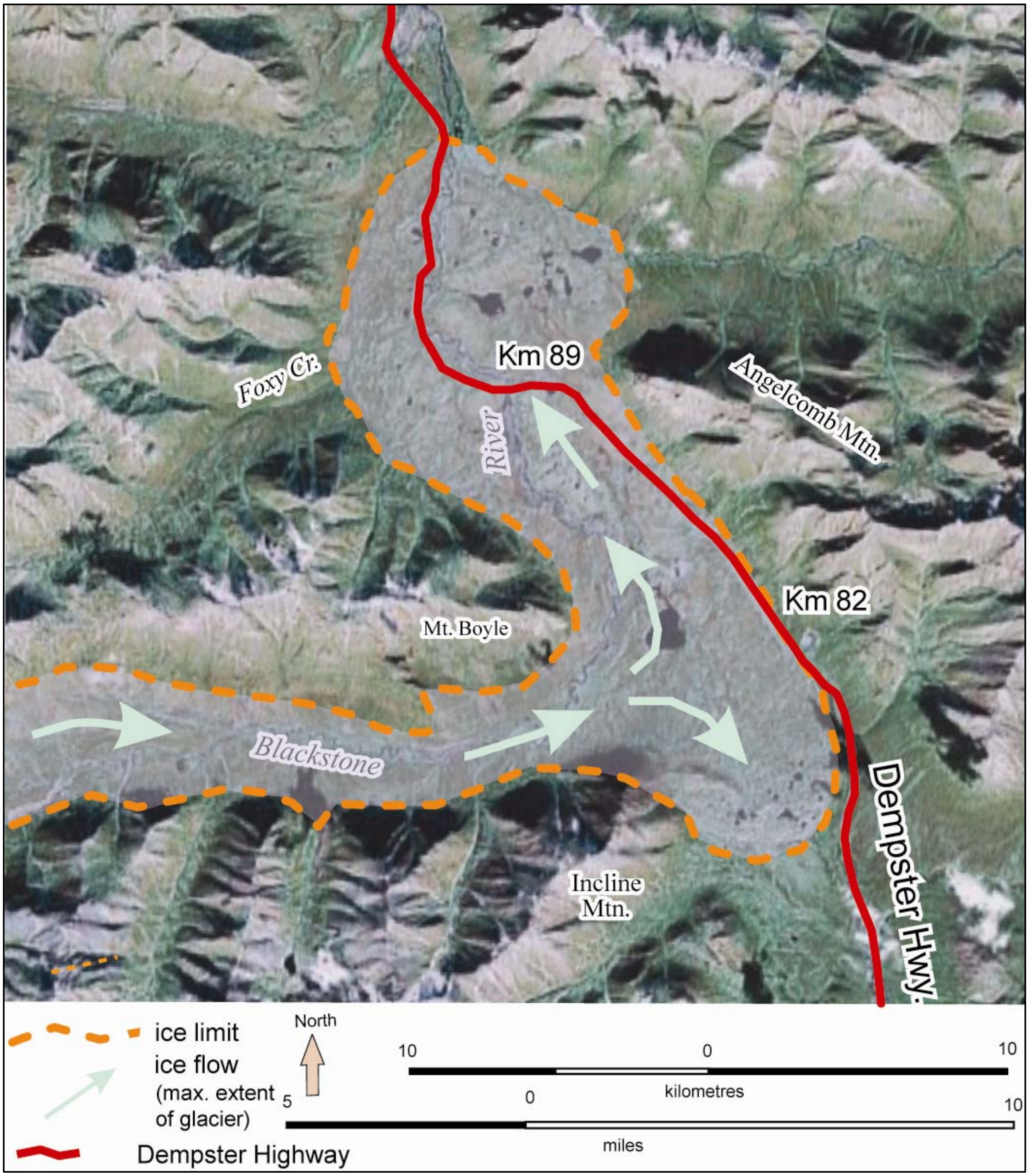


Figure 19. Outline of the alpine glacier moraine that filled this part of East Blackstone valley about 23,000 years ago (McConnell glaciation). Google Earth satellite image, September, 2006.

GEOLOGICAL SYNOPSIS OF TAIGA AND OTHER VALLEYS (FROM NORTH FORK PASS TO CHAPMAN LAKE, KM 70 to 119)

In this segment the Highway leaves the North Klondike River and follows the broad valley of the East Blackstone River. Its headwaters are the confluence of small streams issuing from large side valleys carved by alpine glaciers. Because most of ice-free Beringia was very dry, this broad valley at the snout of melting glaciers must have been biologically fecund. McConnell-age terminal moraines mark the limits of alpine glaciers that extended into the main valley (Figure 6). A moraine plain of Reid-age surrounds Chapman Lake: before 100 ka, a large glacier extended north over the Blackstone plateau. In contrast, mountains east of the Dempster exhibit smooth, straight slopes and skyline tors characteristic of Beringia. These rocks are deeply weathered after millions of years of exposure.

The bedrock consists of repetitions of Neoproterozoic to Middle Devonian strata as far north as the Dawson Fault (about Km 98), and Upper Devonian to Permian sediments further north. Going northward "down-section" through the Dawson thrust sheet, the geological traveler crosses (top to bottom): Jurassic and Triassic shale (Lower Schist and Jones Lake Formation), Middle Devonian to Carboniferous black siltstone and conglomerate (Earn Group), Ordovician to Lower Devonian black chert and shale (Road River Group) and Late Proterozoic to Cambrian maroon slate and coarse sandstone (Narchilla and Yusezyu formations of the Hyland Group; Figure 19).

Strata of Road River and Hyland groups form several west-trending belts as they are repeated by folds and faults. Between them are lenses of the Marmot Formation (some 5 km long and 500 m thick) mostly consisting of volcanic breccia. These volcanic rocks form grey-weathering towers. Angelcomb and Rake mountains receive their names from their jagged skylines that result from weathering of the volcanic rocks within them. The rock is alkali basalt, and the linear distribution of the submarine volcanic breccia within deep water shales indicate periods of extension in the floor of Selwyn Basin. Some underwater volcanoes grew almost to sea-level as suggested by the presence of a few limestone reefs that yield Middle Ordovician microfossils within the breccias (viewed from Km 94).

The Dawson Fault is the northern limit of the Hyland Group and the southern extent lower Paleozoic carbonate (Bouvette Formation). These units epitomize Selwyn Basin and Mackenzie Platform respectively (Figure 5). The Dawson Fault is a steep, largely straight boundary that extends at least 80 km westward; a crustal break of probable Cambrian age that formed the edge of Selwyn Basin, and later reactivated as a north-directed thrust. The Dempster Highway crosses the fault, hidden under sediments, at about Km 96. Here the geological traveler encounters the Mackenzie Platform, abundantly exposed in the Northern Ogilvie Mountains.

North of Dawson Fault different rock sequences are exposed in mountains on either side of the Dempster Highway. On the east side lie Road River Group shale and chert (a thin tongue of sediments deposited when the basin briefly flooded on to the Mackenzie Platform) are overlain by black siltstone and chert-pebble conglomerate of the Earn Group, and capped by grey limestone, sandstone and calcareous shale of the Lower Permian Jungle Creek Formation (Pilot Peak/Mount Vines; Figure 19). The low mountains west of the highway expose uplifted carbonate strata underlying the Road River Group, in ascending order: orange dolostone of the Paleoproterozoic Gillespie Lake Group (older than 1600 Ma) unconformably overlain by Cambrian dolostone (White Hat hills). This unconformity therefore represents about a billion years of missing time! Collectively, these carbonate units form the southern flank of the Northern Ogilvie Mountains.

Km 89.5 [628.0 km]: Gravel pit, palsa mounds

Km 90.7 [626.8 km]: Foxy Creek (culvert)

Km 92.5 [625.0 km]: Outfitter's camp

Horses are used from August to October to ferry hunters for Dall sheep, bear, caribou and moose.

The view northward from east of the highway shows the terrain change from peaks of volcanic rocks such as in Mount Adney west of the highway, to low, rounded, unglaciated hills that are dominantly shale such as Road River Group and Narchilla Formation (upper Hyland Group) to the north.

Km 94.0 [623.5 km]: Rake Mountain (to the west)

Tilted layers of submarine volcanic rocks (Marmot Volcanics), primarily breccia and epiclastic detritus, contain a 40 m thick band of limestone reef on the north side of the mountain (Figure 20). The limestone contains microfossils called conodonts (phosphatic tooth-like structures of extinct vertebrates) of Early Ordovician age.

Km 95.0 [622.5 km]: Dawson Fault

This west-trending fault separates shale and pebble conglomerate (Hyland Group) on the south side from dark shale and chert (Road River Group) to the north. The fault is buried in the valley beneath tundra and colluvium, and on the slopes by shaly rubble. The fault, however, approximately

Figure 20. Rake Mountain, which lies west of Km 94, is studded with outcrops of grey volcanic breccia, and a white limestone reef of Early Ordovician age.

coincides with a change in topography from high narrow ridges (south) to low rolling hills.

Km 96.5 [621.0 km] GEOLOGY STOP: Melting permafrost - Palsa bog

While driving slowly along this straight stretch of the highway, look for ponds and lumpy ground below the relatively level tundra. There is no pullout; park as far off the highway as possible.

This feature has developed since the early 1960s as a mistake in road construction. The vegetation and unfrozen cover was scraped off and unfrozen fill was used to build the road. Without insulation, underlying permafrost melted. Moss, heather and shrub birch have re-colonized the bare earth but melting continues, indicated by toppling of the thick peat cover dozens of metres from the original disturbance.

Dome-shaped ***palsas*** are periglacial landforms that have an ice-rich core and are heaved upward during seasonal thaw and re-freeze cycles. Where sub-surface ice lenses melt, the peat cover cracks and sags, and the meltwater ponds in the resulting depressions (Figure 21). This ***thermokarst*** process is difficult to stop and the warming climate increases the rate. In Yukon the average annual temperature has risen by 6°C since 1970, chiefly the result of fewer and shorter periods of deep cold during the winter. To remain healthy, permafrost needs prolonged -30°C air temperatures to drive the cold through the insulating peat layers.

Figure 21a. Hummocky periglacial terrain (Km 96.5).

Figure 21b. Ice-cored mounds called palsas are cracking due to permafrost melting.

Km 97.8 [619.7 km]: HIKING ACCESS: Microwave installation

On the west side is a 2 km road to a microwave installation that also provides hiking access to nearby hills and views to Pilot Mountain and the Northern Ogilvie Mountains. Parking is limited along the single-lane road.

Km 102.1 [615.4 km]: Two Moose Lake: Rest area with interpretive signs

Two Moose Lake fills a depression underlain by permafrost. The signs describe "thaw lakes" and waterfowl. A good place to view the thermokarst is about 200 m north of the rest area, where the Highway diverges from the edge of the lake.

Northeast of the lake are the rounded Puddingstone Hills, composed of Devonian to Mississippian chert-pebble conglomerate, interstratified with black shale (Earn Group). Resistant knobs on the peaks are limestone and conglomerate of the Permian Jungle Creek Formation (Figure 22).

Km 107.5 [610.0 km]: Rest area (with outhouses) on east side

From Km 104 to 112, the road descends below the Blackstone Plateau into low hills or moraines made of sand and gravel that are a resource for road surfacing (borrow pit at Km 106).

Km 110.1 [607.4 km]: Slope failure: Retrogressive thaw-slump

West of the highway is a fresh landslip in ice-rich glacial sediments. Once frozen ground is exposed, summertime melting undercuts the support of upslope vegetation. When the insulating vegetation mat topples the chain reaction continues (Figure 23).

Km 115.5 [602.0 km]: Blackstone River and Pingo

Traditionally Gwitchin people from the north, and Northern Tutchone people from the south met in this area in late summer while hunting caribou and picking blueberries and lingonberries. To the Gwitchin this stream was called *Th'oh zraii njik*: 'Black Boulder Creek'. Until the 1920's the Northern Tutchone encampment near here was called 'Black City'.

Five km up the Blackstone River (in the broad valley to the west) is a pingo. This is one of 400 plotted in central Yukon. These are open-system pingos, formed by movement of groundwater into a growing (aggrading) frost feature, resulting in upward growth of an ice-cored mound.

Figure 22. View northeast (Km 102) to Puddingstone Hills.

These features may be several thousand years old, growing as long as their ice core expands and the overlying insulating vegetation remains intact.

The whole valley north of Two Moose Lake is a moraine complex deposited during Reid glaciation. The steep bank cut by the Blackstone River downstream (east) of the Highway bridge gives an example of stream piracy. An aggressively eroding gully of the East Blackstone River (800 m east of this point) captured the Blackstone drainage (from the valley to the southwest). Previously the Blackstone River flowed northward, and Chapman Lake lies in a remnant of the old channel.

Figure 23. Slope failure cause by melting permafrost. Person for scale.

Km 116.0 [601.5 km]: Chapman Lake rest area

This shallow lake, the largest in the region, was an important place in human history during the last century: it lay at the intersection of trails and float planes could land here. The RNWMP maintained a small post here, on the winter patrols route. The first phase of Dempster Highway construction ended here in 1961.

Across the valley to the east is Pilot Mountain (a.k.a. Mount Vines; Figure 24). Note the smooth lower slopes and the summit erosional remnants (tors) indicative of unglaciated terrain. As in the Puddingstone Hills, lower slopes are underlain by black shale and peaks are made of limestone and conglomerate.

The next 15 km of the Dempster Highway is across rolling terrain comprising the Taiga Valley, which separates the Southern from the Northern Ogilvie Mountains. It is a west-trending, northward-sloping peneplain underlain by poorly exposed, recessive Upper Paleozoic shale, limestone, and minor quartzite. Erosion of faulted uplifts and anticlines reveal underlying resistant strata, such as dolostone in the White Hat Hills and Vista Ridge, both west of the Highway. The Northern Ogilvie Mountains are visible to the northeast.

Figure 24a. Pilot Mountain (Km 116) has unglaciated peaks of Permian limestone and conglomerate and slopes of Devonian black shale.

Figure 24b. View northwest from Two Moose Lake (Km 116) across Blackstone Uplands to Northern Ogilvie Mountains in the distance.

Km 121.0 [596.5 km]: Buildings on the east side belong to an outfitting concession

Km 124.0 [593.5 km]: Emergency airstrip

Km 129.5 [588.0 km]: Cash Creek (culvert)

Km 130.2 [587.3 km]: Terminal moraine of Reid glaciation

A low ridge here is a terminal moraine of Reid glaciation which marks the northern limit of hummocky to rolling terrain. On the north side of the hill stream gravel is quarried and sieved for use in road maintenance. This part of the highway is surfaced with abundant pebbles, providing excellent traction under most conditions.

