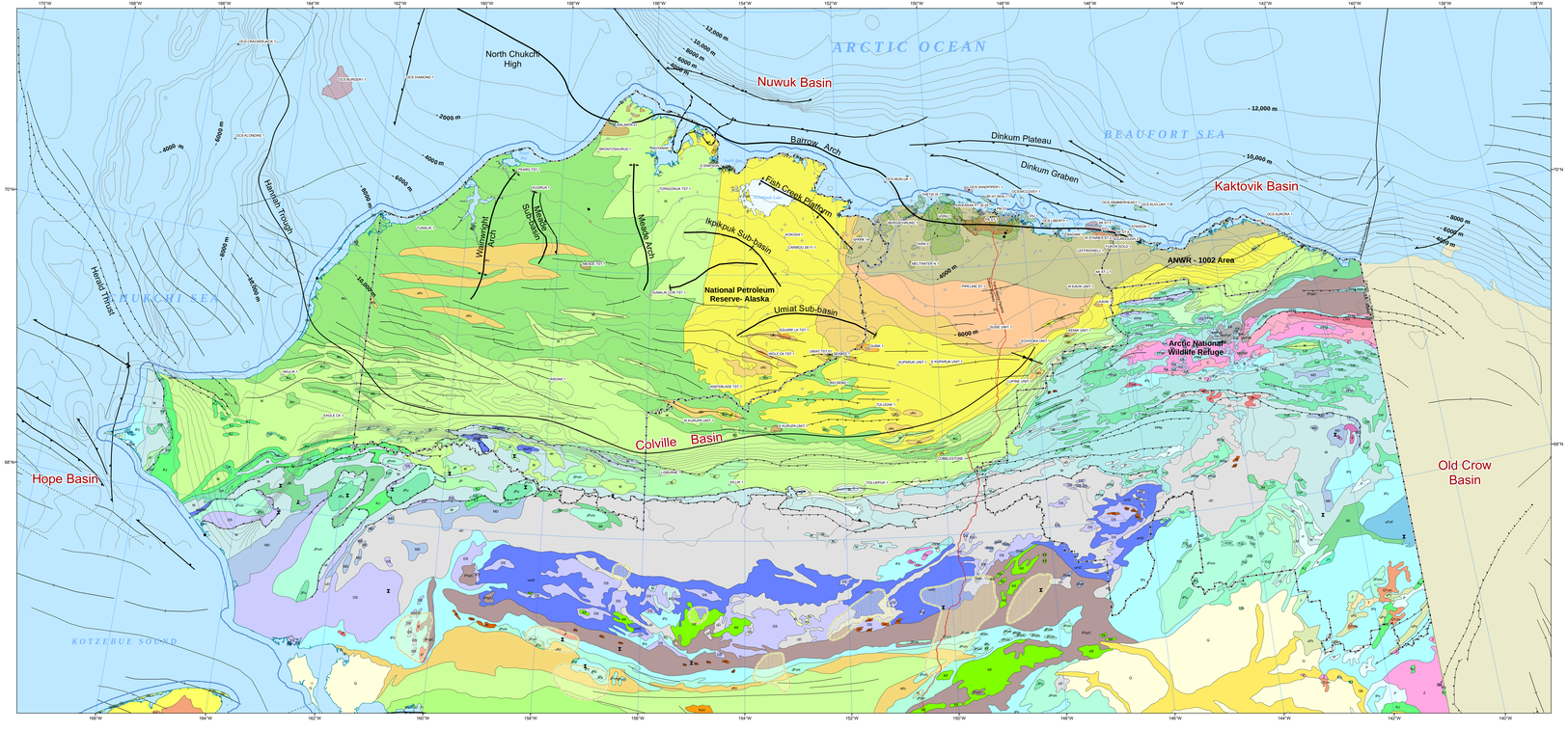
Regional Geology of the North Slope of Alaska



DATA SOURCES

Basemap data, including hydrology, roads, village and town locations, glaciers and icefields, land status and boundaries, etc. are from the State of Alaska Statewide Core GIS database. Oil and gas wells are from the Alaska Division of Oil and Gas database as adapted from the Alaska Oil and Gas Conservation Commission dataset. Surrounding local geology from Beikman (1980) was digitized and modified to fit the Brooks Range geology of Wallace et al. (1999). Geologic cross section location C was digitized from J. Cole, and others, (1999) USGS OFR 98-34, Figure SM2. Geologic cross section locations A and B were digitized from C.G. Mull, and others. (1987) Geological Society of America, Map and Chart Series, MC-28b. Oil and Gas seep locations were tabulated for confirmed occurrences by Paul Decker. Accumulations are based on multiple public sources and were compiled by the Division of Oil and Gas.

