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# BEDROCK GEOLOGY OF THE MT. MICHELSON C-2 QUADRANGLE, ARCTIC NATIONAL WILDLIFE REFUGE NORTHEASTERN ALASKA

By

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## GEOLOGIC MAP SYMBOLS

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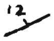
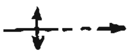
|---|---|
|  | Strike and dip of bedding |
|  | Strike and dip of bedding where stratigraphic top is known |
|  | Strike and dip of overturned bedding |
|  | Apparent strike and dip of bedding |
|  | Horizontal bedding |
|  | Strike and dip of cleavage |
|  | Strike of the axial trace and plunge of the axis of a large anticline, dashed where approximately located |
|  | Strike of the axial trace and plunge of the axis of a large syncline, dashed where approximately located |
|  | Axial trend of a small anticline |
|  | Axial trend of a small syncline |
|  | Contact, solid where known, dashed where approximately located, dotted where inferred, queried where questionable |
|  | Fault, solid where known, dashed where approximately located, dotted where inferred, queried where questionable |
|  | Thrust fault, teeth on upper plate, solid where known, dashed where approximately located, dotted where inferred, queried where questionable |
|  | Form lines, trace of bedding |
|  | Breccia zones |

## DESCRIPTION OF MAP UNITS

TKc **Canning Formation** (Molenaar, Bird, and Kirk, in press) Gray to brown and black, very fine- to medium- grained, thin- to thick-bedded, interbedded lithic sandstone, siltstone, shale, and minor tuff and bentonite. Bouma intervals are variable, shows evidence of shallowing-upward depositional environments. Sandstone are petrographically similar to those in the Arctic Creek facies (Molenaar and others in press) of Albian(?) age. The lower contact with the Hue Shale (Molenaar and others in press) is located whenever possible at the first up-section occurrence of sandstone or siltstone turbidites.

uKs **Hue Shale** (Molenaar et al in press) (formerly the Shale Wall member of the Sea Bee Formation of the Colville Group) Multi colored organic-rich shale, siltstone, tuff and bentonite. Distinguished from underlying Pebble Shale by brightly colored (generally shades of red, orange, and, maroon) low relief exposures, and the first upsection occurrence of bentonite.

## THE ARCTIC CREEK UNIT

The Arctic Creek unit consists of deformed Cretaceous (Albian) turbidites and shale which occur in poorly exposed low relief hills east of Ignek Valley between the Shublik Mountains and the Aichilik River. Preliminary studies of the Arctic Creek unit indicates that the section includes, from bottom to top, black shale (Jurassic to Early Cretaceous), manganiferous shale, interbedded black shale and siltstone turbidites, and sandstone turbidites (Albian). Bentonite occurs locally but its volume and stratigraphic significance could not be determined due to the poor exposures. Beds are generally south-dipping and the section has been repeated along north-vergent faults. The Arctic Creek unit is dissimilar to the typical Cretaceous section exposed in Ignek Valley. The more typical Ignek Valley sequence consists of Kingak Shale (Jurassic to Neocomian), Kemik Sandstone (Hauterivian), Pebble Shale (Hauterivian-Barremian), Hue Shale (Aptian? to Santonian), and turbidites of the Canning Formation (Campanian to Paleocene). The two main differences which distinguish the Arctic Creek unit from the typical Ignek Valley section are: 1) the lack the regionally persistent Kemik Sandstone in the Arctic Creek section, and 2) the lack of Albian turbidites in the typical Ignek Valley section.

The Arctic Creek unit is more similar to the Cretaceous section exposed at Bathtub Ridge about 180 km to the southeast. The Bathtub Ridge section consists of black shale with local siltstone beds (Jurassic to Lower Cretaceous), manganiferous shale, interbedded shale and siltstone turbidites (Albian), and sandstone turbidites (Albian?).

The Arctic Creek and Bathtub Ridge sequences probably were once part of a continuous depositional basin, and the Arctic Creek unit has been thrust northward into juxtaposition with the typical Ignek Valley strata.

Kas **Sandstone turbidites:** Sandstone turbidites of the Arctic Creek unit (Molenaar and others, 1987) consists of gray to brown, very fine- to medium- grained, thin to very thick bedded quartzose lithic sandstone and siltstone, interbedded with black shale. Bouma intervals are variable but generally contain well developed Tc intervals in turbidites thinner than 30 cm while thicker beds are dominated by Ta and Tab intervals. Amalgamated Tbcbc turbidites are common along the Hulahula River section. Although poorly exposed, sandstone beds at the base of the turbidite section are up to 3 meters thick and can be traced for several kilometers on arial photographs. These beds coarsen and thicken upward from the underlying siltstone turbidites and probably were deposited in a non-channelized outer-fan environment. The outer-fan deposits are overlain by thin to medium bedded turbidites arranged in weakly developed thinning and fining upward cycles well exposed along the Hulahula River and less well exposed along the Kekiktuk River. Turbidite facies C, D, and E are most common, and channelization occurs locally. These beds are laterally discontinuous and probably were deposited in a channelized middle-fan environment.