Northern Ogilvie Mountains (Km 130 to 245)

After crossing the rolling hills of Blackstone Uplands and Taiga Valley, the Dempster Highway traverses the Northern Ogilvie Mountains which are largely formed by limestone and dolostone of an ancient tropical carbonate platform. In contrast to the Southern Ogilvie Mountains, these ranges were not glaciated and exhibit spectacular castellated peaks. Mountain tops are bare and high slopes have sparse vegetation, which contributes to flash flooding during heavy rains. River valleys contain aspen, white and black spruce, tamarack, and tundra.

The Dempster Highway continues beside the Blackstone River, then turns west through Windy Pass (Km 153) to follow Engineer Creek Valley and ultimately the Ogilvie River (Km 194.3).

Km 132.0-134.0 [585.5 to 583.5 km]: View east to Blackstone River

Look eastward across Blackstone River to see thick Proterozoic strata - the grey-brown Quartet and orange-brown Gillespie Lake groups of the Wernecke Supergroup. A red-weathering diorite dyke cuts orangish grey dolostone of the Gillespie Lake Group high on a ridge. Cambrian Bouvette Formation dolostone unconformably overlies phyllite of Proterozoic Quartet Group. The underlying Gillespie Lake Group is erosionally truncated by the sub-Cambrian unconformity across Blackstone Valley.

GEOLOGICAL SYNOPSIS OF THE NORTHERN OGILVIE MOUNTAINS (FROM BLACKSTONE RIVER TO OGILVIE RIVER - KM 120 TO 223)

Dempster Highway threads it way through this dramatic mountain belt by hugging the Blackstone River, then ascending a tributary to Windy Pass at the headwaters of Engineer Creek, and following this shallow stream 43 km northward to its mouth. The landscape strongly contrasts with the Blackstone and Klondike river vistas. The Northern Ogilvie Mountains are mostly light grey carbonate rubble with ridge-crest cliff-bands and the flat-floored Engineer Creek drainage is mostly underlain by shale. Although elevations are similar to the Southern Ogilvie Mountains, the higher latitude and poor soil conditions (alkali on carbonate substrate; acidic and metalliferous in the valleys) conspire to support pauperized boreal forest (black spruce of smaller stature), less boggy terrain and large areas of bare, broken rock. Several creeks sport bright orange (iron oxy-hydroxide) bottom precipitate. Most of these mountains remained ice-free: there are few cirques and moraine is uncommon (noted in the broad Windy Pass). Ridge crests of tilted carbonate strata are castellated, producing spectacular skylines and ideal nest and lookout sites for predatory birds.

Bedrock geology consists of interspersed dark (sandstone, shale) and light coloured (shallow water carbonate) units, part of the Lower Paleozoic Mackenzie Platform succession (Figure 4).

The Northern Ogilvie Mountains are a geologically recent uplift that exposes compressed Paleozoic strata (tight anticlines separated by broader synclines; some thrust-faulted) that unconformably overlie Proterozoic shelf rocks that are less folded. The regional distribution of Proterozoic inliers suggests a “hump” or detachment edge in the underlying basement. Continuing seismic activity along the northern edge of these mountains implies their northward movement, forcing deeply buried strata upward.

From the south the Highway passes ridges of grey to white dolostone of the Cambrian to Middle Devonian Bouvette Formation which here is only a few tens of metres thick, in contrast to several hundred metre thick sections in the core of this mountain range.

From Km 135-145 roadcuts expose the old sedimentary rocks of the Paleoproterozoic Wernecke Supergroup. The Quartet Group sandstone and siltstone are intruded by a unique breccia (Km 143) while the overlying carbonate Gillespie Lake Group dolostone is visible on ridge tops northeast of the Highway. The Wernecke Supergroup is a much older succession (older than 1600 Ma) than similar lithologies exposed in the Mackenzie Mountains of western NWT; the supergroup correlates with Hornby Bay Group on the northeast shore of Great Bear Lake which was deposited on Archean age rocks of the Canadian Shield.

GEOLOGICAL SYNOPSIS OF THE NORTHERN OGILVIE MOUNTAINS (FROM BLACKSTONE RIVER TO OGILVIE RIVER - KM 120 TO 223) - continued

The angular unconformity where this stable shelf succession is truncated beneath the Bouvette Formation, a shallow-water dolostone exposed at the top of Windy Pass, is seen up a valley west of Km 137. Good hiking is accessible from there on the barren spurs of Mount Distincta. Descending westward from the pass, travelers of the highway go “up-section” through overlying Road River Group shale, fossiliferous jet-black shale of the Lower Devonian Michelle Formation, and into grey limestone of the Devonian Ogilvie Formation. Then one travels into a broad valley underlain by Upper Devonian and Carboniferous Canol Formation, Ford Lake Shale, Hart River and Ettrain formations (these units are identified from measured sections; there are few outcrops near the Dempster Highway). The geological map (Figure 25) shows the east-trending ridges cored by Bouvette Formation and flanked by Ogilvie Formation, or truncated by a steep contractional fault. The straight course of Engineer Creek, transverses this structural trend, indicating the stream kept pace with regional uplift.

North of the Ogilvie River bridge (Km 195) the Highway follows the Ogilvie River through an incised meandering valley and across several more anticlines. The axial trace of these folds is bent (note the “Twisted fold train” on Figure 32) in the Ogilvie Deflection between the Taiga fold belt (trends east) and the Nahoni fold belt (trends north-northwest). Younger strata are preserved, including brown limestone (Carboniferous Hart River Formation), grey and orange limestone (Upper Carboniferous Ettrain Formation) and recessive calcareous mudstone (Permian Jungle Creek Formation). Although these units undergo lateral facies changes, they extend northward beneath the Cretaceous cover of the Eagle Plain. In contrast to folded strata of the rugged Northern Ogilvie Mountains these same units appear to form broad open synclines beneath the Eagle Plain.

Km 136.7 [580.8 km]: Proterozoic Quartet Group

A palisade-like outcrop across a pond on the west of the highway is Proterozoic Quartet Group - the second oldest unit of the Wernecke Supergroup and the oldest exposed near the Dempster Highway. It consists of 1800 Ma 2-6 cm thick rhythmic couplets of dark grey, well bedded meta-siltstone and sandstone. The siltstone is finely laminated. These rocks suggest either a passive continental margin or an intracratonic basinal depositional setting.

Km 137.0 [580.5 km]: View west to Mount Distincta

The mountainside at the head of the tributary west of the highway shows the sub-Cambrian unconformity, with dark Quartet Group sandstone (Proterozoic Wernecke Supergroup) beneath the light grey Bouvette dolostone (Paleozoic Mackenzie Platform). Mount Distincta (1760 m) is the highest of the rounded peaks in the area (figures 25, 26).

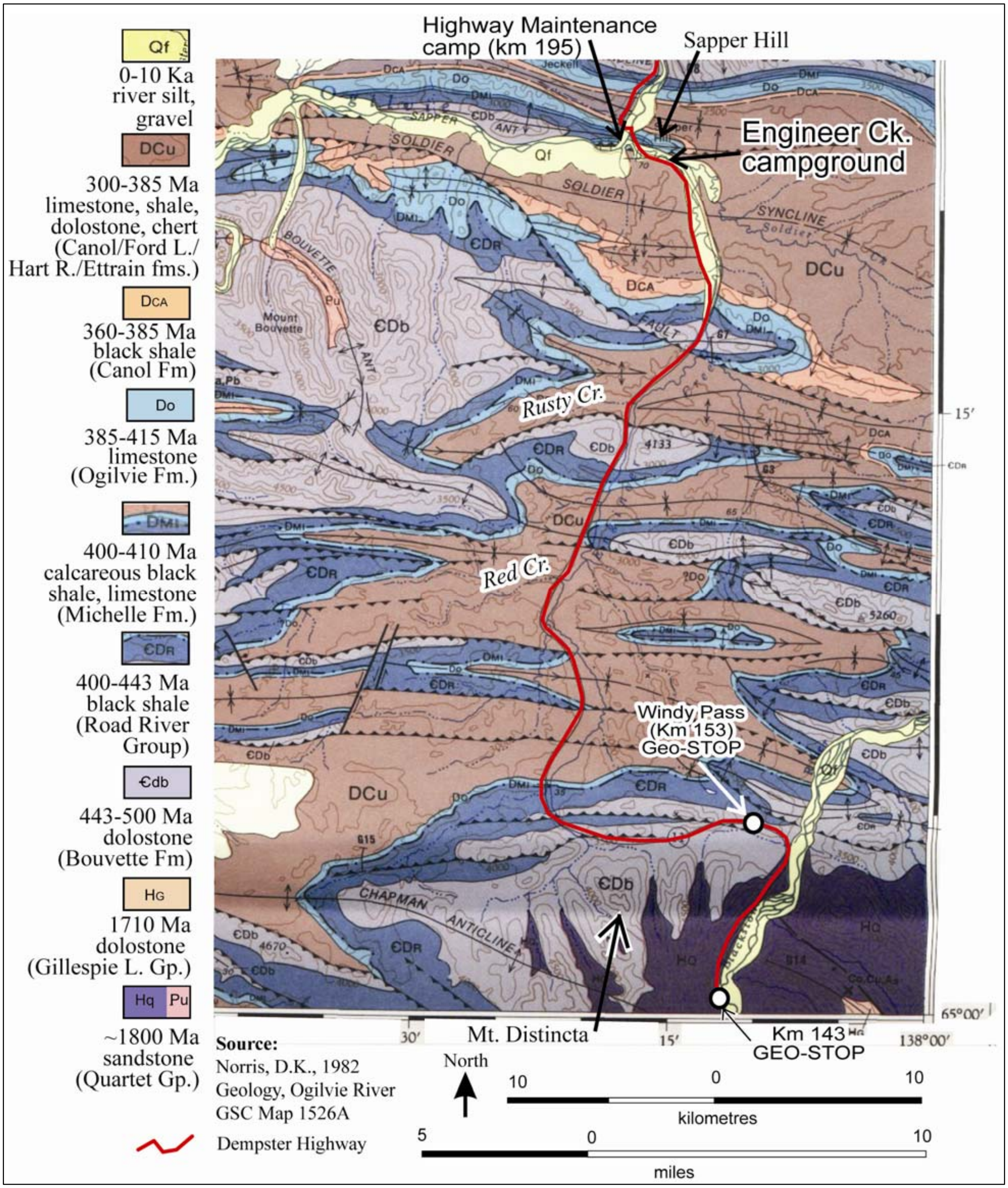


Figure 25. Rock units of the Northern Ogilvie Mountains near the Dempster Highway.

Figure 26. View west from Km 137 to brown Proterozoic metasedimentary rocks of the Wernecke Supergroup overlain unconformably by Lower Paleozoic carbonate rocks of the Bouvette Formation.

Km 143.0 [574.5 km] GEOLOGY STOP: Proterozoic Wernecke Breccia

A small pullout on the west side of the road is surrounded by rubble of dark brown rock that forms the second exposure of Proterozoic rock on the Dempster Highway: a dark weathering siltstone (Quartet Group). Large boulders a dozen metres south are a distinctive breccia studded with specular hematite in the matrix (Figure 27). The clasts are light-coloured sandstone and siltstone of the Fairchild Lake Group, which stratigraphically underlies the Quartet Group. The breccia was emplaced 1600 million years ago, as gas rich fluid moved upward through and disrupted the shelf sediments.

Wernecke breccia is prospective for minerals because it is similar in age and texture to rock hosting very large copper-uranium-gold deposits in central Australia (Flinders Ranges). The similar Proterozoic stratigraphy of the Ogilvie Mountains and Flinders Ranges suggests they were adjacent in the supercontinent Rodinia before being rifted apart about 700 million years ago. This breccia occurrence contains abundant magnetite and has been sampled, although only low-grade mineralization has been located.

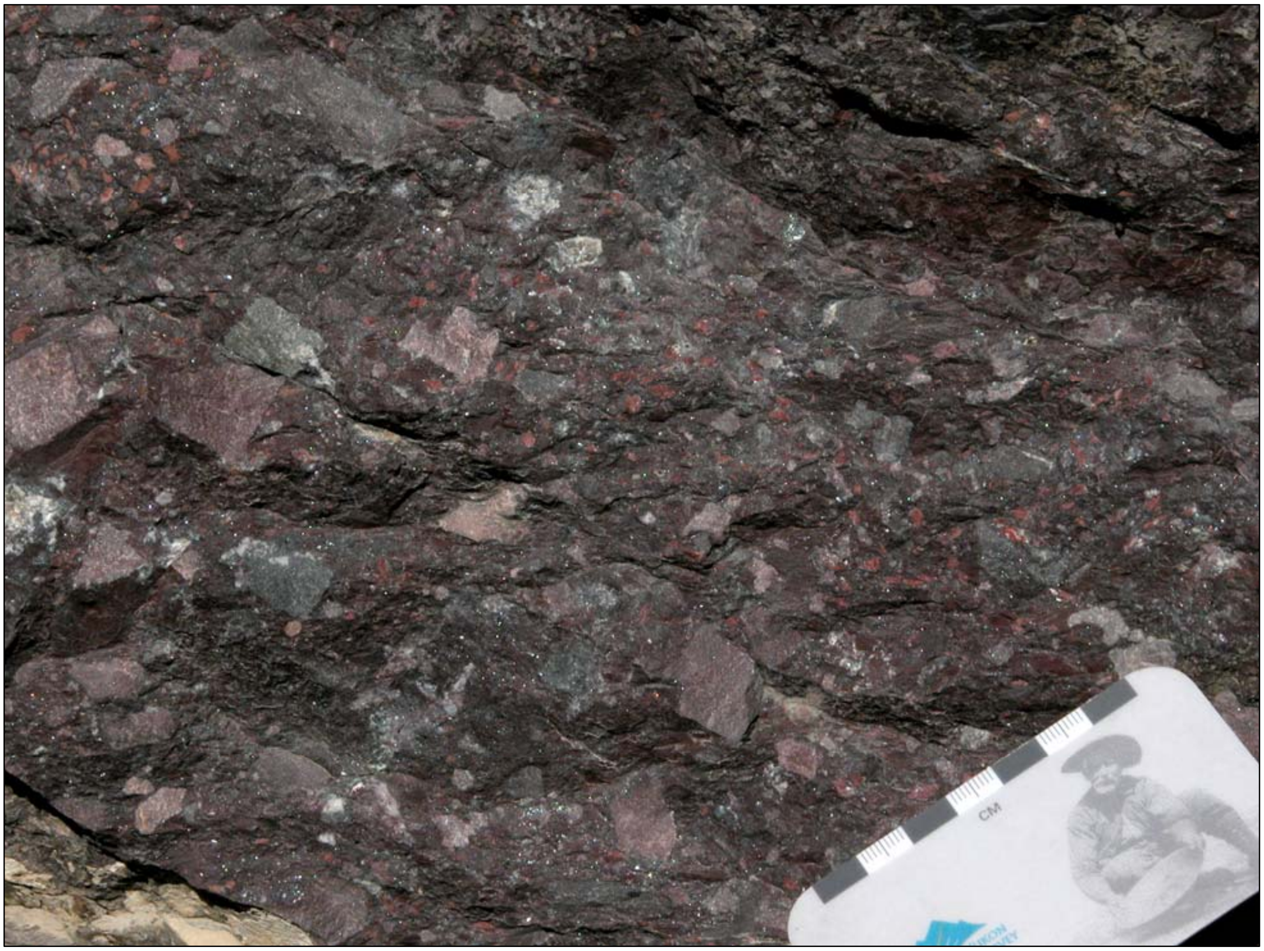


Figure 27. This breccia consists of sedimentary fragments in a sparkly hematite matrix. Mineralizing fluids intruded and disrupted the Wernecke Supergroup 1600 million years ago. It is exposed in boulders near Km 143.