REFERENCES CITED

Beikman, H.M., 1980, Geologic map of Alaska, U.S. Geological Survey, scale 1:2,500,000.

Cole, F., Bird, K.J., Mull, C.G., Wallace, W.K., Sassi, W., Murphy, J.M., and Lee, M., 1999, The Oil and Gas Resource Potential of the 1002 Area, Arctic National Wildlife Refuge, Alaska, by ANWR Assessment Team, U.S. Geological Survey Open-File Report 98-34.

Kruchkov, C.E., 1988, Map showing sedimentary basins of onshore and continental shelf areas, Alaska, USGS Miscellaneous Investigations Series I-1873, scale 1:2,500,000

Mull, C.G., Reeder, D.H., Tailleur, I.L., Pessel, G.H., Grantz, Arthur, May, S.D., 1987, Geologic sections and maps across Brooks Range and Arctic slope to Beaufort Sea, Alaska, The Geological Society of America, Map and Chart Series, MC-28S.

Saltus, R.W., and Bird, K.J., 2003, Digital depth horizon compilations of the Alaska North Slope and adjacent arctic regions, U.S. Geological Survey Open-File Report 03-328, 21 p.

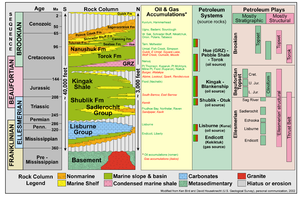
DISCLAIMER

This map was created, edited, and published by the State of Alaska, Department of Natural Resources, Division of Oil and Gas, and is for informational purposes only. An attempt has been made to reconcile discrepancies among conflicting sources of map data in this compilation. The user is cautioned against using this product as the basis for detailed interpretations.

The State of Alaska makes no expressed or implied warranties (including warranties of merchantability and fitness) with respect to the character, function, or capabilities of this product or its components. The State of Alaska shall not be liable to the user of this product for any liability for any incidental, indirect, special, and consequential or other damages suffered by the user or any other person or entity whether from use of the product, any failure thereof or otherwise, and in no event will the State of Alaska's liability exceed the fee paid for the product.

Map Published April 2008

GENERALIZED NORTH SLOPE STRATIGRAPHIC COLUMN



MAP SYMBOLS

Energy and Resources

- Gas Accumulation
- Oil Accumulation
- Placer Deposits
- Metallic and Industrial Ledge Deposits

Geologic Structure

- Fault
- Normal Fault
- Fault - Inferred
- Thrust Fault
- Thrust Fault - Inferred
- Syncline
- Synclinorium
- Syncline - Inferred
- Anticline
- Anticlinorium
- Anticline - Inferred
- Paleo Canyon

Structure Contours (1000 m CI)

on Pre-Mississippian Basement

Oil & Gas Wells - Exploration

- Drill Hole
- Oil Well
- Gas Well
- Service Well (Un-differentiated)
- Suspended
- Suspended - Oil Show
- Plugged & Abandoned
- Plugged & Abandoned - Oil Show
- Plugged & Abandoned - Gas Show
- Plugged & Abandoned - Oil and Gas Show
- Plugged & Abandoned - Oil (Certified or Significant)
- Shut-in Location
- Operational Shutdown
- Permitted Location

Indicators of Petroleum

- Gas Seep
- Oil Seep

1:1,000,000

POINTS OF CONTACT

DEPARTMENT OF NATURAL RESOURCES
550 West 7th Ave., Suite 1000
Anchorage, AK 99501

Tom Irwin, Commissioner
(907) 269-8431
Tom.Irwin@alaska.gov

Marty Rutherford, Deputy Commissioner
(907) 269-8431
Marty.Rutherford@alaska.gov

DIVISION OF OIL & GAS
550 West 7th Ave., Suite 800
Anchorage, AK 99501

Kevin Banks, Acting Director
(907) 269-8783
Kevin.Banks@alaska.gov

Diane Skellenham, Petroleum Geophysicist
(907) 373-8241
Diane.Skelleham@alaska.gov