Petrographically, sandstones clasts consist of varying porportions of quartz (including chert), mica (prodominantly white mica), and carbonate, with relatively few rock fragments. Carbonate grains typically are composed of individual or composite hexagonal plates most likely from the disaggregation of echinoid shells. Carbonate grains comprise from 5% to 95% of the rock but are commonly disolved in the deeply weathered surface outcrops. Carbonate-rich beds are up to tens of centimeters thick and have excellent dissolution porosity potential in the subsurface.

The stratigraphic thickness of the sandstone turbidite unit is uncertain due to several thrust faults and folds which repeat section. A composite section generalized from the several thrust sheets is 1800 m thick.

KJas **Shale** Black shale underlies the sandstone turbidites and includes the type locality of the Kingak Shale (Leffingwell, 1919). However, a thrust fault is suspected to occur between the sandstone turbidites and the type Kingak exposures. Shale beds with demonstrable stratigraphic continuity immediately below the sandstone turbidites are unfossiliferous and may be in part correlative with the Pebble Shale in Ignek Valley or the manganiferous shale at Bathtub Ridge. Low in the shale section, black clay shale with red-weathering ironstone beds and nodules predominates. Higher in the section, blue-black chatoyant shale occurs. The characteristic color probably is due to manganese oxide on weathered surfaces. The chatoyant shale also contains red weathering ironstone beds and is more resistant than the underlying black shale. The stratigraphic thickness of the shale units beneath the turbidites is uncertain, but it occurs over an outcrop distance of 5 km south of Kikiktat Mountain.

## Kongakut Formation

The Kongakut Formation (Detterman et al, 1975) is a lower and upper Cretaceous sequence of shale, siltstone and sandstone. The Formation is divided into four members, in descending order: the Siltstone member, the Pebble Shale member, the Kemik Sandstone member, and the Clay shale member. Only the Pebble Shale and Kemik Sandstone members have been mapped in the Sadlerochit Mountains.It is the most distinctive unit in the formation, is at least 160 meters thick and contains a manganese-rich zone near the middle of the section. Flattened, highly polished chert pebbles up to 2.5 cm in diameter and minor well rounded quartz grains are present throughout the section. Clay ironstone nodules are also common. The pebble shale member has little fauna to offer as an indicator of depositional environment. The paucity of fossils is interpreted by Detterman et al (1975) as indicating a deepwater, inhospital environment. The Kemik Sandstone member is mainly a fine-grained, medium- to thick-bedded subfeldspathic quartz arenite near the top of the member and is a feldspathic wacke in the lower part. White tripolitic chert grains and pebbles are characteristic throughout the Kemik section. The Kemik contains sparse megafossil fauna consisting of ammonites, pelecypods, belemnites, gastropods, and annelid worms (Knock, 1987). A distinctive ammonite assemblage including Simberskites sp. indicates a Hauterivian (Early Cretaceous) age (Mull, 1986). The Kemik Sandstone and Pebble Shale units occur above a regionally extensive lower Cretaceous age unconformity (LCU) (Craig et al, 1985 and Mull, 1986) which cuts out stratigraphically younger units to the east across the Sadlerochit Mountains. This results in the deposition of the Kemik Sandstone on successively younger rocks to the east. For example, along the north flank of the Sadlerochit Mountins west of the Nularvik River, Kemik Sandstone was deposited on Kingak Shale of early Jurassic age; and at Marsh Creek, 6 kilometers to the east, Kemik was deposited on the Ledge Sandstone member of the Ivishak Formation of lower Triassic age. East of the Itkilyariak River, Kemik was deposited on Fire Creek Sandstone, the lower to middle Triassic age member of the Ivishak Formation; and at Last Creek, still farther to the east in the Sadlerochit Mountains, Kemik was deposited on sediments of the Shublik Formation of upper Triassic age.

uKp **Pebble Shale Member** Dark-gray to black shale and silty shale with locally abundant quartz and black chert pebbles. Zones containing clay ironstone concretions commonly occur in weakly recrystallized beds and lenses which display atleast some original sedimentary structures.

IKk **Kemik Sandstone Member** Medium- to dark-gray siltstone and very fine grained sandstone with common pebbles. Unit is extensively burrowed. Consists in general of a lower thin- to medium-bedded, hummocky, cross stratified sandstone alternating with highly bioturbated muddy sandstone, overlain by a unit composed of clean, cross bedded, conchoidally fracturing sandstone and muddy sandstone with vertical, U-shaped burrows. A basal conglomerate commonly occurs overlying the unconformity (LCU) surface (Knock, 1987).