Km 153.0 [564.5 km] GEOLOGY STOP: Windy Pass

At 1060 m elevation, this lightly vegetated landscape is a plausible stand-in for a Beringian landscape. At the time that the first humans arrived from Asia, coniferous forests were absent in the valleys of eastern Beringia, and the bare rock slopes had little organic soil.

The large pullout south of the highway is a three-minute stroll from outcrops and the base of a broad shoulder south of the pass (Figure 28). The fossiliferous Paleozoic Bouvette Formation dolostone has a mottled appearance from burrowing, and fragments of silicified coral are abundant. Brown weathering diorite in the talus comes from dykes, possibly of Ordovician age.

Figure 28. Blocky talus of Bouvette Formation dolostone is easy to examine south of Km 153 (Windy Pass).

Km 156.0-158.0 [561.5 to 559.5 km]: Groins for flash flood diversion

The usually dry stream bed south of the highway is prone to flash floods after summer cloudbursts. Washouts plagued this section of the highway until groins (embankments) were installed in 1990 (Figure 29). Flash floods occur because the dolostone bedrock is close to the surface, soil and vegetation are sparse, thus the slopes retain little water.

Km 160.0 [557.5 km]: Tors on limestone ridges; Engineer Creek

Unglaciated Northern Ogilvie Mountains along the valley of Ogilvie River exhibit castellated peaks or erosional remnants called ***tors*** and unvegetated slopes of limestone rubble created by intense physical weathering.

To the west is the dark shale of the Road River Group (quarried around Km 159 to surface the road). These shales are deeper water equivalents of platformal Lower and Middle Devonian Ogilvie Formation. Large blocks of limestone near the culvert have sedimentary textures (fenestral porosity and microbial laminations) characteristic of a very shallow marine (peritidal) depositional environment that has been periodically above sea level.

Figure 29. This large hoe is repairing a levee to restrict floods from damaging the highway (Km 156). Also note dark shale used to surface this stretch of highway.

Km 168.3 [549.2 km]: Red Creek (bridge)

This tributary dramatically changes the chemistry of Engineer Creek! The bottom and banks of Red Creek are coated in orange iron oxy-hydroxide minerals. Seeps in the headwaters of this creek contain 148 ppm zinc, as well as high concentrations of nickel, copper and arsenic likely derived from the black shale of the Road River Group. In the headwaters the pH is 3.4, but is diluted to pH 6.8 at the highway culvert (Figure 30). Sphagnum and ferric oxy-hydroxide on the stream banks and bottom effectively bind metals, purifying the water. Stream sediment collected near the culvert contained 5770 ppm zinc (J. Kwong, written communication to Roots).

To the west is a cliff of deformed (folded) black shale and interbedded limestone of the Michelle Formation. This unit is a few tens of metres thick, between deep water shale (Road River Group) and shallow water limestone (Ogilvie Formation).

Km 170.0 [547.5 km]: Sulphur springs nearby (also at Km 184.5)

Km 173.0 [544.5 km]: Anticline

The nose of a ridge east of the highway shows the typical structure of the Northern Ogilvie Mountain: a steep-sided anticline cored by Bouvette dolostone, the south limb down-faulted and the north limb consisting of Road River shale, overlain by Michelle Formation. The valleys are underlain by undifferentiated Upper Devonian and Carboniferous units.

Figure 30. View north (Km 168.3) from Red Creek crossing to folded black shale and limestone.

Km 179.9 [537.6 km]: Rusty Creek (culvert)

Sheep are often observed licking the mineral rich precipitate along the creek.

Km 186.0 [531.5 km]: Soldier Fault

The fault offsets the eastward extension of the anticline of Mount Bouvette.

Km 193.4 [524.1 km]: Government campground beside Engineer Creek

Km 194.0 [523.5 km]: Divii Ddhaa: Sappers Hill

This castellated ridge consists of a north-dipping limb of Lower and Middle Devonian Ogilvie Formation limestone in the ***hanging wall*** of a south-directed thrust fault. Differential erosion at the base of the cliff produces conical outcrops rising from grey limestone rubble (Figure 31). 'Sapper' is a nickname for army engineers and here honours the 3rd Royal Canadian Engineers who built the Ogilvie River bridge in 1971. The craggy ridge is popular with gyrfalcons and peregrine falcons. Limestone blocks, exposed in a quarry west of the highway at Km 194.1, contain abundant ***bioclastic*** debris containing ***crinoids***.

Km 194.3 [523.2 km]: Big Engineer Creek (bridge)

Km 195.0 [522.5 km]: Ogilvie River (major bridge) and Highway Maintenance Camp (north bank, west side)

Limestone of Ogilvie Formation is quarried north of the bridge.

Figure 31. View north (Km 190) to tors in Ogilvie Formation on Sapper Hill.

Km 198.8 [518.7 km]: Gwazhal Nijik: Canyon of Ogilvie River

The river and highway weave an S-bend through Bouvette dolostone in the core of Jeckell Anticline (figures 32, 33). The canyon is cut across the structural trend, showing that the antecedent river kept pace with uplift during the Laramide orogeny (Early to Late Cretaceous period).

Km 203.0 [514.5 km]: Castellated limestone peaks of the Bouvette Formation

Look south to Jeckell Anticline which plunges westward into a major structural depression between the west- and north-trending arms of the Ogilvie Depression.

Km 207.0 [510.5 km]: Blackstone anticline in Ogilvie Formation

Look north toward gently dipping strata on the summit at the west end. The faces of beds are steeply south-dipping.

Km 210.0 to 212.0 [507.5 to 505.5 km] GEOLOGY STOP: Ogilvie and Michelle formations and fossils

At Km 210, look west of the highway to the black shale and yellowish grey limestone of the Lower Devonian Michelle Formation. Recessive shale beds contain large, resistant ***concretions*** (Figure 34).

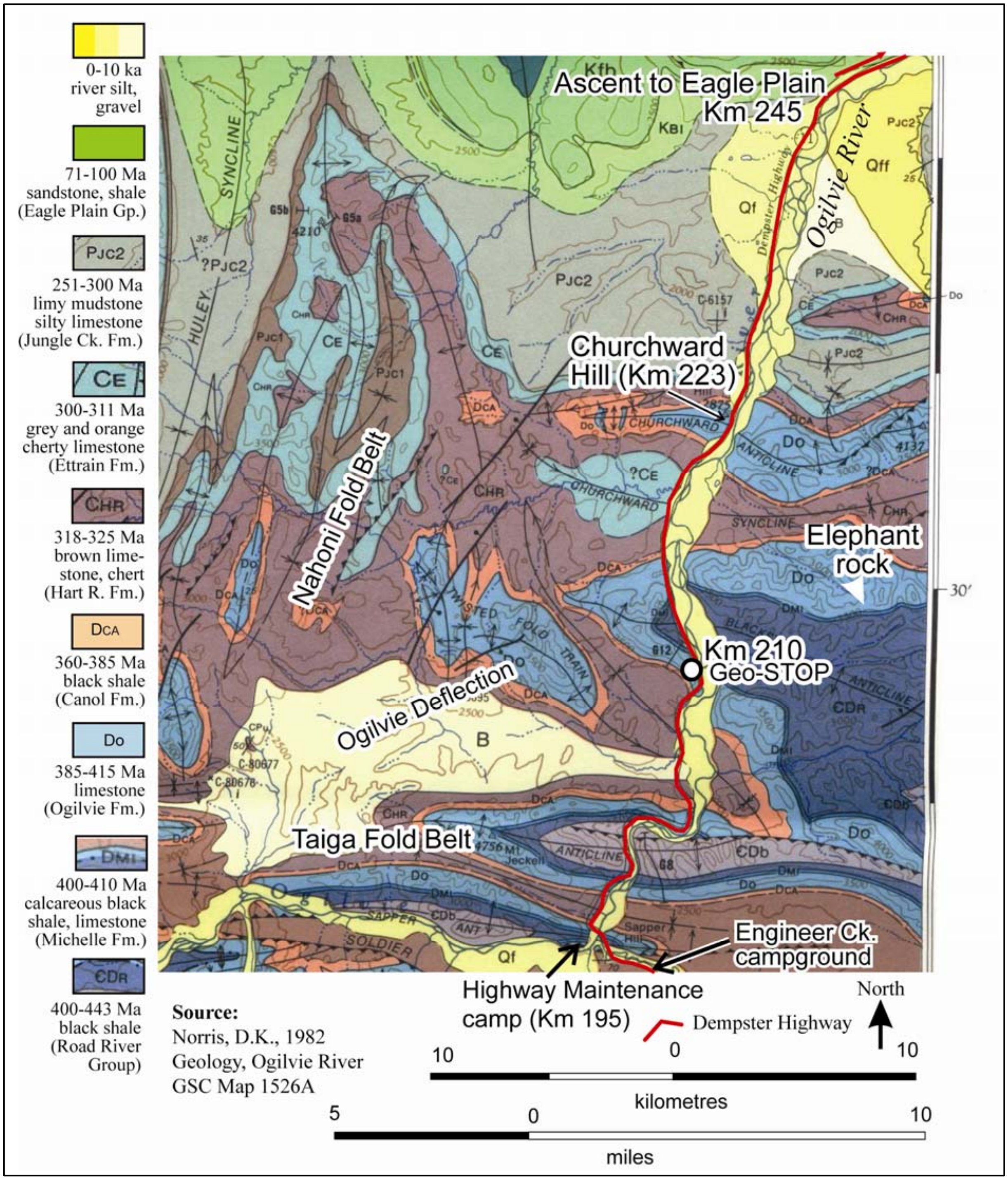


Figure 32. Geological units in the Northern Ogilvie Mountains. The map patterns illustrate the change in structural trend resulting from deformation around the Eagle Plain.

Figure 33. View south (Km 203) to Jeckell Anticline, folded Ogilvie Formation.

Near Km 211, a road cut with a wide shoulder on the east side of the highway along the Ogilvie River exposes the contact between light grey weathering limestone of the Lower-Middle Devonian Ogilvie Formation and fossiliferous black limestone of the Michelle Formation. These formations are on the south flank of Blackstone Anticline. The cliff of the Ogilvie Formation consists of thick beds of fossiliferous limestone containing two-holed crinoids, ***bryozoans***, and ***trilobites***. Large blocks of this limestone form rip-rap, a barrier to erosion, along the west bank of the river.

At Km 212, tors occur in the ridge on the west side of the highway. The highway is surfaced with grey crushed limestone from a quarry around Km 217.

Figure 34. View west of highway (Km 210) to black shale and limestone of Michelle Formation overlain by limestone of Ogilvie Formation.

Km 221.4 [496.1 km]: Elephant Rock rest area

The elephant does not roam in this taiga valley! Look high on the skyline 5 km to the south, where pillars of carbonate form a familiar silhouette (Figure 35), a weathering feature of carbonate rocks on a distant ridge. A prominent fold in a resistant cap of limestone is also visible to the southwest.

Km 223.0 [494.5 km]: Chii Ahan: Churchward Hill

Thickly bedded limestone of the Ogilvie Formation is exposed in an anticline (Figure 36). Precipitous cliffs makes stopping too hazardous here. The Gwitchin name means "Beaver House Mountain" and the legend concerns a giant (Pleistocene?) beaver in the area. The English name honours Guy Churchward, the tinsmith in Dawson during the Klondike Gold Rush. He invented the Yukon airtight heater, a lightweight stove well-liked by prospectors and homesteaders.

Km 237.0 [480.5 km]: Sideroad east: Airstrip and Ogilvie River

Km 243.0 [474.5 km]: Enter Gwitchin settlement lands

The Dempster Highway leaves the Ogilvie River and begins the 11 km ascent to Eagle Plain.

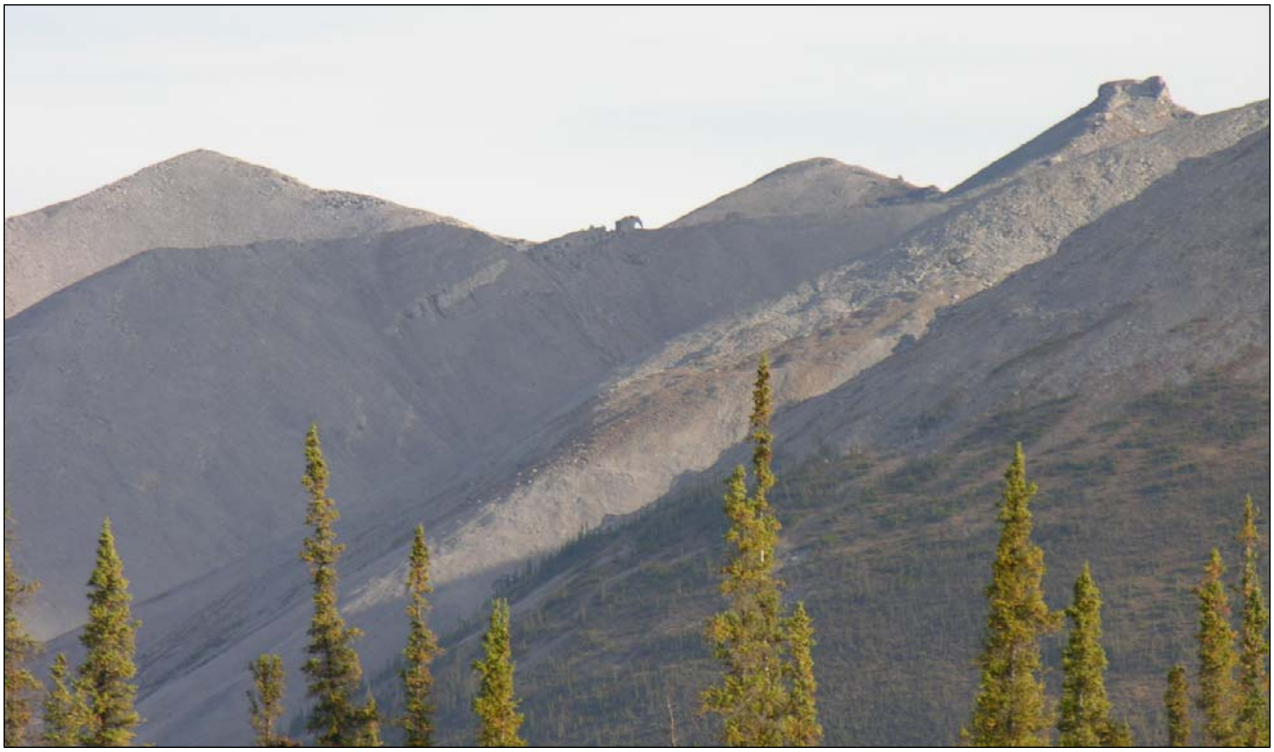


Figure 35. Yukon's elephant, in the distance; view to south from Km 221.4.