Kurt Gibson, Acting Deputy Director
(907) 269-8754
Kurt.Gibson@alaska.gov

Paul Anderson, Petroleum Geophysicist
(907) 269-8836
Paul.Anderson@alaska.gov

Julie Houle, Section Chief Resource Evaluation
(907) 269-8753
Julie.Houle@alaska.gov

John Meyer, Petroleum Geophysicist
(907) 269-8765
John.Meyer@alaska.gov

Paul Decker, Petroleum Geologist
(907) 269-8779
Paul.Decker@alaska.gov

Tyt Ann Axton, Cartographer
(907) 269-8774
Tyt.Axton@alaska.gov

DESCRIPTION OF MAP UNITS

North Slope Geology (Beikman 1980)

Continental Deposits

- Hu - Shale, claystone, siltstone,sandstone, conglomerate, coaly shale and coal, ironstone, bentonite (Lower & Upper Cretaceous)
- TTr - Claystone, siltstone, sandstone, conglomerate, coal and lignite (Tertiary)
- TKu - Conglomerate, breccia, sandstone, alcose, mudstone, shale, tuffaceous rocks, lignite (Tertiary and Cretaceous)
- uKc - Sandstone and conglomerate and interbedded shale, clay, silt, and bentonite (Upper Cretaceous)

Intrusive Rocks

- JPzm - Gabbro mafic intrusive rocks (Lower Paleozoic)
- Ki - Undifferentiated rocks (Cretaceous)
- KJf - Granite to granodiorite felsic intrusive rock (Cretaceous)
- MzPzf - Granite to granodiorite felsic intrusive rock (Mesozoic and Paleozoic)
- TKzf - Granite to granodiorite intrusive (Tertiary and/or Cretaceous)
- Zmm - Gabbro mafic intrusive rock (Precambrian Z)
- Zgf - Granite to granodiorite felsic intrusive rock (Age Unknown)
- uKi - Undifferentiated intrusive rock (Upper Cretaceous)
- Lmm - Gabbro mafic intrusive rock (Age Unknown)
- uMzf - Granite to granodiorite felsic intrusive rock (Upper Cretaceous)
- uMzs - Syenite to diorite intermediate intrusive rocks (Upper Cretaceous)
- uPzf - Granite to granodiorite felsic intrusive rocks (Upper Paleozoic)

Metamorphic Rocks

- PzpPzu - Metasedimentary and metaigneous rocks, schist and gneiss (Paleozoic and/or Precambrian)

Stratified Sedimentary Sequence

- C - Siltstone, sandstone, and phyllite (Cambrian)
- DS - Limestone, dolomite, marble, and shale (Devonian and Silurian)
- SK - Graywacke, sandstone, shale, siltstone, and conglomerate (Lower Ordovician)
- Dv - Carnbian through Devonian rocks metamorphosed to greenschist and amphibolite facies (Lower Paleozoic)
- JPzpC - Sandstone, limestone, shale, chert, phyllite, argillite, and quartzite (Lower Paleozoic and/or Precambrian)
- J - Shale, siltstone, and sandstone (Jurassic)
- TJd - Unnamed slate and quartzite (Jurassic to Mississippian)
- JP - Shale, siltstone, chert, and graywacke (Jurassic, Triassic, and Permian)
- JTR - Chert and argillite (Jurassic and/or Triassic)
- KJ - Argillite, shale, graywacke, quartzite, conglomerate, lava, tuff, agglomerate (Cretaceous and Jurassic)
- TR - Claystone, siltstone, sandstone, conglomerate, coal and bauxite (Triassic)
- MD - Sandstone, graywacke, quartzite, and conglomerate (Mississippian and/or Devonian)
- MzPzu - Sandstone, shale, chert, dolomite, conglomerate (Mesozoic and Paleozoic)
- DC - Limestone and shale (Ordovician)
- OpC - Phyllite, sandstone, siltstone, limestone, chert, quartzite (Ordovician, Cambrian, and Precambrian)
- P - Chert, shale, and siltstone (Permian)
- PPM - Limestone, conglomerate, shale, dolomite, chert (Pennsylvanian and Mississippian)
- Pp - Shale and limestone (Mississippian)
- TKsf - Granite to granodiorite intrusive (Tertiary and/or Cretaceous)
- Qs - Alluvial, glacial, lake, estuarine, swamp, landslide, flood plain, and beach deposits (Holocene)
- Qp - Alluvial, glacial, lake, estuarine, and reworked sand and silt deposits (Pleistocene)
- T - Sedimentary rocks concealed beneath Quaternary cover (Tertiary)
- Tr - Shale, chert, and limestone (Triassic)
- DJS - Radiolarian chert, slate, and argillite (Triassic to Devonian)
- TrJP - Sandstone, siltstone, and shale (Triassic and Permian)
- Z - Slate, phyllite, graywacke, quartz schist, and graphitic schist (Precambrian Z)
- LZ1 - Schistose, argillaceous, dolomitic limestone and tactite (Younger Precambrian Z)
- PZ1 - Schist, gneiss, and migmatic and metamorphic rocks (Older Precambrian Z)
- uD - Shale, sandstone, chert, conglomerate and quartzite (Upper Devonian)
- uK - Shale, sandstone, and conglomerate (Upper Cretaceous)
- uPz - Argillite, chert, shale, limestone, and siltstone (Upper Paleozoic)
- uT - Undifferentiated volcanic beds (Upper Tertiary)
- JPz - Carbonate rocks, graywacke, phyllite, shale, sandstone, and limestone (Upper and/or Middle Devonian)