## Kingak Shale

The Kingak Shale (Leffingwell, 1919) consists primarily of dark, noncalcareous shale, siltstone, claystone and clay ironstone that ranges in age from Early Jurassic to Early Cretaceous (Valanginian) and conformably to disconformably overlies rocks of the Shublik Formation, Karen Creek Sandstone and Kemik Sandstone. The lowest part of the Kingak consists of up to 180 meters of fissile black shale that contains abundant clay ironstone concretions locally. Overlying the basal shale unit is a unit composed of at least 100 meters and possibly as much as 300 meters of dark gray, clay shale and claystone. The upper part of this unit contains beds and nodules of clay ironstone that weather to a characteristic brick red (Detterman et al, 1975). The concretions in the Kingak commonly contain distinctive quartz veining within the core of the concretions a characteristic that may aid in the identification of the Kingak Shale where it is not fossiliferous.

JKk **Kingak Shale** Black fissile shale, and claystone that is rarely silty, and contains some chert and quartz pebbles locally. Common clay ironstone concretions and ironstone layers, that are typically recrystallized. Ironstone rich layers weather to a brick red color. Unit contains a distinctive assemblage of ammonites locally. Ironstone is more common than in the Pebble Shale.

## Shublik Formation

The Shublik Formation forms a distinctive and readily recognizable unit in northern Alaska. In northeastern Alaska, the unit occurs in a narrow belt along the north flank of the Brooks Range and along the Sadlerochit and Shublik Mountains. In structurally complex areas, the Shublik may be missing, or duplicated. In most of northeastern Alaska, the Shublik Formation is divided informally into three members: the basal member is the siltstone member, an overlying limestone and dolomite member, overlain by a clay shale member. The siltstone member is composed predominantly of dark siltstone and calcareous siltstone with a high organic content. The contact with the underlying Fire Creek Siltstone Member of the Ivishak Formation is an unconformity and is marked by a thin but widely distruibuted chert pebble conglomerate horizon that overlies silty shale of the Fire Creek. Calcite may constitutes between 20 and 40 percent of the siltstone locally and is of secondary origin (Detterman et al, 1975). Conformably overlying the basal siltstone member is the limestone and dolomite member that contains many coquinite layers, most of which contain significant amounts of phosphate. Calcite is the dominant component of rocks in this member and constitutes as much as 90 percent of the rock. Secondary dolomite is present and may constitute up to 20 percent of the rock locally. The clay shale member at the top of the formation is predominantly a very fine-grained, silty, calcareous sandstone. The Shublik Formation forms a widespread sequence of rocks that ranges from 100 to 150 meters thick. Locally, structural duplication may account for much thicker sections.

Porosities in the Shublik Formation range from 5 to 30 percent (Jones and Speers, 1976) and total organic carbon contents range from 0.5% to 2%. The formation has fairly good source rock potential and reservoir potential. It has produced gas at the Kemik field and it is part of the main reservoir at Prudhoe Bay.

Trs **Shublik Formation** Thin- to medium-bedded, fine- to medium-grained, calcareous and siliceous, phosphatic, sandstone interbedded with dark, sooty limestones and calcareous siltstone. The unit is very fossiliferous locally and forms subdued outcrops due to its incompetent nature. Horizons that contain abundant phosphate nodules weather a light blue color.

## SADLEROCHIT GROUP (Detterman et al, 1975)

### Ivishak Formation

The Ivishak Formation (Keller and others, 1961) is the upper-most formation of the Sadlerochit Group in northern Alaska. The contact between the Ivishak and the overlying Shublik Formation is probably a minor unconformity. Fossils from the upper-most Ivishak and the lowest Shublik indicate that there was apparently some local pre-Shublik erosion of the Ivishak section (Detterman et al, 1975).

The Ivishak Formation is broken into three formal members in northeastern Alaska. The Fire Creek Member consists of thin-bedded to massive, argillaceous sandstone siliceous siltstone and minor silty shale. Most of the rocks are cemented by silica, and secondary authigenic calcite has replaced the silica locally (Detterman et al, 1975). Detterman et al (1975) believe that the silica content decreases to the north in the Fire Creek Member. Mud lumps, worm trails and clay ironstone concretions as well as flute and load casts are common in rocks of the Fire Creek Member.

Conformably underlying the the Fire Creek Member is the Ledge Sandstone Member of the Ivishak. The Ledge Sandstone is a resistant, massive sandstone unit that forms prominent hogbacks ridges and questas along the north flank of the Brooks Range and in the Sadlerochit and Shublik Mountains. The Ledge Sandstone Member in outcrop averages from 15 meters thick near Wahoo Lake to as much as 120 meters thick near the Alaska-Canada boundary. Thicker sections are known in the Sadlerochit Mountains (Harun, 1987). The Ledge Sandstone is primarily a clean, massive quartz arenite, that occurs in beds that range from .5 to 3 meters thick. Locally the sandstone is conglomeratic, generally in zones in the upper part of the member. A few thin siltstone and silty shale intervals also occur . Compositionally, the siltstones are fine-grained versions of the sandstone with a sericitic clay matrix (Detterman et al, 1975). Chert forms between 30 and 40 percent of the rock. Some of the chert is highly weathered (tripolitic). Tripolitic chert grains are characteristic of this member. The composition and sedimentary stuctures indicate a northerly source area and the Ledge Sandstone unit becomes thinner and finer grained to the south. Regional isopachs of the thickness of the Ledge suggest that it may have been deposited in several depositional centers; one at Prudhoe Bay, one north and east of the Sadlerochit Mountains and a third near and to the east of the Alaska-Canada boundary. Thick accumulations of the Ledge Sandstone Member correspond to these depocenters.