Figure 36. Churchward Hill is the most northerly exposure of the lower Paleozoic carbonates in the Northern Ogilvie Mountains.

Eagle Plain to the Arctic Circle (Km 245.0-405.6)

The Dempster Highway transects the southeast corner of Eagle Plain, which lies between the Ogilvie and Richardson mountains. This lowland area covers more than 20,000km^2 and is a series of hills between 400 and 800 m elevation, which makes it more of an upland than a lowland! The highway initially follows broad, meandering ridgetops of Eagle Plain, which is an area of nearly continuous permafrost, and then follows a path through black spruce muskeg from about Km 280 toward Eagle Plains Lodge at Km 369. Ridges form local divides with dendritic drainage of the dissected Eagle Plain. This low, rolling terrain continues to the Richardson Mountains, which come into view from the Eagle Plains Lodge.

Seismic lines visible from the Highway were cut during petroleum exploration in the 1950s and 1960s to collect geophysical or seismic data (energy passed through the subsurface rock to record its properties, geometry, composition, fluid content). The petroleum potential of this area was the impetus for the initial phase of road construction.

Km 245.0 [472.5 km]: Seven-mile hill to Eagle Plain

From the Ogilvie River valley (400 m elevation) the highway gradually ascends northeastward. Rusty weathered shale is exposed near the bottom. The hilltop (870 m elevation) presents a new landscape: the broad hilltops are above the forest. Sandstone, siltstone and shale of the Late Cretaceous Parkin Formation, the oldest unit of the Eagle Plain Group is exposed near the top of the hill.

Km 253.0 [464.5 km] GEOLOGY STOP: Pullout, Cretaceous Eagle Plain Group

A pullout above the west side of the highway provides easy access to a bulldozed brow of a hill where you can examine fresh rock (interbedded sandstone and shale of the Fishing Branch Formation) without physical difficulty or distraction by traffic. This is the second oldest unit of the Eagle Plains Group (Figure 37).

The sandstone beds contain fine to coarse quartz and lithic grains, and reveal ***cross-bedding***. Plant fossils are common as carbonized impressions of wood fragments. On the bottoms of sandstone beds, there are raised ridges where objects were dragged along the sea floor to leave tool marks, and fossils trackways of marine animals. ***Liesegang bands*** are common and represent precipitation of iron-rich fluids through the sandstone. Compact masses of iron-rich limonite or goethite mineral concretions also occur in the sandstone and are not dinosaur eggs! ***Ammonites*** (extinct mollusks with a straight or coiled, chambered shell) of Early to Late Cretaceous age (Albian-Cenomanian) have been reported from this unit in north-central Eagle Plain.

Km 259.0 [458.5 km]: Gwazhal Kak: Ogilvie Ridge Rest area

A panorama south and east of light-coloured carbonate formations in the Northern Ogilvie Mountains is seen from Ogilvie Ridge (65°47’06”N, 137°46’40”W). Below the viewpoint is the braided floodplain of the Ogilvie River. It becomes the Peel River when joined by the northward-flowing Blackstone River and flows 300 km eastward to the ferry crossing near Fort McPherson (Km 537). The interpretive signs describe the bedrock and glacial history of the Northern Ogilvie Mountains, and petroleum exploration in the area (Figure 38).

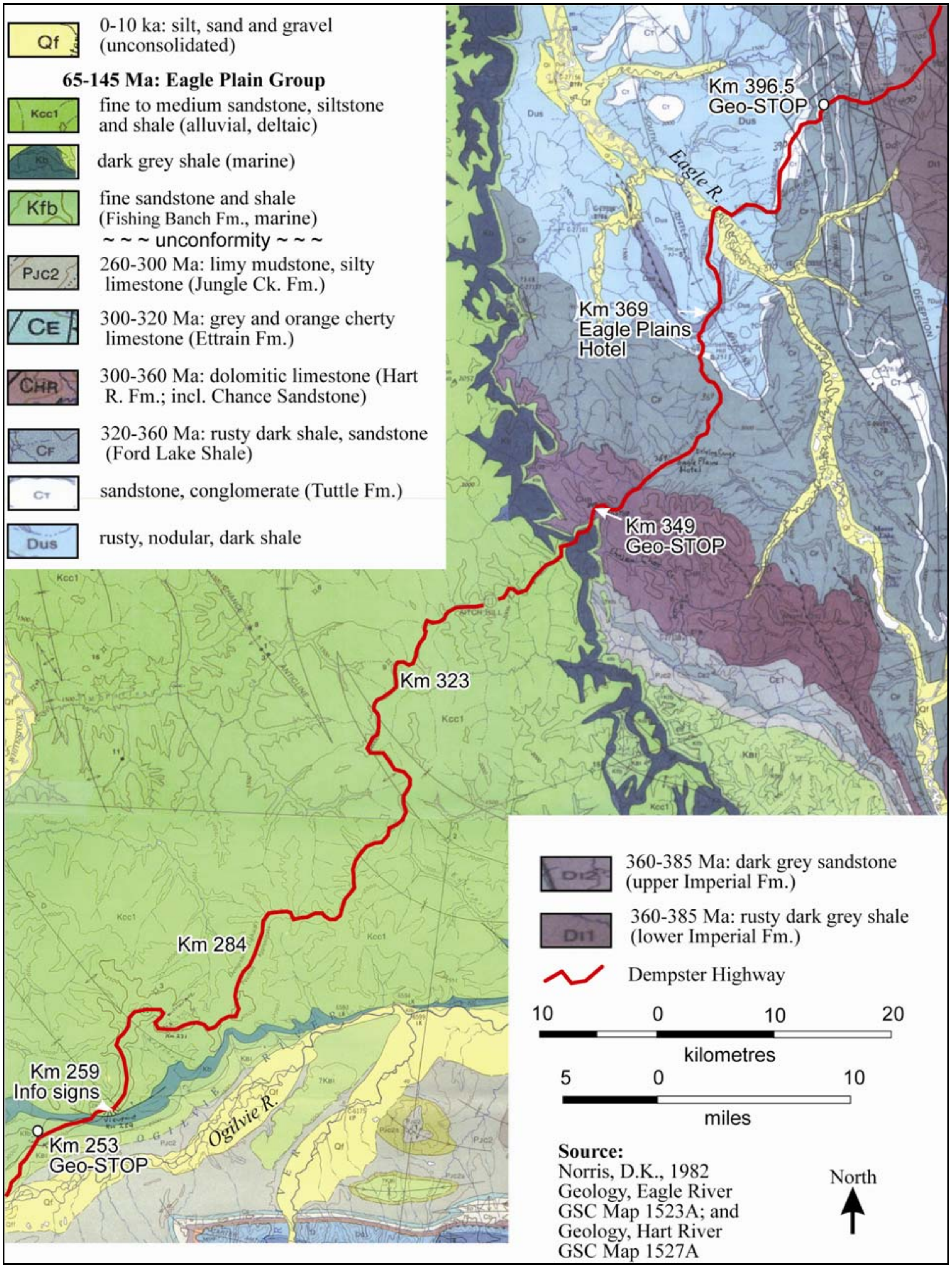


Figure 37. Geological units traversed by the Dempster Highway in the Eagle Plain area.

Figure 38. View southeast to Ogilvie River in foreground and Northern Ogilvie Mountains (Km 259).

Km 260.0 [457.5 km]: Airstrip beside road

For the next 20 km the Highway is mostly above treeline, along the crest of a rounded ridge.

Km 271.0 [446.5 km]: Microwave Installation, Periglacial boulder-creep

The sideroad going north 1.5 km leads to a NorthwesTel tower (parking very limited). The high point (943 m elevation) 80 m distant exposes the Eagle Plain Group sandstone (Figure 39). Channel scour is visible in the clean faces of outcrop blocks. The outcrop has been fractured and these fractures have been widened by freeze-thaw cycles and periglacial creep. The Eagle Plain was not glaciated, so the transport agent is gravity and the plasticity of the ice-rich soil. Slabs as large as 4 m across have moved up to 50 m downslope. The "bow-wave" on the downslope side of such blocks provides a fertile site for pioneer shrubs, and in late August the blueberries are ready for picking.

Km 272.6 [444.9 km]: Pullout east side of highway

The view to the south is the Ogilvie River in the distance with Taiga Ranges of the Ogilvie Mountains in the far distance. Note the long linear patch, oriented north-south, of cleared forest to the south. This is a legacy of mid-1960s seismic survey in search of structural traps for oil and gas. A pair of ***cuestas*** is visible to the west.

Figure 39. Sandstone of the Eagle Plains group is shifting downslope from this knoll (Km 271).

The road cut at Km 273 exposes Cretaceous and Lower Tertiary Eagle Plains Group. The sandstone exhibits sedimentary features such as large scale cross-beds, Liesegang banding and plant fossils. The highway re-enters spruce forest near here.

Km 276.0 [441.5 km]: Seismic line and Wellsite

A seismic line is visible north of the highway. A few km north of this point, the Chevron Imperial South Chance YT D-63 well was drilled in 1972 to a total depth of 2021 metres into Upper Carboniferous strata. The current well status is dry and abandoned. There have been 33 wells drilled in the Eagle Plain region to date.

Km 286.0 [431.5 km]: Former government campsite

The cleared area marks the boundary between road sections maintained by the Yukon Department of Highways maintenance stations at Ogilvie River and Eagle Plains. The adjacent quarry is in brown sandstone with abundant black slate containing plant impressions.

The transition between shrub tundra and black spruce forest is about 900 m elevation on south-facing slopes, and at 750 m on north-facing hillsides.

GEOLOGICAL SYNOPSIS OF EAGLE PLAIN (FROM OGILVIE RIVER TO EAGLE RIVER, KM 223 to 378)

Here's another dramatic landscape change: travelers of the Dempster Highway ascend to about 850 m (2800 feet) and wind along a series of broad ridge crests. Despite the moderate elevation gain the northern latitude, poor soil, and winter exposure conspire to keep the treeline low, at least in the southern part of the Eagle Plain. The area was not glaciated and where incised by stream gullies the exposed rock (chiefly sandstone) has crumbled into long rubble slopes. Peat bogs overlie drainage-inhibiting permafrost, but in other areas the soft and porous rock is deeply weathered and surface water is scarce.

The exposed rock on the south part of Eagle Plain consists of flat-lying interbedded argillite, siltstone, and sandstone called the Eagle Plain Group. These rocks are formed by Late Cretaceous marine (and possibly non-marine in its upper part) tidal flat and coastal fan sediments shed from rising mountains in the first stage of the Cordilleran orogeny. The combined thickness of the Cretaceous strata varies from less than 500 m in the southeast to over 2000 m in the west; beneath it lies an angular unconformity. Late Devonian to Permian shelf sedimentary rocks were uplift and beveled before Cretaceous deposition.

The eastern part of Eagle Plain reveals the sub-Cretaceous succession. The uppermost exposure on the Highway is the Hart River Formation, a silty dolomitic limestone (roadcut at Km 349) of Upper and Lower Carboniferous age. Below it lies the Ford Lake Shale, a shale-dominated unit containing siderite nodules and less common sandstone lenses. The Tuttle Formation is the best known and exposed (at Km 369 and 396) sandstone. Another sandstone horizon mapped as Dss is observed in this area; its relationship to Tuttle Formation is currently under review. In reconnaissance mapping the sandstones were identified as separate formations but more recent work suggests they both interfinger with the Ford Lake Shale. Strata as old as Late Devonian are exposed in the Eagle River valley, as far east as the Deception Fault (about Km 403) against which uplifted older strata comprise the west flank of the Richardson Mountains.

Km 302.0-331.0 [415.5 to 386.5 km]: Forest recovery from fire

A large fire in 1991, as well as older and more recent burns (2005) in this area reveal stages in regeneration of the boreal black spruce forest. A typical succession is: fireweed and alder shrubs, dwarf birch and poplar (where permafrost lacking), and black spruce. Although the thick peat floor is generally singed rather than consumed by a fire, in places the denuded and blackened ground does not sufficiently insulate the underlying permafrost; meltwater pools form here, so slumping and landslips are more common than in unburned areas.

Km 323.0 [394.5 km]: Wellsite of Canoe River E. Chance C-18

A prospective oil well was drilled here in 1968 by Westmin Resources Ltd to a depth of 1541 metres. It encountered gas in the Chance sandstone member of the Hart River Formation, and gas mixed with mudstone in the Permian Jungle Creek Formation. Its current status is dry and abandoned. The site is a waterfilled ditch on the west side of the highway, but there is no pullout nearby.

EAGLE PLAIN - FUTURE GAS AND OIL FIELD?

The Dempster Highway began as a winter freighting route following recognition of petroleum potential on the Eagle Plain. The first well was drilled in 1958 and the Western Minerals Chance YT No. 1 M-08 significant discovery was made in 1959. In this well, gas was encountered in the Fishing Branch Formation and other units of the Cretaceous Eagle Plain Group, as well as in the Carboniferous Chance, Canoe and Tuttle formations. Furthermore, oil was found in the Chance and Canoe sandstones. In total, 33 wells were drilled before 1986. Most seismic surveys, with concurrent gravity and magnetic measurements, were made before 1975. The surveys focused upon the southern half of the Eagle Plain (these surveys are revealed by linear cut lines across the forested hills; a discontinued practice). The discovered resource for this area is 83.7 billion cubic feet (Bcf) of gas and 11.1 million barrels (MMbbls) of oil - the only place in Yukon with a calculated reserve*.

Eagle Plain is considered by the Oil and Gas Management Branch of the Yukon Government to be an under-explored structural basin. Fifteen petroleum plays (nine gas and six oil) are located in various structural and stratigraphic traps (see symbols on Figure 4, Table of Formations). Since 1999, three permits for exploration have been issued, and most land dispositions are in the vicinity of the Eagle Plains Lodge. If the market price for petroleum remains high, it is possible that further hydrocarbon exploration will take place in this area.