Ultramafic Rocks

- Um

Volcanic Rocks

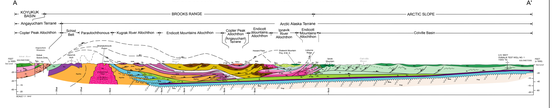
- CZm - Basalt, mafic volcanic rocks (Cambrian)
- Dv - Undifferentiated volcanic rocks (Devonian)
- DSm - Basalt, mafic volcanic rocks (Devonian)
- KJv - Undifferentiated volcanic rocks (Lower Cretaceous)
- Kvt - Trachyte to andesite intermediate volcanic rocks (Lower Cretaceous)
- JPzm - Basalt, mafic volcanic rocks (Jurassic, Triassic, and Permian)
- KJvt - Trachyte to andesite intermediate volcanic rocks (Cretaceous and/or Jurassic)
- QTv - Undifferentiated volcanic rocks (Pleistocene)
- QTv - Undifferentiated volcanic rocks (Quaternary or Tertiary)
- QTvm - Basalt, mafic volcanic rocks (Quaternary or Tertiary)
- TKvf - Rhyolite to dacite, felsic volcanic rocks (Tertiary and/or Cretaceous)
- Zv - Undifferentiated volcanic rocks (Precambrian Z)
- uKvf - Rhyolite to dacite, felsic volcanic rocks (Upper Cretaceous)
- Uvf - Rhyolite to dacite, felsic volcanic rocks (Age Unknown)

Other Areas

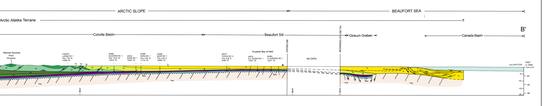
- Ice
- Water

CROSS SECTION LOCATIONS

CROSS SECTION OF SCHWATKA AND WESTERN ENDICOTT MOUNTAINS



CROSS SECTION OF EASTERN ENDICOTT MOUNTAINS - ARCTIC SLOPE



Reformated from the Geological Society of America
Map and Chart Series MC-28S
GEOLOGIC SECTIONS AND MAPS ACROSS BROOKS RANGE
AND ARCTIC SLOPE TO BEAUFORT SEA, ALASKA

By
C.G. Mull, D.H. Roeder, I.L. Tailleur, G.H. Pessel, Arthur Grantz, and S.D. May
CONTRIBUTION OF THE PLATE MARGINS GROUP
U.S. GEODYNAMICS COMMITTEE, IN COOPERATION
WITH THE ALASKA DIVISION OF GEOLOGICAL AND
GEOPHYSICAL SURVEYS
1987

GEOLOGIC HISTORY AND STRATIGRAPHIC SEQUENCES OF NORTH ALASKA

The Brooks Range foothills between the Brooks Range front and the North Slope consists of a series of rolling hills, mesas and east-trending ridges with elevations from 900 to 1,500 feet. The rocks in the foothills are younger and less deformed than those in the Brooks Range to the south. Rock exposures in the foothills provide useful information about the subsurface geology to the north.