Conformably underlying the Ledge Sandstone Member is the Kavik Member of the Ivishak Formation. The Kavik Member is a recessive-weathering unit of silty shale and siltstone, that varies between 15 meters and 75 meters thick in undisturbed section to structurally repeated sections of over 250 meters thick. Lithologically, the Kavik Member consists of thin-bedded, laminated, silty shale, siltstone and minor argillaceous sandstone. Quartz forms about 30 to 40 percent of the rock, generally in well-rounded grains. Most of the sandstone layers are very fine-grained quartz arenites with a clay-rich matrix.

Porosities in the Ivishak range between 2 and 10 percent for surface samples in the ANWR compared to porosities as high as 30 percent for similar units at Prudhoe Bay. Jones and Speers (1976) suggest that the average porosities in the Ivishak may improve northward away from the mountain front. Therefore, there is a high probably that good reservoir quality sandstones occur in the Ivishak Formation.

The Ivishak Formation contains "dead" oil near the Nularvik River in the Sadlerochit Mountains (Gar Pessel, personnel communication, 1985), it has produced gas at the Kavik field, and it contains the main reservoir. at Prudhoe Bay.

ITrfc **Fire Creek Member** Fine- to medium-grained, medium light brown to brown and gray, dark-brown weathering, thin- to massive-bedded, convolute-bedded, quartz-lithic sandstone interbedded with dark-gray to brown very fine-grained siliceous siltstone and minor shale. The sandstone intervals may contain large crossbeds and may represent storm deposits. Shale and siltstone intervals contain abundant mudlumps and show signs of extensive bioturbation. Unit forms a distinctive hump on top of the Ledge Sandstone. The contact between the Fire Creek and the underlying Ledge Sandstone appears to be conformable and gradational.

lTrl **Ledge Sandstone Member** Fine- to medium-grained, light gray to brown, bone to brownish weathering, thin- to massive-bedded, well sorted, mature quartz sandstone. The sandstone contains abundant pyrite locally. The pyrite occurs as blobs to ten mm in diameter and as diseminated concentrations. Layers of poorly sorted, coarse-grained conglomerate occur near the top of the unit. Clasts in the conglomeratic layers range up to 15mm in diameter and are composed of gray and black chert and black shale in a clean quartz sandstone matrix. Unit is thin to massive-bedded and occurs in beds that range from 2 to 30cm thick that are graded locally. Bottoms of some massive beds contain lobate bed forms. Some good porosity is present in the northern exposures in the Sadlerochit Mountains, where the unit contains dead oil. Contact between the Ledge Sandstone and the underlying Kavik Shale is conformable and is marked by a change in overall bedding character and decrease in grainsize of the sandstone. Thickness of the Ledge Sandstone ranges up to 150 meters.

lTrk **Kavik Member** Dark reddish-brown to black and brown, bone weathering, fine- to very-fine grained, thin-laminated, to thin-bedded, and cross stratified, sandy siltstone and shale. Contains spheroidal-weathering sandstone clots locally. Some thin laminated, flaky, black shale occurs near the top of the unit. Contains ripup clasts and pyrite concentrations as blobs and disseminations along bedding surfaces. Often contains brachiopods and crinoid debris and the trace fossil zoophycus(?). Up to 15 meters thick locally.

**Echooka Formation**

Conformably to disconformably underlying the Kavik Member of the Ivishak Formation is the Echooka Formation (Keller and others, 1961). The Echooka has been subdivided into two members: the upper Ikiakpaurak Member and the lower Joe Creek Member. The Ikiakpaurak Member consists of a sequence of orthoquartzite, quartzitic sandstone and siltstone that form the main part of the Echooka Formation (Detterman et al, 1975). The sandstones are generally dark, fine-grained quartz arenites. Quartz grains are generally subround to subangular and are cemented by silica that has formed overgrowths. Calcite is a dominant cementing agent locally, and where calcite is the dominant cement, the rocks commonly contain abundant glauconite. Siltstones and shales are essentially fine-grained versions of the quartz arenite with a siliceous clay-rich matrix. The Iklakpaurak Member ranges from less than 10 meters thick to as much as 110 meters thick in the central part of the Sadlerochit Mountlans and it thins rapidly to the north.
Underlying the Ikiakpaurak Member conformably is the Joe Creek Member, a unit dominated by calcareous siltstone, limy mudstone, chert, and limestone. The calcareous siltstone and limy mudstone are composed of 15 to 30 percent detrital quartz and 15 to 30 percent rounded detrital calcite. Euhedral dolomite grains are present and suggest dolomitization of the unit. The limestones in the upper part of the member are quartz calcarenites and contain 10 to 30 percent detrital quartz. Some of the limestone beds are bioclastic limestone or microcoquinite (Detterman et al, 1975) composed of rounded fragments of brachiopods, bryozoans, corals, gastropods and foraminifera. Glauconite is a common constituent of this unit. The Joe Creek Member ranges from 10 meters to 120 meters thick.