* *Eagle Plains Resource Assessment, Oil and Gas Branch, Yukon Department of Energy Mines and Resources, Open File 2005-2.*

Km 325.0 [392.5 km]: Rest stop with outhouses

This area is underlain by the gently folded Cretaceous Eagle Plain Group. Two dirt airstrips in this area were used during oil exploration.

Km 347.0 [370.5 km]: Hart River Formation

Sideroad to the west leads several hundred metres to a quarry that exposes several lithologies of Lower and Upper Carboniferous Hart River Formation. Light grey, siliceous limestone lies at the lowest level of the quarry and contains discontinuous beds of carbonate breccia and pebble conglomerate. The limestone is overlain by discontinuous black, soft, silty shale and sand to conglomerate with coalified plant remains. This coaly shale layer is interbedded with light grey, coarse-grained sandstone (Figure 40). The uppermost exposure contains brown shale and medium grey weathering sandstone and conglomerate with limestone clasts and sandstone clasts.

From the hills near here the Richardson Mountains are visible to the east, about 80 km distant.

Km 348.0 to 349.0 [369.5 to 368.5 km] GEOLOGY STOP: East-central Eagle Plain, Hart River Formation

An exposure of Hart River Formation extends for about 1.5 km along the east side of the highway (Figure 41; 66°14.3'N, 136°54.03'W). The outcrop is mainly pale orangish grey weathering, siliceous, laminated limestone that contains plant fossils (impressions) and shelly fossils such as brachiopods. South along the highway around Km 348, cross-sections of broad channels occur in the roadcut.

Figure 40. Immature sandstone and coal fragments in the upper Hart River Formation of Carboniferous age (Km 347).

Figure 41. Thick beds of siliceous limestone of Hart River Formation is one of the few resistant roadside outcrops on the Eagle Plain (Km 349).

A COATING OF MANY COLOURS…

Gravel roads are built and maintained with local materials, and suitable aggregate can be a challenge to procure in unglaciated terrain and on hilltops where stream deposits are far away. On the Dempster Highway in the Eagle Plain segment you'll notice abrupt changes in the colour of the road surface and, especially after a spell of wet weather, its ability to withstand heavy traffic. Calcium hydroxide is spread on the road to reduce the dust during dry spells.

In the absence of glacial till and stream gravel, transportation engineers have excavated local rock types. Because of the quantity required and the transport cost, they use the nearest acceptable source. The Highway leaves the Ogilvie River (Km 245; where carbonate gravel is abundant) and ascends Seven-mile Hill, where the road consists of sandstone and shale to about Km 300. Quarries likely used for this purpose are at Km 253 and 286. From Km 300 to 346 the road was surfaced with brown shale, which is prone to slickness and ruts. North of Km 346 light brown sandstone provides a more durable, knobby surface. The sandstone was likely excavated at km 347. Grey sandstone is quarried at Km 362 and used for similar purpose. In 2006 a new quarry at Km 403 is being prepared to supply re-surfacing gravel to the shaly and muddy sections.

As you drive the Dempster Highway, consider the effort of locating and transporting good road material. Not only are the roads more complex to construct across permafrost and poorly drained ground than they are in a southern climate, but they require considerably more aggregate and maintenance - commodities that are scarce and precious in this beautiful land.

Cretaceous Eagle Plain Group overlies the Hart River Formation on an angular unconformity: the latter disappears about 15 km north of the Dempster Highway. The unconformity results from Early Cretaceous uplift, referred to as the Eagle Arch.

Km 350.4 [367.1 km]: Ehnjuu Choo Creek

Km 351.0 to 352.0 [366.5 to 365.5 km]: Fly Camp Hill: Hart River Formation

Limestone outcrops weathers light grey, brown, and platy which distinguishes this formation from the Tuttle Formation exposed at Km 368-369. A nearby quarry in the Ford Lake shale (Figure 42a) yields limonite-stained concretions (Figure 42b).

Km 369.0 [348.5 km] GEOLOGY STOP: Eagle Plains Lodge and Maintenance Camp

This year-round service centre was built in 1978 and provides gas, food and lodging (66°22.283'N 136°43.383'W). The site was selected because bedrock was close to the surface, otherwise costly pilings are required to keep the permafrost under the buildings from melting.

Pale orange weathering sandstone of the Lower Carboniferous Tuttle Formation is exposed across the road about 200 m southeast from the hotel (Figure 43). Here, and in blocks around the hotel parking lot and campground, the sandstone consists of clear quartz grains, white chert chips, and minor mineral fragments like ***pyrite***. Plant fossils are common and trace fossils (animal

Figure 42a. Quarry in Ford Lake shale reveals flat lying beds of more resistant sandstone.

Figure 42b. Claystone concretions contain pebbles (Km 353).

Figure 43. Eagle Plains Lodge is a service centre built on sandstone of Carboniferous Tuttle Formation (quarried at left; Km 369).

tracks and trails) occur on bedding surfaces (Figure 44). Iron concretions and staining occur, giving an overall orange colour. This porous sandstone is a potential reservoir for natural gas and crude oil.

From the observation deck north of the hotel one can see a northern ridge crowned by an airstrip (Figure 45). It was used by the oil industry beginning in the late 1950s, and was one of the busiest airstrips in the Yukon in the late 1970s to support construction of the Eagle River Bridge (by the Royal Canadian Engineers) as well as oil and gas drilling crews.

The crest of the Tuttle Anticline was explored by the Mobil Oil Tuttle N-5 well located 10 km north of the hotel. It was drilled to a depth of 3513 m in 1965, and its current status is dry and abandoned. The porous Tuttle sandstone is one horizon of interest as a reservoir for natural gas and crude oil. The Richardson Mountains can be viewed to the northwest (Figure 46).

Figure 44. Tuttle Formation contains wood fragments, more than 300 million years old (Km 369).

Figure 45. View north from observation deck behind Eagle Plains Lodge (Km 369) overlooking Eagle Plains and Dempster Highway.

Figure 46. Sunrise view northeast from Eagle Plains Lodge (Km 369) toward Richardson Mountains.

Km 373.5 [344.0 km]: "The Driving Range"

The pullout east of the Highway (66°23.958'N 136°42.184'W) has exposed dark grey, gypsiferous marine shale, called the Ford Lake Shale. The unit is determined here to be Late Devonian to Early Carboniferous in age based on spores. It occurs on the east flank of the south-plunging Tuttle Anticline.

The bank of shale is used as a catchment for golf balls from two driving range platforms at this stop, which bears a no-entry sign.

Km 378.0 [339.5 km]: Eagle River (major bridge)

This pullout west of highway has a view of the river and an interpretive sign about the history of the infamous Mad Trapper, Albert Johnson.

Km 384.0 [333.5 km]: Eagle River during the last glaciation

The Eagle River valley is a meltwater channel remnant from the last glaciation approximately 30,000 years ago. The presence of the Laurentide ice sheet in the Mackenzie River lowlands and Bonnet Plume basin to the south caused the upper Peel River to back up and form glacial lake Hughes (Figure 6). Drainage of this lake was forced to occur northward across the Eagle Plains in this locality and is marked by terraces up to 70 m above the present river level. The continuous flow of water from glacial lake Hughes incised the soft bedrock creating the box-shaped valley visible today. Drainage from glacial lake Hughes inundated basins to the north and resulted in the formation of glacial lakes Old Crow and Bell.

Km 390.0 [327.5 km]: Emergency airstrip

Km 396.5 [321.0 km] GEOLOGY STOP: Ford Lake Shale, Tuttle sandstone, fossils (Park at the south end of the outcrop and walk downhill to the roadcut)

The gradational contact between the Carboniferous Ford Lake Shale and Tuttle Formation is exposed at this site (Figure 47). The Ford Lake Shale contains dark grey shale interbedded with rusty weathering sandstone. These deposits mostly represent deeper water conditions; however, at this location the abundance of sandstone units suggest shallower water conditions. The Tuttle Formation contains pale orange weathering chert-pebble conglomerate and quartz and chert sandstone with centimetre-scale grey/brown shale intervals. In the Eagle Plain area, the Tuttle Formation has been interpreted to represent deltaic and fluvial environments. In the subsurface of the Eagle Plain and Peel Plateau, minor gas showings have been associated with the Tuttle Formation. In Eagle Plain an estimated reserve of 58 Bcf of gas lies in the Tuttle Formation. Quarries into the Tuttle Formation west of the Highway occur around km 335.

Abundant plant fossils occur in sandstone pieces lying below the outcrop. Fossils called *Lepidendron* are scale-like impressions of large trees (up to 40 m tall!) related to modern lycopods or club mosses. Use caution around outcrop overhangs, especially on the east side of the road – they may be unstable.

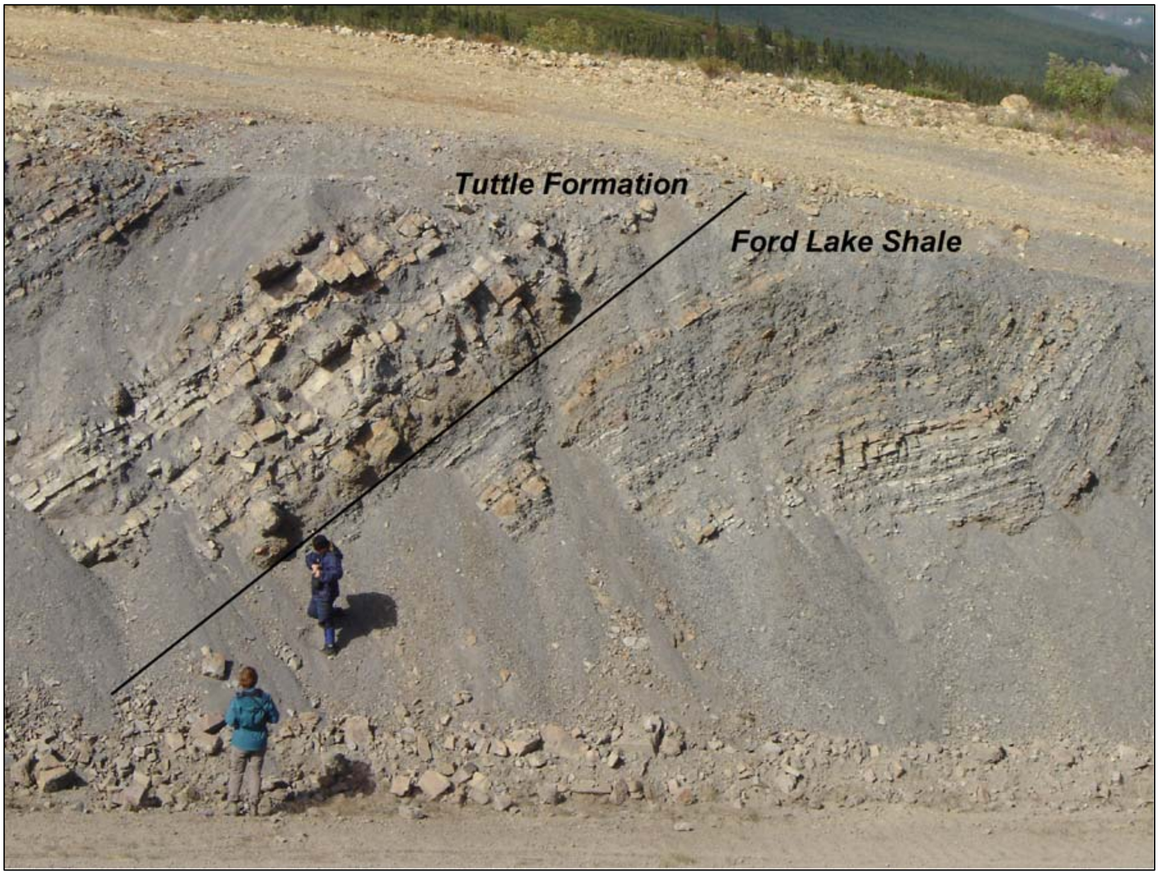


Figure 47. Roadside exposure on west side of highway (Km 396.5), Ford Lake Shale and Tuttle Formation.

Km 403 [314.5 km]: Deception Fault (covered)

This west-side-down, pre-Cretaceous break marks the boundary between the Eagle Plain and Richardson Mountain tectonic elements (Figure 3). It is the western manifestation of the Richardson Fault Array and bounds the Richardson Anticlinorium to the west. The anticlinorium formed during the Cordilleran Orogeny, from Late Cretaceous to early Tertiary east-west convergence. It is a broad structure that coincides in position with the Paleozoic Richardson Trough, a Paleozoic deep-water basin (Figure 5).

Arctic Circle and Richardson Mountains (Km 405.6 to 487.0)

In this segment the Dempster Highway follows the western flank of the Richardson Mountains, crosses them at Wright Pass (Km 464) and continues eastward in the Northwest Territories to the Peel Plateau and Plain (Figure 48). The Richardson Mountains were named by Sir John Franklin in 1825 for John Richardson; his popular and versatile first mate, surgeon, naturalist and artist during two overland expeditions along the coast of the Beaufort Sea. The mountains, up to about 1200 m in elevation, are characterized by cold, dry and windy conditions which result in sparse vegetation (mountainsides above 760 m are bare). Geologically, the mountains are an anticlinorium between north-trending strike-slip faults, composed of deep marine sediments deposited in the Paleozoic Richardson Trough (analogous to Selwyn Basin). During the Ice Age they limited the westward encroachment of the Laurentide Ice Sheet (see Km 472).