Figure 5-1 shows the general geological structure of northern Alaska.

The geologic history of northern Alaska has resulted in four stratigraphic sequences. From oldest to youngest, these are the Franklinian, Ellesmerian, Beaufortian and Brookian sequences. The sequences reflect major tectonic cycles, and are distinguished by significant differences in sediment source areas, depositional environments, and structural framework. Relatively short-lived events, such as changes in sea level, altered the depositional environment and created internal complexities within the sequences.

Franklinian Sequence The Franklinian sequence, also informally called the pre-Mississippian sequence, formed on a stable continental platform before Middle Devonian time (about 400 million years ago). The sequence contains a wide range of rock types that include metamorphosed argillites, graywackes, quartzites, carbonates, and some local volcanics and granites. Some of the sequence may have formed on a passive margin sloping under a sea that deepened to the south. The Franklinian sequence is often considered non-prospective "basement" due to its high thermal maturity and generally poor reservoir quality. However, shows of migrated oil are common in basement rocks throughout the North Slope. Oil from Cretaceous rocks at Umiat Field produces from fractured dolomite, vuggy and fractured dolomites. Gaseous production from Franklinian sequence rocks at some point in the future is not out of the question.

Franklinian sequence deposition ended across most of northern Alaska with a period of mountain building, and metamorphism (the Ellesmerian orogeny). Franklinian rocks were highly deformed and moderately to severly altered throughout the mountain belt. The continental uplands were rapidly eroded in a low-lying, north-facing coastal plain that began to subside below sea level, accelerated replacen by the formation of failed rift sub-basins such as the Kuparuk and Kugmallit Creek subsidences of NPR-A. The Ellesmerian sequence developed from the widespread pre-Middle to Late Devonian time with renewed deposition of northerly-derived sediments onto the widespread pre-Mississippian unconformity.

Ellesmerian Sequence Early Ellesmerian sequence clastic sediments, eroded from uplifted Franklinian rocks in the landmass that by mostly to the north of the modern Beaufort Sea coast, spread southward where they accumulated in coastal and marine settings of the so-called Arctic Alaska basin. This south-facing passive margin basin was bounded on its south by a north-facing continental margin located south of the present Brooks Range trend line. Deposited in highly varied marine to non-marine settings over at least 150 million years, Ellesmerian strata constitute a diverse suite of clastic and carbonate formations, including prolific petroleum source rocks, excellent reservoirs, and strong seal units that collectively define a self-contained, world-class petroleum system. From a belt of maximum thickness that coincides with the Herna Trough in the Chukchi Sea and the Meade and Ikpikpuk (near sub-basins onshore, the Ellesmerian thins southward due to depositional distance from the source of the sediments. The Ellesmerian also thins northward due to a combination of depositional onlap against the (erosional landmass and post-depositional uplift and erosion.

Beaufortian Sequence The Beaufortian sequence, deposited between Early to Middle Jurassic and Early Cretaceous time, is restricted to the Colville and Hanna troughs and equivalent rocks in the Brooks Range. It contains a coarsen/shoaling stratigraphic sequence that reflects the initial rifting of the North Slope Ellesmerian landmass away from equivalent platform rocks in Arctic Canada. A number of alternative tectonic models have been proposed that interpreted the northern Alaska margin as the product of various strike-slip movements, but compelling evidence for these hypotheses has never developed. According to the more widely accepted rift model, the Barrow Arch developed near what is now the Beaufort Sea coast as a chain of asymmetric rift shoulder uplifts in multiple episodic phases. The Barrow Arch is bounded on its steep northern side by the system of rift grabens and plateaus that transition outward into the oceanic crust of the Canada basin. The southern flank of the Barrow Arch rift shoulder initially sloped very gently southward into the Arctic Alaska basin. There is considerable uncertainty over the exact timing of earliest Beaufortian sequence rift deposition because the based-to-rift sediments cannot be directly dated. Seismic stratigraphic correlations tie the base of the rift sequence to the Kingak Shale Formation offshore north of the Prudhoe Bay area, now deeply buried where they have never been penetrated by drilling.