Pe **Echooka Formation Undifferentiated** Unit mapped where the Iklakpaurak Member and the Joe Creek Member are to thin to be represented separately at this map scale.

Pei **Iklakpaurak Member** Interbedded dark-brown, fine-grained quartz arenite and siliceous siltstone. The siltstone contains secondary quartz veining locally. Both calcite and silica are common cementing agents.

Pej **Joe Creek Member** Interbedded brown to dark brown, fine- to coarse-grained, calc arenite and calcareous shale. Contains a glauconitic sandstone and shale interval that forms a resistant ledge above the contact with the underlying Wahoo Limestone. A distinctive orange-weathering horizon at the contact with the Wahoo Limestone is composed of calcareous pebble conglomerate, pebbly lithic sandstone, and glauconitic shale and siltstone. Black chert pebbles are the most common pebbles in the orange-weathering unit, although gray and white chert pebbles also occur. Fossil debris composed of brachiopod, crinoid and coral fragments also form a major component of the orange-weathering unit. Unit commonly channels into the underlying Wahoo Limestone.

## LISBURNE GROUP

Schrader (1902) described and named a thick sequence of light gray limestone in the Anaktuvak River area, of the central Brooks Range, the Lisburne Formation. Later, Leffingwell (1919) referred to similar rocks in northeastern Alaska as the Lisburne Limestone. Detailed work by Bowsher and Dutro (1957) in the Shainin Lake area, subsequently raised the Lisburne Formation (Limestone) to the Group status and subdivided the rocks into two formations. The lower formation, the Wachsmuth Limestone is of Lower and Upper Mississippian age and the upper formation is the Alapah Limestone is of Upper Mississippian age. The Wachsmuth Limestone apparently thins to the east and northeast and is absent in the map area. In the northeastern Brooks Range, the Alapah Limestone is overlain by the Wahoo Limestone (Brosge and others, 1962) of Late Mississippian to Early Pennsylvanian age (Armstrong and others, 1970). Lisburne Group rocks thicken to the east along strike in the Sadlerochit Mountains and also to the south in the Shublik Mountains.

Pw **Wahoo Limestone** Light-gray to buff and tan, fine- to medium-grained, thin to massive-bedded, interbedded lime mud and bioclastic grainstone. Bedding ranges from a few centimeters to as much as 15 meters thick near the base of the unit. Irregular layers and nodules of gray and black replacement chert are common. It is abundantly fossiliferous, and contains a rich fauna of crinoids, brachiopods and bryozoans. Some tan, thin-laminated dolomitic beds occur locally. Top of the unit is marked by a slight unconformity, on which the orange-weathering unit of the Echooka Formation was deposited. Some channeling on the unconformity surface is present. Where the channels are well exposed, large rip up clasts of limestone are present in the channels.

Mau **upper Alapah Limestone** Light- to medium-gray, thin- to medium-bedded limestone that weathers buff locally. Composed predominantly of lime mudstones that weather into small shard-like irregular pieces. The unit is poorly exposed in the Sadlerochit Mountains and form distinctive talus aprons below the Wahoo Limestone. In the Shublik Mountains the unit is thicker and is represented by dark gray to medium gray, interbedded lime mudstones. The contact between the upper Alapah and the Wahoo Limestone is marked by a massive bed of yellow-brown weathering limestone.

Mal **lower Alapah Limestone** Medium light gray to gray and tan, thin- to massive-bedded limestone that forms a distinctive cliff-forming unit below the upper Alapah Limestone. The contact between the upper Alapah and the lower Alapah unit appears to be gradational. Bedding in the lower unit ranges from less than 1 meter to over 10 meters thick of predominantly pelletoidal packstone and grainstone. Massive bedded pelletoidal grainstones contain large-scale forset crossbeds that are capped by ferruginous interbeds of hematite-stained sands and shales. Some dark gray to green and red shale are also present locally.