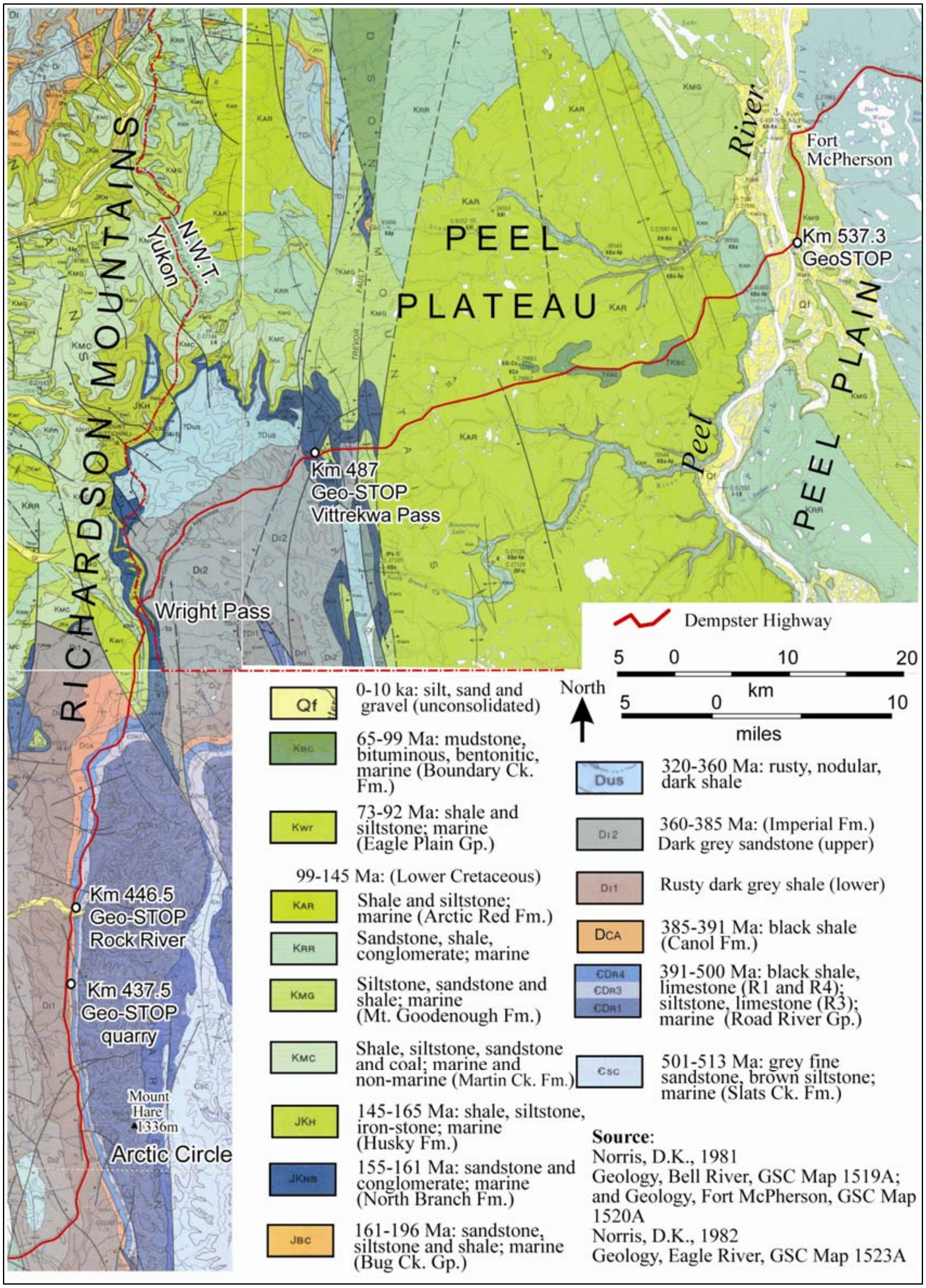


Figure 48. Geological units traversed by the Dempster Highway in the Richardson Mountains area.

Km 405.6 [311.9 km]: Arctic Circle

The rest area contains interpretive signs. A panorama eastward shows the western flank of this linear range. The mountains are underlain by the Richardson Anticlinorium (page 10) which exposes the basinal facies of the Devonian Canol and Imperial formations in the foreground, with older strata of the Cambrian to Silurian Road River Group forming the higher peaks in the Richardson Mountains (Figure 49). These deeper water deposits are equivalent in age to shallow water platform carbonates of Mackenzie Peel Shelf of the Mackenzie Fold Belt and Northern Interior Platform (Figure 3).

At this latitude (66.3°N) the sun does not set below a sea-level horizon on June 21. You can see the sun at midnight from high elevations as far south as about 65°N.

Km 437.5 [280.0 km] GEOLOGY STOP: Quarry and Fossils

A small quarry on the east side, (66°52.485'N 136°19.770'W), one of many quarries along this portion of the highway, exposes black shale of the Canol Formation. Most quarries are marked 'no-entry', except for this one that was unmarked in summer 2006. Fossils (mainly impressions in the shale) of ***cephalopod*** molluscs occur in these rocks.

Km 445.8 [271.7 km]: Rock River Campground

The river at the campground cuts through Devonian Imperial Formation to create about a 2 km wide valley. It was a natural passage for seasonally migrating caribou, and funnel-shaped fences were constructed to divert them into snares.

Figure 49. View to western flank of Richardson Anticlinorium from the Arctic Circle (Km 405.6).

Km 422.0 [295.5 km]: *Vadzaih lean njik* (creek culvert)

The Gwitchin name means "Caribou Den Creek" and is a traditional hunting area.

Km 446.5 [271.0 km] GEOLOGY STOP: Rock River and Fossils

In the vicinity of Rock River, the Devonian Imperial Formation is exposed along both sides of the Highway. The Imperial

Formation overlies the Devonian Canol Formation which can be observed by hiking east (upstream) along the creek (Figure 50). The bright red color of Canol shales can be viewed from the bridge over Rock River, and again at Km 450. These 'burnt shales' are likely the result of the burning of carbonaceous material in the rock during a forest fire.

Even further east are older strata of the Road River Group (Cambrian to Silurian age) in the core of the Anticlinorium. This Paleozoic marine succession was deposited in a deep basinal setting called the Richardson Trough. Basinal shale contains fossils of mollusks and ***graptolites***, extinct Cambrian to Carboniferous age colonial marine organisms that look like pencil markings on shale.

Unglaciated portions of the Richardson Mountains in this area contain pediments of pre-glacial Tertiary age that are influenced by the underlying geology. West of the highway, erosion of Imperial Formation sandstone and siltstone created upland soils, whereas east of the highway, the lower slopes of the Richardsons are organic-rich colluvium derived from Road River Group.

Km 452.0 [265.5 km]: Richardson Anticlinorium

A panoramic view west from the west flank of the Richardson Anticlinorium includes exposures of black and light blue-grey shale and cherty shale of the late Devonian Canol Formation. The western flank also exposes well developed, gently sloping pediments that are probably late Tertiary age.

Figure 50. Devonian black shale of the Canol Formation along Rock River. Section is located approximately 750 m east of the highway (Km 446.5).

Km 464.0 [253.5 km]: Wright Pass

Here the highway crosses the continental divide at the crest of the Richardson Mountains. Waters flowing west are bound for the Pacific (Bering Sea) and those flowing east are part of the Arctic Ocean (Beaufort Sea) drainage.

Cuestas on the west flank of Richardson Anticlinorium (Figure 51a) are viewed south from the pass. To the south in the distance, the west flank of the anticlinorium swings west, affected by the Richardson Fault Array. About 10 km south, west of the Highway, a thin slice of highly deformed, resistant quartzite of the North Branch Formation rises along a fault, above the ***pediplain***. The faulted slice (or horse) was dragged at least 2 km northwest as a result of right-hand displacement. The Rat River Formation is underlain by the following units from youngest to oldest: recessive shales and siltstones of the Mount Goodenough Formation; white sandstone of the Kamik Formation; recessive shale of the McGuire Formation; and ridge-forming sandstone of the North Branch Formation (Figure 51b).

The pass name honours Allan Wright, a highway engineer for the federal government who surveyed and determined the alignments for much of this northern road.

Km 465.0 [252.5 km]: NWT / Yukon Border

Welcome to the Northwest Territories or Yukon (Figure 52). This is the boundary between Pacific Standard or Mountain time zones (1 hour difference), so set your watch accordingly.

Km 467.0 [250.5 km] (2.0 km from border): Pleistocene terraces

A view to the northeast shows spectacular ***pediments*** that cut indiscriminately across deformed Imperial Formation (quarried at about km 240). Pediments record periodic and progressive uplift of the core of the southern Richardson Mountains during pre-glacial, mid- to late Tertiary time.

Figure 51a. View south from Wright Pass (Km 464) across cuestas formed of resistant sandstone of the mid-Lower Cretaceous Rat River Formation.

Figure 51b. Wright Pass roadside marker on white, cross-stratified sandstone of the Kamik or North Branch Formation.

Km 472.0 [245.5 km] (7.0 km from border): Laurentide Drift

Massive glacial drift deposits left behind by the Laurentide Ice Sheet dammed southeastward drainage of the valley and deflected streams southwestward for 4 km. The Laurentide Ice Sheet flowed into this area from the east; constituting the western fringe of a large, continental ice sheet which covered a significant portion of Canada and the northern United States. Ice covered this area sometime between 30,000 and 13,000 years ago. If traveling south from this point, the Dempster passes through unglaciated terrain until it reaches Windy Pass and Blackstone River in the Yukon.

Figure 52. Signs at Km 465 mark the NWT/YT border; enjoy the interpretive roadside signs on the NWT side.

Km 482.0 [235.5 km] (17.0 km from border): Richardson Anticlinorium

Over the last few kilometres, beds of the Devonian Imperial Formation are deformed (some are reoriented nearly vertical in parts of the pass) and overlain by white quartzite of the Jurassic-Cretaceous Kamik Formation. The east rim of the Richardson Anticlinorium is visible to the northeast.

Km 485.0-487.0 [232.5 to 230.5 km] (20.0-22.0 km from border) GEOLOGY STOP: Vittrekwa Pass

The eastern slopes of the Richardson Mountains are dominated by glacial and lacustrine (lake) sediments left during the advance and retreat of the Laurentide Ice Sheet. The ice sheet trapped water between the ice and slope, dotting the slopes of glacial till with small lakes.

Throughout the pass (Figure 53a), the Devonian Imperial Formation has a two-phase history of deformation. Principal deformation occurred during the Ellesmerian Orogeny (late Paleozoic, Carboniferous) and further tilting occurred during the Laramide Orogeny (early Cenozoic, early to mid-Tertiary). These rocks form the eastern limb of the Richardson Anticlinorium and the deformed Imperial Formation represents the southern limit of Ellesmerian orogenic effects on the North American Plate. Cretaceous rocks in the pass were affected by the younger uplift of Richardson Trough to turn it into an anticlinorium. Folds are a common feature in the Imperial Formation within the pass (Figure 53b). The Imperial Formation consists of rhythmically bedded siltstone and shale, deposited by turbidity currents in a deep basin.

At the summit (around Km 487.0) from the east, the highway enters Vittrekwa Pass, a high-walled abandoned glacial meltwater channel containing terraces of glaciofluvial deltaic sediments that flank the highway. Gravel from these terraces is a potential source of road aggregate.

Exposures in creeks alongside the road reveal deformed Devonian Imperial Formation. The pass is the transition of the Richardson Mountains to Peel Plateau to the northeast.

Figure 53a. Deformed Imperial Formation is exposed through Vittrekwa Pass (Km 485).

Figure 53b. Folded Imperial Formation (Km 485 to 487).

Peel Plateau and Peel Plain (Km 487.0 to 605.2)

Past Vittrekwa Pass, the Dempster Highway crosses the northwest corner of a physiographic region called Peel Plateau and Peel Plain. These lowlands have limited outcrop and are blanketed by tundra, muskeg, and shallow lakes. The area is covered by glacial sediments and was once covered by the Laurentide Ice Sheet.

The Peel River (Km 537.3) divides the plateau area from the plain. Peel Plain extends to just north of the Mackenzie River (Km 605.2). Peel Plateau has elevations up to 950 m while Peel Plain contains lowlands ranging from 150-450 m elevation.

This area, like the Eagle Plain, is prospective for hydrocarbons. There have been more than 70 wells drilled (19 in Yukon) with some hints of oil and gas potential.

Km 491.0 [226.5 km] (26.0 km from border): Cordilleran Orogen

This unmarked pullout on the north side of the highway (67°10.431’N, 135°50.904’W) is the front of the Cordilleran Orogen where the east flank of Richardson Anticlinorium is exposed. A near vertical fault exposed in the creek bed to the north is interpreted to represent the surface expression of Trevor Fault. This fault approximates a dividing line between flat-lying, undisturbed Lower Paleozoic carbonates to the east and deformed basinal shale of the Richardson Mountains to the west. An angular unconformity is apparent at the contact between resistant white weathering sandstone of the Jurassic-Cretaceous Kamik Formation and recessive, deformed shale and sandstone of the Devonian Imperial Formation (Figure 54).

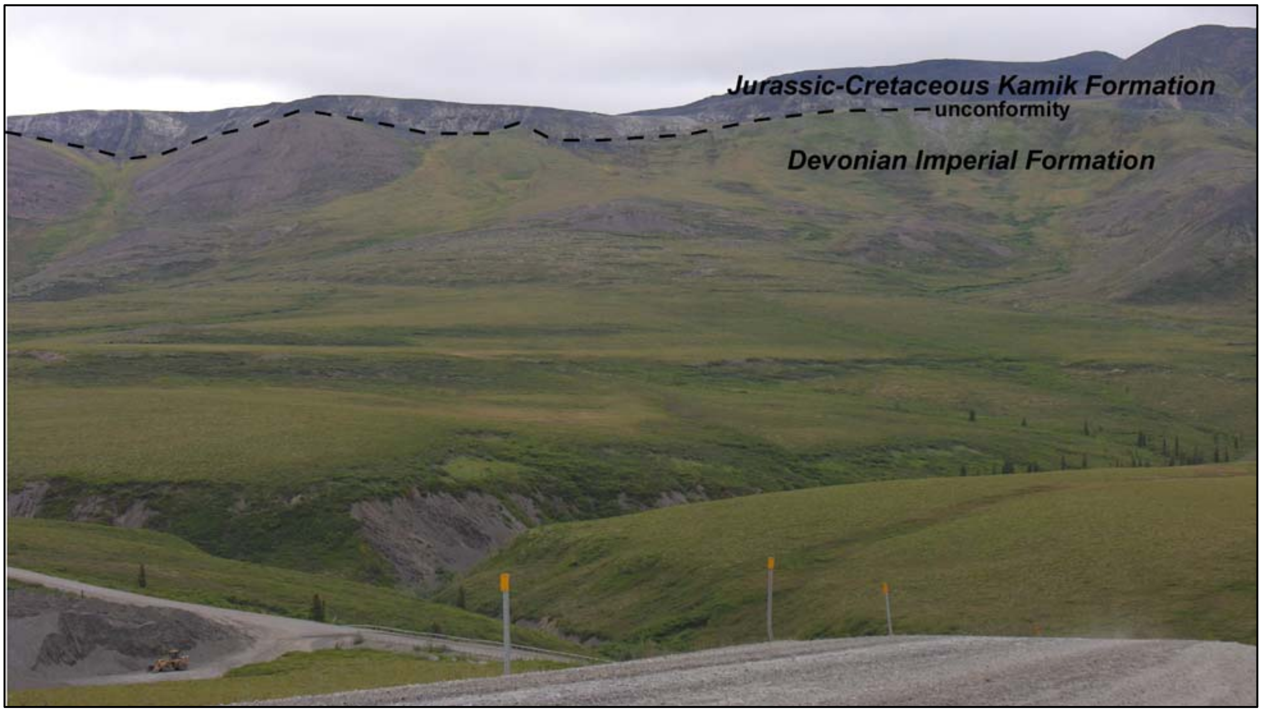


Figure 54. View west toward deformed rocks of the Richardson Mountains (~Km 492); Devonian Imperial Formation is unconformably overlain by Jurassic-Cretaceous age Kamik Formation.