Widespread subaerial erosion along the Barrow Arch likely occurred at more than one stage, and cultivated during Early Cretaceous time to form an unconformity of regional extent. The Lower Cretaceous unconformity forms an important hydrocarbon migration and accumulation element for many of the oil fields on the North Slope, including Prudhoe Bay. Most of the Beaufortian sediments eroded from the rising Barrow Arch likely drained off the gentle southern flank into the Arctic Alaska basin, where they were subsequently deeply buried under the soon-to-develop foreland basin of the Brooks Range. Other erosional products from the Barrow Arch no doubt drained northward into the depths of the rift grabens, where they may never be encountered by drilling. However, Beaufortian sediments were undoubtedly also deposited on the northern flank of the Barrow Arch and on the passive margin, either unconformable to relatively stable structural, erosional, or other bathymetric lows or perched on synrift fault blocks stepping off the Arch to the north. Key examples include the Lower Cretaceous Kuparuk Formation sandstones of the Kuparuk and Point McIntyre fields and Upper Jurassic Kingak Formation sandstones of the Alpine Field.

Brookian Sequence - South-dipping subduction of the part of the Arctic Alaska basin underlain by oceanic crust led to ano continent collision accompanied by north-directed emplacement of thick stacks of far-traveled thrust sheets in Late Jurassic and Early Cretaceous time, forming the thickened crust of the ancestral Brooks Range. This thickening loaded the north's crust north of the range and depressed it to form the Colville Basin, a classic foreland basin that received the erosional products of the Brooks Range. Sediments derived from the rising mountains poured into the Colville Basin, progressively filling it in, including a shelf prograding from southeast to northwest and forming the Brookian sequence. Brookian sediments ultimately spread out over the Barrow Arch and into Sadlerochit basins of the Beaufort Sea, especially during Late Cretaceous and Tertiary time.

In general terms, the older, lower Brookian sequences adjacent to any given location (such as seen in a wellbore) tend to consist of shales and sandstones deposited in water hundreds or thousands of feet deep. The rocks higher in the sequence typically consist of sandstones and shales associated with coastal plains, river deltas, or other shallow-water environments up on the shelf. This transition toward progressively shallower deposition through time demonstrates the progressive filling of the Colville Basin to the Brookian foreland. While the sediments filled the basin, the Brooks Range was being thrust northward and uplifted. As a result the Brookian rocks tend to become younger from west to east in the basin.

Quaternary sediments stack most of the slide bedrock north of the foothills. Most Quaternary deposits consist of unconsolidated sand and gravel, containing reworked Brookian sediments along with materials from the present day Brooks Range. Surficial deposits are typically thin and rarely also that include variable amounts of organic matter. In addition to fluvial deposits, eolian sands are prevalent in northern NPR-A, and mark cold, dry Ice Age conditions.

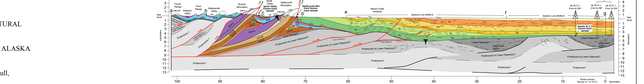
Adapted from DeparDing the Alaska Fiur Factor: A guide to Alaska's oil and gas basins and business environment, 2005/2006, Chapter 1, Northern Alaska's oil and gas provinces, published by Petroleum News.

Reformated from the U.S. Department of the Interior
U.S. Geological Survey
Open-File Report 98-34, Plate SM1

BALANCED CROSS SECTION AND STRUCTURAL
RESTORATION OF TRANSECT A-G,
IN THE WESTERN PART OF
THE ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

By
Frances Cole, Kenneth J. Bird, Charles G. Mull,
Wesley K. Wallace, William Sassi,
John M. Murphy, and Myung Lee
1999

BALANCED CROSS SECTION OF TRANSECT A - G IN WESTERN ANWR


C
C'
NORTH
SOUTH
Top Ellesmerian Unconformity
Top Lisburne Group
Top Sadlerochit Group
Top Kingak Shale
Top Shublik Fm
Top Kuparuk Fm
Top Nanushuk Fm
Top Torok Fm
Top Grandstand Fm
Top Tuluvak Fm
Top Hue Shale
Top Canning Fm
Top Staines Tongue
Top Tuluga Fm
Top Marsupial Fm
Top Sagavanirktok Fm
Top Colville Group
Top Franklinian Basement
Top Brookian Unconformity
Top Ellesmerian Unconformity
Top Pre-Mississipp