## ENDICOTT GROUP

Brosge and others (1962) described the Kekiktuk Conglomerate as a thin quartzitic chert-pebble conglomerate that occurs beneath the Kayak Shale (Bowsher and Dutro, 1957) and unconformably above rocks of the Neruokpuk Formation (Leffingwell, 1919) throughout much of northeastern Alaska. The formation is almost entirely conglomerate and coarse-grained quartzitic sandstone. Clasts in the conglomerate consist of sub angular to rounded granules, pebbles and cobbles of black, gray, and white chert, quartz, quartzite and sandstone and siltstone (Dutro and others, 1962). Thickness of the Kekiktuk Conglomerate ranges from 0 to more than 100 meters thick, and the unit grades upward from a conglomeratic base into finer grained paralic sediments near the top of the unit (Armstrong and Mamet, 1975). Locally the Kekiktuk Conglomerate contains thin discontinuous coal beds in a sequence of interbedded coarse-grained conglomerate and coarse-grained, calcareous sandstone. A coal sample from a bed in the Kekiktuk Conglomerate collected during the 1985 field season on Leffingwell Ridge just east of the Jago River had a vitrinite reflectance value of 4.0 and an average air dried BTU content of 13,516 (Roy Merrit, DGGS unpublished data). A conglomerate sequence in the Kekiktuk Conglomerate just east of the Jago River on Leffingwell Ridge is at least 75 meters thick and contains dead oil (DGGS, unpublished data).
Conformably overlying the Kekiktuk Conglomerate and disconformably underlying rocks of the Lisburne Group in the northeastern Brooks Range is the Kayak Shale (Bowsher and Dutro, 1957), a formation dominated by dark gray to black noncalcareous shale and minor siltstone and thin-bedded ferruginous sandstone .
The Endicott Group in the Sadlerochit Mountains is highly variable in nature and ranges from 0 to 25 meters thick. The Kayak Shale thickens to the south in the Shublik Mountains where it ranges up to 100 meters thick.

IMe **Kayak Shale and Kekiktuk Conglomerate Undifferentiated** Dark gray to black shale and siltstone of the Kayak Shale and sandstone and conglomerate of the Kekiktuk Conglomerate. These rocks occur only sporadically in the Sadlerochit Mountains.

### Nanook Limestone

The Nanook Limestone (Dutro, 1970) is a thick sequence of limestone, dolomite and minor shale that disconformably overlies rocks of the Katakturuk Dolomite in the Shublik and Sadlerochit Mountains. The Nanook Limestone in the Shublik Mountains is at least 1,000 meters thick. Dutro (1970) described fossils found near the top of the unit as Middle Devonian and suggested that the entire sequence, including the lower units were Middle Devonian in age. Recent work by Blodgett, Clough of the DGGS and others in the central Shublik Mountains has resulted in the discovery of fossiliferous horizons below Dutro's unit within the Nanook Limestone (Blodgett and others, 1986). Gastropods and trilobites in these rocks indicate indicate that Ordovician, Silurian and mid Upper Cambrian strata are present.

lPzn **Nanook Limestone Undifferentiated** (central Sadlerochit Mountains) light tan or creamy pink and light gray, fine- to medium-grained, thick-bedded (>10 meters common), gray- to tan-weathering, siliceous dolomite and limestone with pelletal textures. Contains sponge-like webs of quartz and sparry calcite in clots and veins. Unconformably overlies the Katakturuk Dolomite with slight angularity and is unconformably overlain by rocks of the lower Lisburne Group. Irregular, spotty occurrences of this unit suggests that the Nanook in the central Sadlerochit Mountains may represent erosional remnants of the Nanook on the unconformity at the base of the Mississippian sequence.

### Katakturuk Dolomite

The Katakturuk Dolomite uncomformably underlies rocks of the Lisburne Group, Endicott Group, and Nanook Limestone in the Sadlerochit and Shublik Mountains, and structurally overlie rocks of the

Sadlerochit Group, Lisburne Group, and Neruokpuk Formation in the same ranges. Dutro (1970) named the thick sequence of dominantly dolomitic rocks exposed in the Katakturuk River canyon, the Katakturuk Dolomite. He informally subdivided the unit into nine members based on his composite type section in the Shublik Mountains. Dutro's subdivision did not include two units immediately below his nine members and overlying the mafic flows in the western Shublik Mountains. These units were considered to be an older highly silicified unnamed dolomite. During this study, the Katakturuk Dolomite was subdivided into thirteen informal mappable units, which include the unnamed dolomite of Dutro (1970), in the Mt. Michelson C-4 quadrangle based on distinctive lithologies and weathering character. The sequence as recognized is at least 2000 meters thick and appears to thicken to the east. The Katakturuk Dolomite section in this quadrangle is not repeated and generally strikes east-west and dips between 40 and 55 degrees to the south. Extensive sampling for conodonts and other forms in the Kaktakturuk Dolomite by Gus Armstrong and others of the USGS has not yielded any results. Recent work by Blodgett and Clough and others (Blodgett and others, 1986) in the Shublik Mountains has resulted in the discovery of a mid Upper Cambrian through early Middle Devonian sequence of rocks that overlie rocks of the Katakturuk Dolomite. Additonal detailed stratigraphic studies of the Katakturuk Dolomite in the Sadlerochit and Shublik Mountains has found no evidence of skeletal metazoan fossils (Clough, 1986; Clough and others, 1987). Therefore the Katakturuk Dolomite is now considered to be older than mid Upper Cambrian and probably is Proterozoic in age.

pCkh **Horsetooth dolomite** Medium-brown, tan and black, fine-to very coarse-grained, dolomite that contains much webwork quartz veining and coarse-grained secondary quartz flooding that results in a texture resembling horseteeth and vugs filled with quartz crystals. These appear to be the result of tectonic overprinting that may be lithologically controlled. Locally, black-weathering, thin laminated and crossbedded dolomite and dolomite are present. About 75 to 100 meters thick. Corresponds to upper part of Dutro (1970) Unit 9.