Km 499.0 [218.5 km] (34.0 km from border): Meltwater channel

The highway passes through a meltwater channel that is visible to the northeast and south as you reach the top of the scarp. Glacial meltwater and drainage from the Richardson Mountains flowed northward in the channel toward McDougall Pass.

Km 508.0 [209.5 km] (43.0 km from border): Midway Lake

Through this interval of the highway, ***solifluction*** features can be seen (similar to Figure 23 at Km 110). In permafrost terrain, saturated soil layers slide downslope on the ***frost table***. Finer grained sediments and ***diamictic*** material have a slow drainage compared to sand and gravel, and are prone to flow.

Km 528.5 [189.0 km] (63.5 km from border): *Tetlit Gwinjik* Wayside Park

Now in the Peel Plateau, a short trail from a pullout south of the Highway leads to an interpretative platform that gives a good view to the east of the rolling, low-lying Peel Plain.

The Richardson Mountains to the west are the deformation front of the Cordilleran Orogeny. The Aklavik Range may be seen to the north, and peaks of the White Mountains may be seen further to the north-northwest.

Km 537.3 [180.2 km] (72.3 km from border) GEOLOGY STOP: Peel River Ferry Crossing

A stroll along the eastern bank of the Peel River, south of the ferry crossing (67°20.089'N 134°52.200'W) allows access to outcrops of sandstone, shale, and conglomerate of the Cretaceous Mount Goodenough Formation. Abundant fossil shells, iron oxide-coated concretions, and horizontal burrows are present. On either side of the Peel River, the highway has crossed floodplain deposits which comprise the southernmost extension of the Mackenzie Delta. These sediments develop thermokarst lakes and ponds.

Km 541.0 [176.5 km] (76.0 km from border): Visitor Centre, *Nitainlaii* Territorial Park

The park, campground, and visitor centre are perched on a cliff overlooking the Peel River.

Km 548.3 [169.2 km] (83.3 km from border): Fort McPherson

In 1840, Fort McPherson was a Hudson's Bay Company post and in 1903, it served as a detachment post for the RCMP. It is now a community of about 900 in the Gwich'in settlement area. Gas, food, and lodging are available here. If you take a drive down the main street, there is a monument to the tragic Royal Northwest Mounted Police "The Lost Patrol" of 1911. Inspector Jack Dempster led the search party that confirmed the tragedy.

Km 588.8 [128.7 km] (123.8 km from border): Little Frog Gravel Pit

Drive about two km south to view one of the largest aggregate sources for the NWT side of the Highway (67°21.716'N 134°03.832'W). The pit is located on the south side of the highway. This is an outwash plain deposit.

Anderson Plain, Campbell Uplift, and Inuvik (Km 605.2 to 717.5)

Anderson Plain borders Peel Plain and lies east of Mackenzie River. It is a broad lowland below 300 m elevation, covered by glacial sediments, tundra, and stunted trees of the northern boreal forest. Outcrop is rare, except in borrow pits and exposures along rivers. Anderson Plain has had more than 20 wells drilled for oil and gas exploration, but no major discoveries.

Campbell Uplift exposes Proterozoic and Paleozoic strata along the eastern border of the Mackenzie Delta (figures 3, 55), including Paleozoic carbonate rocks visible from about Km 693 to Inuvik along the Dempster Highway.

Km 605.2 [112.3 km] (140.2 km from border): Mackenzie River, Arctic Red River and Ferry

The community of Tsiigehtchic is located at the confluence of the Arctic Red River and the Mackenzie River (67°26.785'N 133°45.189'W). The Mackenzie River, the largest north-flowing river in North America, flows 1600 km from Great Slave Lake to the Beaufort Sea. It drains $1.8x10^6$ km^2, making its catchment the largest in Canada and the twelfth largest in the world.

From the ferry, view the dark grey shale and sandstone of the Upper Devonian Imperial Formation on the east bank of the river (Figure 56). It is overlain by a thick, pale brown sandstone that may be either a channel deposit within the Imperial Formation, or part of the Cretaceous Arctic Red Formation. This question remains unresolved as the upper bed has not been dated. The west bank of the Arctic Red River shows the hummocky terrain that resulted from late Wisconsinan ice-marginal fluctuation. Till that contains blocks of ice and permafrost poses a hazard for slope stability, particularly along roadcuts, as large portions can give way all at once.

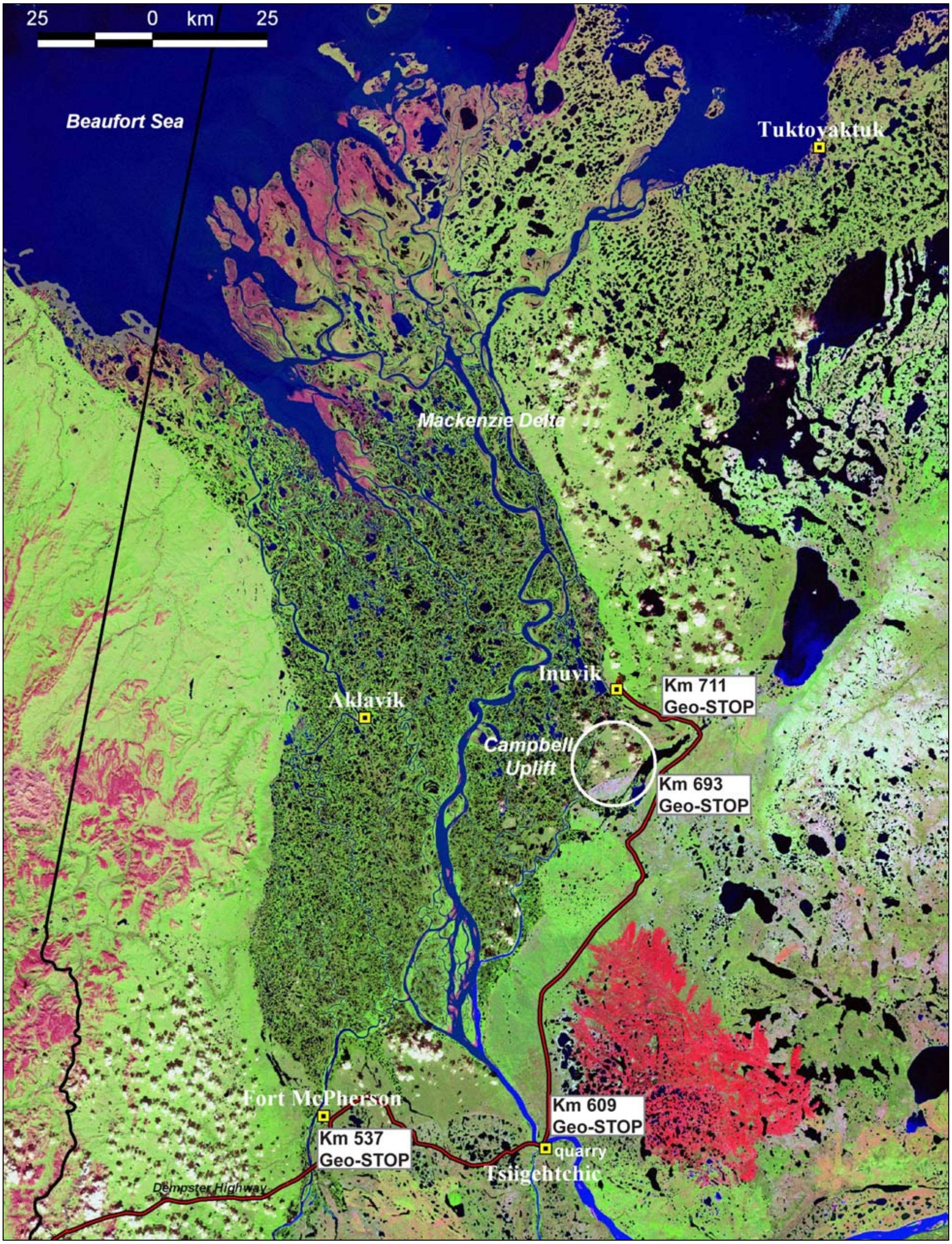


Figure 55. Satellite image of the Dempster Highway in the Mackenzie Delta area. White patchy areas are clouds.

Figure 56. Ferry crossing to Tsiigehtchic, km 608. The community sits on Devonian Imperial Formation.

Km 608.8 [108.7 km] (143.8 km from border)
GEOLOGY STOP: Tsiigehtchic quarry

There is a pullout on the east side of highway (although the pullout was washed out in 2006), immediately after the sign for Tsiigehtchic on the descent into the Mackenzie River Valley (67°28.905'N 133°45.764'W). Although only about five metres of strata is exposed, spectacular sedimentary structures such as ***load casts***, ***tool marks***, ***rip-up clasts***, and ***cross-stratification*** occur in fine-grained, brown weathering sandstone of the Imperial Formation. Abundant, large wood fragments and smaller black organics occur in sandstone beds (figures 57a, 57b). Very coarse-grained sandstone beds with channeled bases occur in the upper part of the section and these fine upward to planar laminated sandstone. Quaternary till unconformably overlies the Upper Devonian Imperial Formation (Figure 58).

Figure 57a. Fossilized wood and rip-up clasts in sandstone, Imperial Formation.

Figure 57b. Cross-laminated sandstone, Imperial Formation (Km 608.8).

Km 638.5 [79.0 km] (173.5 km from border): Rengleng River

Pullout on the north side of the highway. The river valley exposes the Imperial Formation displaying two cycles of grey-dark brown shale and grey, fine grained sandstone that contains ironstone concretions and abundant organic matter (Figure 59). Shales contain ***palynomorphs*** (microfossils) of mid-Frasnian (Late Devonian) age. Rhythmically interbedded shale and sandstone units are interpreted as ***flysch***, deep water, marine deposits that accumulated in a ***foredeep*** basin in front of a rising mountain belt (***orogen***) to the northwest.

Figure 58. Quaternary till overlies the Imperial Formation (Km 608.8).

Figure 59. Imperial Formation at Rengleng River (Km 638.5).

Km 645.5 [72.0 km] (180.5 km from border): Abandoned quarry

Pullout on to the west side of the highway (67°48.234'N 133°45.806'W). A short hike down the road leads to an abandoned, water-filled borrow pit in the Imperial Formation which shows a black mass of solid bitumen (in spring 2006 the water level was too high to see the bitumen). The bitumen essentially is a fossil oil seep, lying conformably within beds of brown and grey, organic-rich siltstone, mudstone and shale (Figure 60). Pyrite is fairly common within the sedimentary rocks adjacent to the bitumen. On rocks scattered along the path near the pit, plant fossils and thin coal seams were observed.

On the south side of the pit is a thaw slump formed from the melting of ground ice and permafrost. The ground is very unstable near the rim of a thaw slump so be careful and do not stand too close to the overhanging edge.

Figure 60. Horizon of bitumen (at arrow and specimen inset, scalebar is 8 cm) preserved in Upper Devonian Imperial Formation north of Rengleng River (Km 645.5).

Km 671.8 [45.7 km] (206.8 from border): Abandoned quarry

South of the Highway is a short pullout to an abandoned, water-filled quarry (68°00.285’ N 133°28.193’W) that exposes gently deformed shale and siltstone of the Upper Devonian Imperial Formation. Shale borrow pits were dug out in areas where only a thin veneer of glacial till is preserved. Plant fossils can be found on some of the flat rock surfaces. The area surrounding is typical of Peel Plain, with extensive lakes, wetlands, and little bedrock outcrop.

Km 680.0 [37.5 km] (215.0 km from border): *Vadzaih Van Tshik* Campground (Caribou Creek)

Km 692.6 [24.9 km] (227.6 km from border) GEOLOGY STOP: *Tithegeh Chi’vitail* Park

Park in a pullout on the northwest side of the Highway. A hiking trail winds through knolls of Devonian age fossiliferous limestone to a lookout over Campbell Lake (Figure 61). Fault-scarps or cliffs of Paleozoic carbonates outline Sitidgi Graben, an extensional feature on the crest of Campbell Uplift possibly related to mid-Tertiary reactivation of the uplift. Campbell Lake lies in the structurally low graben (down-dropped crustal block), but also owes its existence to glacial erosion by a sub-lobe of the Laurentian Ice Sheet. Carbonate rocks exposed in the uplift have been previously assigned to a variety of formations (Vunta, Ogilvie, Gossage or Cranswick) and their correlation to similar platform carbonate units elsewhere in the Cordillera is still uncertain.

Km 694.0 [23.5 km]: Gwich’in Territorial Campground

Km 695.5 [22.0 km]: Unnamed quarry

Turn south off the Highway and drive about 1 km into an abandoned quarry with about a 20 m section of grey, fossiliferous Devonian limestone that becomes more shaly up-section (68°12.119’N 133°24.445’ W).

Figure 61. Paleozoic limestone cliff on east shore of Campbell Lake a short hike from Km 692.6 (inset shows stromatoporoid fossil in limestone).

Km 703.3 [14.2 km]: Cabin Creek Campground

Km 706.3 [11.2 km]: *Nihtak* or Campbell Creek Park

Km 710.5 [7.0 km] (245.5 km from border) GEOLOGY STOP: Paleozoic carbonate

West of the highway are bedrock exposures of Paleozoic carbonate rocks. Another 300 m along the highway (68°18.425'N 133°19.585'W), there are more outcrops in a quarry (which in 2005 was marked by a "no trespassing" sign). Similar exposures occur in the vicinity of this quarry and these are visible from the road. Grey and buff weathering fossiliferous limestone are exposed in thick beds. Abundant ***brachiopods***, two-holed ***crinoid ossicles***, ***tabulate*** and ***rugose corals***, and ***stromatoporoids*** are among the common fossils. The uppermost beds contain abundant ***trace fossils*** that weather brown in contrast to the grey limestone.

Km 717.5 km [0.0 km] (252.5 km from border): Inuvik and End of Dempster Highway

Welcome to the end of the Dempster Highway (Figure 62) and the start of pavement! Construction of Inuvik, located on the East Channel of the Mackenzie River Delta, began in 1955 as a relocation site for the seasonally flooded community of Aklavik to the west. Inuvik was incorporated as a village on April 1, 1967. Extensive geological and engineering studies were integral to the development of the community, which lies in part on a glacial outwash terrace that provided the aggregate used in the town's construction. Geologically, the town lies on the crest of Campbell Uplift (Figure 3), part of the Aklavik Arch Complex.

The modern Mackenzie Delta spans 13,500 km^2 and is a product of postglacial deposition over the last 7000 years. The delta is a dynamic sedimentary environment where channels are constantly shifting, eroding areas and depositing ***alluvial*** material in other places. Satellite images (Figure 55) allow scientists to monitor biological and hydrological components of the delta, which is sensitive to climate and environmental changes.

Oil was discovered in 1970, and natural gas in 1971 in the Mackenzie Delta. Inuvik grew with the ensuing boom. After a hiatus in the 1980s and early 1990s, the oil and gas industry has returned to the area and winter drilling and seismic surveys are common. The Mackenzie Gas Project, a proposal for a natural gas and liquids pipeline anchored by three fields in the Mackenzie Delta, is currently under review.

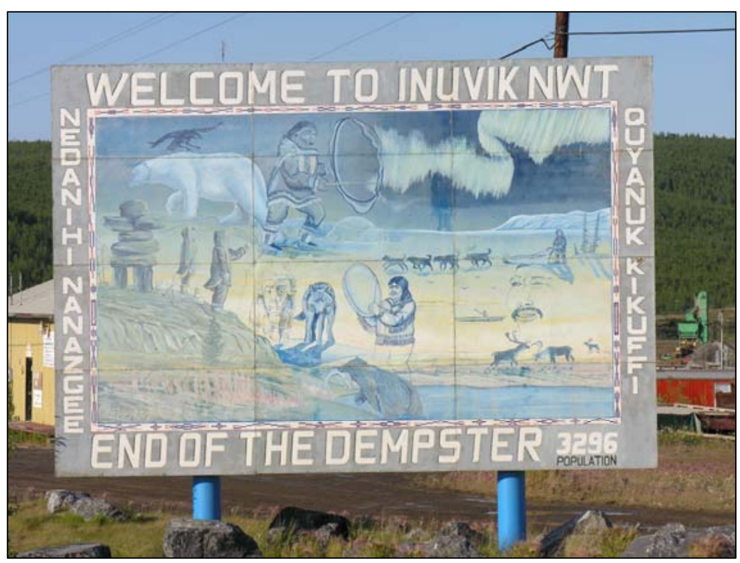


Figure 62. Welcome to Inuvik, the end (or start!) of the Dempster Highway.

BONUS STOPS: INUVIK AIRPORT QUARRY AND DOLOMITE LAKE BOAT LAUNCH

North of the Inuvik Airport, the oldest rocks in the region are exposed in a quarry which is marked “no trespassing”. Turn right 9.3 km out of Inuvik and drive 1.5 km along a gravel road to view the quarry. Maroon, red, green, and grey weathering mudstone, siltstone, shale, and dolostone are exposed through a thickness of about 150 m. Rocks are deformed (folded, faulted, boudinaged). Another 0.5 km down the road takes you to a boat launch at Dolomite Lake, where more exposures of dolostone occur. Dolostone beds indicate shallow marine environments (peritidal), with structures such as ***algal laminations***, ***stromatolites*** (laminated build-ups), and ***rip-up clasts***. The succession of sedimentary rocks is suggested to be Proterozoic in age (up to 1 billion years old). The contact with overlying Paleozoic carbonates is not visible.

Quarry north of Dolomite Lake, near Inuvik Airport (inset of folded Proterozoic rocks from the quarry).

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GLOSSARY OF SELECTED TERMS

algal laminations: lamina are the thinnest layers in a sedimentary rock, in this case formed by thin, wavy bands of algae that trap and bind to the sediment.

alluvial: a general term for sediment (alluvium) deposited by running water, including streams, rivers, floodplains, or alluvial fans.

alkali-feldspar: alkali-rich (potassium or sodium) feldspar (rock-forming, alumino-silicate minerals) such as orthoclase, microcline, or albite.

ammonite: Paleozoic and Mesozoic fossils with a coiled, internally chambered shell; extinct relatives of squid and octopus.

amphibole: rock-forming, dark mineral rich in iron, magnesium, calcium, or sodium as well as silica and aluminum. Minerals in this group have needle-like crystals. One type is ***hornblende***.

angular unconformity: an ***unconformity*** in which younger rocks lie on an eroded surface of deformed (tilted or folded) older rocks, so the two packages are at different angles to one another.

anticline: a convex-upward ***fold***.

anticlinorium: a composite anticlinal structure.

argillite: dense rock that is weakly metamorphosed mudstone or shale.

aufeis: a German term for "ice on top", referring to "icing", or mass of surface ice formed by successive freezing in winter of sheets of water from the ground, rivers, or springs, onto older ice.

bioclastic: biological in origin (bits of skeletal debris).

brachiopod: "lamp shells" have a calcareous, two-valved skeleton and are an extant group of marine organisms that have a fossil record back to the Cambrian; their external shape resembles modern clam shells.

bryozoan: "moss animals" are common fossils in Paleozoic rocks, that are an extant group of colonial, marine organisms with a calcareous skeleton; fossils are full of tiny holes (like lace) and branched.

Canadian Cordillera: area of deformed (***folded*** or ***faulted***) mountain belts and plateaus that extend 2000 km from the US border at the 49th parallel to the Beaufort Sea and Alaska in the north. The Cordillera includes a diverse assemblage of mountain belts, some of which consist of ***terranes*** or crustal fragments. Different tectonic regimes exist along the length of the Cordillera due to variations in plate tectonic interactions.

carbonate: sediment or rock composed of carbonate minerals such as calcite ($CaCO_3$).

cephalopod: group of molluscs, including ammonites, that have a head with tentacles; fossils may be coiled or straight, conical shells with internal chambers.

cirque: erosive feature produced by a mountain glacier, typically a steep-walled, semicircular bowl on a mountainside.

clast: a piece of rock or mineral that differs from the rock type it is found in; clastic refers to rocks made of clasts or pieces of other rocks and minerals.

colluvial, colluvium: general term for loose, unconsolidated material, typically at the toe of a slope.

concretion: a compact, spherical, ovoid, or irregular mass of rock formed by precipitation of cementing minerals around a nucleus of fossil or rock material; typically more resistant than the surrounding rock.

continental divide: river systems on opposite sides of a drainage divide flow toward different ocean drainage basins.

crinoid: "sea lilies" are an extant group of echinoderms with a fossil record back to the Ordovician. They have a root, and long, flexible stem made up of calcareous donut-shaped ossicles that support a calyx made up of plates. Often only parts of crinoids are found as their plated skeletons disarticulated quickly upon death.

cross-bedding or stratification: sedimentary rock beds at an angle to main layering or stratification.

crust: outermost layer of Earth which is about 10 kilometres thick under the oceans and about 50 kilometres thick where it forms continents.

cryoplanation: modification to the land surface through frost action and further impacted by running water or glaciers.

cuestas**:** an asymmetrical ridge with one steep face formed of resistant beds and a long, gentle dip-slope (slope of the land corresponding to the angle of the strata) forming its other side.

diamictic**:** a massive, poorly sorted sediment containing large and small sedimentary grains.

diorite: a type of ***igneous intrusive*** rock that contains more dark minerals (such as ***hornblende***) than ***granite.***

erosion: the wearing away of rock (or soil) by wind, water, gravity, ice, etc.

erratic: a rock fragment transported by a glacier some distance from its original outcrop.

fault: a fracture in the Earth's ***crust*** along which there has been displacement. A fault plane separates rocks on its overlying side (***hanging wall***) from those beneath the fault plane (footwall). A normal fault has movement of the hanging wall downward relative to the footwall; a reverse (or thrust) fault has movement of the hanging wall upward relative to the footwall. Normal faults are caused by extension of the crust, whereas reverse and thrust faults are caused by compression.

flysch: deep-water marine sediments, rhythmically bedded, with thin, graded (layers gradually change grain size) beds.

fold: a plastic deformation structure that bends or curves originally horizontal strata. Folds may occur on a variety of scales, from microscopic to mountain-sized.

foredeep: a depression that borders a mountain belt.

Foreland Belt of the Cordillera: along with the ***Interior Plains***, area of Northwestern Canada consisting of sedimentary rocks or ***strata*** that show the cumulative effects of mountain building (***orogeny***) during the last 150 million years (***Ma***).

frost table: surface that represents a level of winter frost penetration in seasonal frozen ground.

glacial drift: rock material transported and deposited by glacial ice or meltwater.

glacial till: unstratified (non-layered) ***glacial drift***, consisting of unsorted glacial deposits (clay to boulder sized pieces of rock) and not reworked by meltwater from the glacier.

***glaciofluvial*:** related to meltwater streams flowing from glaciers.

graben: a depressed crustal block bound by ***faults*** that results from pulling or extension of the crust.

granite: an igneous intrusive rock with 10-50% quartz and rich in ***alkali-felspar*** minerals.

granodiorite: igneous intrusive rock that is intermediate in composition between ***diorite*** and ***monzonite***.

graptolites: extinct (Cambrian to Carboniferous) colonial marine organisms, with a tubular shape. The colony may have several branches (stipes) with a series of cup-shaped thecae that housed individual organisms. Fossils look like pencil markings on shale, because they are often preserved as carbonized impressions.

hanging wall: in rocks that are faulted, the rocks that lie above the fault plane.

igneous: rock solidified or crystallized from molten material (magma). ***Intrusive*** refers to magma emplaced in the Earth's crust; ***extrusive*** refers to igneous rock erupted onto the Earth's surface.

Interior Plains: large area of nearly horizontal bedrock comprising plains and plateaux covered by thick ***glacial drift.***

ka: stands for thousand years old or ago.

***Liesegang banding*:** rings or bands, concentric or nested, that occur throughout a rock; caused by precipitation of iron-rich fluids in a saturated rock.

load cast: a type of sedimentary structure on the underside of a bed formed as a bulge of sand protruding into a finer-grained mud or clay.

Ma: stands for million years old or ago.

McConnell glaciation: glaciation events that spanned from 25 to 12 thousand years ago.

metamorphic: rock formed through recrystallization, mineral or chemical change to pre-existing rock, due to high temperature or pressure.

monzonite: ***igneous intrusive*** rock that is intermediate in composition between ***syenite*** and ***diorite***, with little quartz, and equal amounts of ***alkali feldspar*** and ***plagioclase.***

moraine: mound like deposit left by a glacier (***glacial drift*** or ***glacial till***).

nepheline: sodium-aluminum or potassium-aluminum silicate mineral that occurs in igneous rocks (used in ceramics and enamels).

Orogen, orogeny: rocks subjected to deformation (***folding*** and/or ***faulting***) during mountain building (***orogenic belt***).

outwash: deposits of sand and gravel left by meltwater streams of a glacier (at its margin, or in front of an end ***moraine***).

palsas: periglacial landforms with an ice-rich core, heaved upward during seasonal thaw and re-freeze cycles.

palynomorph: resistant organic microfossils, typically spores and pollen; their study is called palynology.

passive continental margin: a subsiding (sinking or settling downward) continental margin formed by rifting (splitting) of the Earth's crust. The margins of the North Atlantic are a modern example.

pediment: veneer of alluvium (sediments deposited by flowing water) over a broad, gently sloping, erosional surface, typically developed by running water.

***pediplain*:** an extensive erosional area formed in an arid region.

permafrost: Ground (rock or soil) that remains at or below 0ºC for at least 2 years. It may be continuous in a zone uninterrupted by unfrozen pockets of ground, or discontinous in a zone with patches of unfrozen ground.

phyllitic: containing phyllite, a metamorphic rock with a sheen.

physiography: the physical expression of the land, also referred to as geomorphology, the description and origin of landforms.

plagioclase: common rock forming feldspar minerals containing sodium, calcium, aluminum and silica.

pluton: an intrusive igneous rock body that cools within the crust; ***plutonic*** refers to rocks formed at depth.

pseudoleucite: light coloured, potassium aluminum silicate mineral in irregular crystal form (pseudomorph).

pyrite: "fools gold", a yellow, metallic, iron sulphide mineral (ore of sulphur), often crystallizes in cubes.

pyroxene: rock forming, dark mineral, rich in iron, magnesium, calcium or sodium as well as as well as silica and aluminum. Minerals in this group have stout crystals.

quartzite: metamorphosed sandstone consisting of recrystallized quartz due to heat and/or pressure.

Reid glaciation: glaciation events that spanned from 300 to 150 thousand years ago.

rip-up clast: a rock fragment that may or may not be the same as its host lithology (rock type).

rugose corals: colonial or solitary, calcareous, horn-shaped corals that range from Ordovician to Permian.

sedimentary: rocks formed by deposition of sediment, solid material that is either transported by water, wind or ice, or chemically precipitated from solution.

seismicity: or ***seismic activity***, refers to phenomenon of Earth's movements, usually earthquakes.

siliciclastic: silicon-bearing (e.g., quartz) rocks or sediments made up of clasts, or broken fragments of pre-existing rocks or minerals that have been transported from a source land.

solifluction: slow flow of water-saturated earth downslope.

strata: or ***stratum***, a layer or bed of ***sedimentary*** rock.

stratigraphy: Study of rock layers, including their attributes, origin, arrangements, and relationships.

strike: direction taken by a geological features (bedding, faults), relative to the horizontal.

strike-slip fault: a fault that strikes parallel with the strike of the rock it has faulted and the fault blocks move sideway past each other.

stromatolite: a layered ***sedimentary*** rock produced by microbes that trap, bind, and cement sediment; they form biologically produced sedimentary structures such as domes or columns.

stromatoporoid: extinct (Cambrian to Cretaceous) sponge-like, colonial marine organisms that had a porous, calcareous skeleton.

syenite: an igneous intrusive rock rich in feldspar, with little quartz and one or more dark accessory minerals (***hornblende***).

tabulate coral: colonial forms of coral that lived form Ordovician to Permian that had internal partitions to their calcareous skeleton.

tectonics: study of relationships, origins, and evolution of Earth's crust.

terrane: a crustal block or fragment that has a distinct geological history from adjacent blocks, and is commonly fault-bound.

thermokarst: landscape characterized by pits, ponds, and depressions related to melting of ***permafrost***.

thrust fault: a ***fault*** with a dip less than 45 degrees, caused by horizontal compression and in which the ***hanging wall*** moves upward relative to the footwall (similar to a reverse fault, but shallower).

tinguaite: a group of potassium aluminosilicate (feldspathoid), coarse crystalline, igneous rocks containing light coloured, ***alkali feldspar*** minerals, and dark-colored (mafic) minerals such as biotite, amphibole, and pyroxene.

tool mark: a mark preserved on the underside of a sedimentary bed and produced by an object (bone, wood, shell, pebbles) in the water impacting the soft sediment bottom.

tor: craggy peak that results from weathering of rock.

trace fossils: any traces of activity in the sediment, such as tracks, trails, and burrows.

transcurrent fault: a large-scale ***strike-slip fault***, steeply inclined, where crustal blocks move horizontally in the direction (or strike) of the fault.

trilobite: a Paleozoic fossil group of arthropods, with a three-fold segmented body (head, thorax, and tail), and three-fold lateral division of the body into lobes (axial and side regions).

unconformity: a surface that represents a gap in the geological record, such as a period of ***erosion*** of ***strata***.