pCkbk **Black laminated dolomite** Dark-gray to brown, fine- to medium-grained, thin-laminated to thick-bedded, dolomite, interbedded with fine-grained, brown dolomite and dolomite breccia. Unit contains abundant, large-scale trough cross-bedding composed of ooids. Where ooid beds are silicified they weather a distinctive black, similar to pCkso. About 75 to 100 meters thick. Corresponds to upper part of Dutro (1970) Unit 9.

pCkp **Pink dolomite** Medium-gray, brown, pink and buff, medium- to coarse-grained, dolomite. Weathers to distinctive pinkish gray alternating with gray in beds averaging 5 meters thick. Generally cross bedded to massive grainstone with ooids and algal mat debris. Locally, thin-laminated , dark-gray, dolomite horizons occur near the top of the unit. Minor tectonic breccia and secondary quartz veining and vugs are present. White, gray and pink dolomite crystals and clear quartz crystals fill the voids locally. About 200 meters thick. Corresponds to lower part of Dutro (1970) Unit 8.

pCkuc **Upper gray craggy dolomite** Medium dark-gray to gray, fine- to coarse-grained, thick-bedded, coarsely crossbedded dolomite. Weathers to gray to light gray. Unit contains abundant ooids and algal mat rip up debris including tabular clasts parallel to bedding. Minor occurrences of laterally linked to discrete columnar stromatolites in the middle to lower part of unit. Ridge-forming unit due to its resistant nature. About 250 meters thick. Corresponds to Dutro (1970) Unit 8.

pCka **Thin bedded algal dolomite** Dark-gray to gray, thin bedded to thin laminated, dark-gray, locally recessive weathering, dolomite. Weathers to various shades of light gray to dark brownish-gray. Thin laminated horizons contain various algal mat types. Some laterally linked to discrete columnar stromatolites are present in the lower part of the unit. Thin bedded layers often composed of algal debris grainstone. Thickness of pCka is variable ranging from about 50 to 150 meters thick. Corresponds to upper part of Dutro (1970) Unit 7.

pCklc **Lower gray craggy dolomite** Medium- to dark-gray, fine- to medium-grained, thick- and massive-bedded, dark-gray to black weathering dolomite. Unit characterized by coarse cross- and parallel-bedded rip up clasts of algal debris and ooids; and laterally linked to discrete columnar and digitate stromatolites. Forms prominant ledges due to its resistant nature. Averages 150 meters in measured thickness. Corresponds to middle part of Dutro (1970) Unit 7.

pCkbn **Brown marker** Interbedded, brown to light-brown, fine- to medium-grained, thin- to medium-bedded, sandy dolomite; and dark-gray to black, thin-laminated, recessive weathering, dolomite. Contains minor polygonal mudcracks, small collapse breccias and speleothem infillings. Locally contains minor algal debris, cross bedding, and ripup clasts. Unit averages 35 meters in measured thickness. Corresponds to lower 50 feet of Dutro (1970) Unit 7.

pCkw **White marker** Unit light gray dolomite weathering to yellowish-tan and very light gray. Extensively cryptalgal laminated dolomitic mudstone and locally stromatolitic. Stromatolite morphologies follow a regular vertical succession from discrete columnar forms to hemispheroid forms to elongated forms representing intertidal shallowing. This unit averages 44 meters in measured thickness. Corresponds to Dutro (1970) Unit 6 with the exception of Dutro's pisolite zone which is depositionally part of and placed in the underlying pCkso unit.

pCkso **Silicified oolite unit** Light- to dark-gray, fine- to very coarse-grained, thin laminated to cross-bedded, light-gray weathering oolitic dolomite interbedded with light-gray , thin-bedded silicified oolitic and stromatolitic dolomite. Unit contains abundant ooids and compound ooids, algal debris, and algal mat horizons including columnar stromatolites near the top. Algal mats are commonly silicified locally along with cross-bedded oolitic grainstone horizons which generally weather to a distinctive black. The base of this unit is marked by a 22 meters thick, medium gray weathering to brownish-gray, dolomite containing black chert spheroids to 2 cm in diameter and thinly laminated dolomite. The top of this unit is marked by a very distinctive 11 meters thick pisolitic dolomite. The entire chert and oolite unit is about 320 meters thick. The basal chert spheroid unit corresponds to Dutro (1970) Unit 4; the predominantly oolitic portion to Dutro (1970) Unit 5.

pCkl **Thin laminated dolomite** unit Medium gray, rhythmically thin bedded, orangish-tan to red weathering dolomitic mudstone at base; and black to dark gray weathering to gray and tan, thin bedded platy limestone and calcareous shale at top. Rhythmites contain rip up clasts locally and numerous channels which pinch out laterally. Unit is 53 meters thick, 42 meters of orangish-tan to red weathering rhytmites overlain by 11 meters of platy limestone to shale. Corresponds to Dutro (1970) Unit 3. Where not mapped as separate pCkl, this unit is included in underlying pCkc.

pCkc **Cobweb dolomite** Gray- to medium dark-gray to brownish-gray, fine- to medium-grained, thin bedded to massive, light gray and orange weathering planar laminated to conglomeratic dolomite. Laminations are mm to cm scale, accompanied by thin black hummocky layers locally. Dolomite conglomerate consists of debris flows with clasts derived presumably from underlying pCkv. Unit characterized by a dense network of white and tan-weathering quartz veinlets. Lower part of the unit contains thin chert layers. 50 meters thick. Corresponds to Dutro (1970) Unit 2. Overlying pCkl rocks, where poorly exposed, are included in this map unit.

pCkv **Variegated dolomite** Interbedded light-gray, tan to orangish weathering, fine- to medium-grained, silty dolomite, silty limestone, and brown and black, thin bedded, calcareous shale. Dolomite layers contain planar lamination and some minor chert layers near the top of the unit. Thicker beds of dolomite contain a network of white quartz veinlets. 84 meters thick where measured at best exposure in Hue Creek, Shublik Mtns. Corresponds to Dutro (1970) Unit 1.

pCkz **Zebra dolomite** Brown- to brownish-gray, fine-grained, thin- to medium-bedded dolomite containing small to medium (1 cm to 25 cm high) irregular white silicified vugs and chert bands. Unit is brecciated locally and contains black chert clasts to 30 cm long. 57 meters thick. Corresponds to Dutro (1970) unnamed dolomite.

pCks **Spire dolomite** Medium light-gray to gray, thick-bedded to massive, pisolitic to faintly laminated dolomite that weathers into spires and tors on ridgelines. Dolomite contains a fine network of thin quartz veinlets. About 300 meters thick. Corresponds to Dutro (1970) unnamed dolomite.

pCkgn **Greenstone** Dark green, maroon, and black, fine- to coarse-grained, orange and brown to dark-green weathering, altered andesite. Andesite contains calcite, chlorite, and zeolite filled vesicles that range from 1 to 5mm in diameter. Plagioclase mircrolites contain swallow-tail terminations; suggestive of volcanic origin. Andesite occurs in a variety of textures, ranging from aphanitic to porphyritic, and occurs in massive to well-layered sequences. One occurrence of andesite in the Shublik Mountains contains native copper and minor chalcocite.

pCku **Undifferentiated** Undifferentiated units of the Katakturuk Dolomite.

## Neruokpuk Quartzite

Leffingwell (1919) named interlayered quartzite, siliceous phyllite, argillite, limestone, and shale that crop out in the Romanzof Mountains the Neruokpuk Schist. Reiser and others (1971, 1978) suggested a Proterozoic age for the Neruokpuk schist and noted that it is generally less metamorphosed to the north. The Neruokpuk Schist is interlayered Proterozoic(?) limestone, calcareous and dolomitic sandstone, shale, phyllite, mafic volcanic rocks, and quartzite that form several mappable units (Reiser and others, 1978). In the Demarcation Point Quadrangle, these Proterozoic(?) rocks are overlain unconformably(?) by latest Proterozoic-Lower Paleozoic Franklinian rocks.

pCn **Neruokpuk Quartzite undifferentiated** Crops out in the central and eastern Sadlerochit Mountains. Unit is in thrust fault contact with overlying Katakturuk Dolomite. It is polyformed and contains isoclinal folds and well defined axial plane cleavage as the dominant fabric. Lithologies include: quartzite, fine-grained metasedimentary rocks (locally phyllitic and schistose) and argillaceous dolomite.

pCnq **Quartzite and argillite** Brown and tan-weathering quartzite and shale. Unit varies from fine to coarse-grained, from white to reddish-brown and locally to dark greenish-gray. Interbedded shale intervals are dark gray, green and black, thin to thick bedded, and sheared locally. Isoclinal folding is the predominant structural style in the shale and argillite intervals.

pCnd **Argillaceous dolomite** Light- to dark- gray and black, thin laminated to massive, dolomite. Dolomites are predominantly boundstones and packstones. Contains stromatolites and pisoliths. Thin laminated, argillaceous dolomite and argillite layers are isoclinally folded, and have well developed axial plane cleavage foliation.

pCng **Mafic volcanic flows** Dark maroon to black and green, fine- to coarse- grained, andesite or basalt. Occurs as recognizable flow units locally. Volcanics contain chlorite, calcite and zeolite(?) vesicle fillings. Vesicles vary from less than 1mm to 5mm in diameter. Similar to volcanic rocks in the Shublik Mountains. Basal contact in the central Sadlerochit Mountains is a thrust fault. Upper contact is a disconformity with units of the Katakturuk Dolomite, and with rocks of the Lisburne Group. Plagioclase microlite swallow-tail terminations and plagioclase crystal clots suggest volcanic origin.

pCns Slate Dark red, black, and green slate. With well-developed slaty cleavage. Tightly folded and contorted with pencil cleavage and rodding structure developed locally. Occurs with quartzite (pCnq) and best exposed in upper Marsh Creek near Mt. Weller. Total thickness approximately 70 feet.

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