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PRELIMINARY BEDROCK GEOLOGIC MAP OF THE WESTERN SHUBLIK MOUNTAINS, ARCTIC NATIONAL WILDLIFE REFUGE, NORTHEASTERN BROOKS RANGE, ALASKA

by

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INTRODUCTION

This report summarizes a stratigraphic and structural study conducted in the western Shublik Mountains, Arctic National Wildlife Refuge (ANWR) Northeastern Brooks Range, Alaska, during the 1987 field season. The preliminary geologic map, covering approximately 35 square miles and mapped at a scale of 1:25,000, is part of my M.S. research at the University of Alaska Fairbanks (UAF). The detailed map documents the structure and stratigraphy in this area and the accompanying five preliminary, schematic cross sections illustrate the various structures contained in the study area. The map and cross sections were compiled from data collected during the 1987 field season, while participating in the UAF Brooks Range Geologic Research Program, an ongoing program of structural and stratigraphic studies in ANWR. The program is being conducted by the Department of Geology and Geophysics and the Geophysical Institute at the University of Alaska Fairbanks in cooperation with the Alaska Division of Geological and Geophysical Surveys (ADGGS). Previous work in the area includes Reiser et al. (1970, 1971), Robinson et al. (1987), and Imm (1987).

The Shublik Mountains are defined by an E–trending, N–vergent, doubly–plunging anticline cored by pre-Mississippian, Franklinian sequence, rocks. Franklinian and overlying Ellesmerian sequence rocks are separated by a pre-Mississippian angular unconformity which has had a prominent influence on the local structural style. In the study area, the Franklinian sequence consists of, in ascending order, pre-Cambrian (?) mafic volcanic rocks, the pre-Cambrian(?) Katakturuk Dolomite, and the pre-Cambrian(?) to Devonian Nanook Limestone. The unconformably overlying Ellesmerian sequence is composed of carbonates and clastics, including, in ascending order, the Lower Mississippian Endicott Group, the Mississippian to Pennsylvanian Lisburne Group, and the Permian to Lower Triassic Sadlerochit Group.

The study area is located at the western terminus of the Shublik Mountains where the anticlinal structure of the range plunges sharply to the west. Immediately to the west of the study area, the range plunges into the subsurface. The study focused on two major decollement horizons which influenced the structural style of the range in this location.

STRUCTURE IN THE PRE-MISSISSIPPIAN ROCKS

The Shublik Mountains anticline and the range–front fault bounding it to the north formed by northward displacement over ramp-flat steps in a thrust fault branching upward from a decollement at depth in the pre-Mississippian rocks. Steps in this thrust fault are reflected by dip changes in the pre-Mississippian Katakturuk Dolomite, which are well displayed in the peaks to the east of Nanook Creek. The southernmost ramp in the study area is reflected at the surface by a S–dipping panel exposed south of the east branch of Nanook Creek. It is marked by a 50 to 70 degree dip in the pre-Mississippian basement rocks and a gentler, 30 degree dip in the Mississippian and younger cover rocks.

The steeply S–dipping panel forms the south limb of a large, asymmetric anticline. The north limb of this anticline is a flat panel in the Katakturuk Dolomite, probably overlying a flat step in the detachment surface. The trace of the axial plane of the asymmetric anticline runs parallel to and just north of the east branch of Nanook Creek. A syncline of smaller magnitude occurs within this anticline and is displayed by chevron folding in an incompetent unit within the Katakturuk Dolomite.

The next panel, immediately north of the flat panel, forms the range front. This panel contains mafic volcanic rocks and the Katakturuk Dolomite which dip sharply to the south at an angle of 45 degrees. This suggests that these rocks are underlain by a ramp that dips approximately 45 degrees to the south.

The range-front panel and the flat panel to the south define an asymmetric syncline. The trace of the axial plane runs parallel to the range front and along the first drainage south of the range front. A fault-bounded pop-up block formed within the mafic volcanic rocks and the Katakturuk Dolomite due to space problems in the core of the asymmetric syncline. As the thrust sheet moved northward up the range-front ramp, tightening between two limbs of the syncline caused this pop-up block to form.

The range-front fault is located in or below the pre-Mississippian mafic volcanic rocks, and probably marks the northernmost and structurally highest continuation of the decollement forming the base of the major thrust sheet in the Shublik Mountains. The trace of the fault plane is covered along the range front by alluvium, but its location can be inferred by the exposures of Brookian sequence units to the north in Ignek Valley. The range-front fault marks the base of several imbricate thrusts in which mafic volcanic rocks have been thrust over the Katakturuk Dolomite (cross sections A, B, C, D, and E). The range-front fault places the entire imbricated sequence over the Cretaceous Hue Shale and Cretaceous to Tertiary Canning Formation.

The imbrication now exposed above the range-front fault probably existed within the Franklinian sequence rocks prior to Mississippian time. Several lines of evidence suggest this, including: 1) the southerly dip of the pre-Mississippian basement rocks beneath the pre-Mississippian unconformity, which creates the angular unconformity with the overlying Ellesmerian sequence cover rocks, 2) the repetition of a stratigraphic sequence consisting of mafic volcanic rocks - Katakturuk Dolomite - Nanook Limestone in both the Shublik and Sadlerochit Mountains, and 3) the greater displacement between the mafic volcanic rocks and the Katakturuk Dolomite than the displacement of the Endicott Group on the same faults.

The greater displacement between the pre-Mississippian volcanic rocks and dolomites than the displacement of the Mississippian Endicott Group on the same faults, (cross sections D and E), suggests that the displacement on the faults between the volcanic rocks and the dolomites occurred during pre-Mississippian time. Then, during the formation of the Shublik Mountains anticline and range-front fault these faults were reactivated. Therefore, original deformation and movement along these fault surfaces pre-dates the pre-Mississippian unconformity and the reactivation of these surfaces post-dates the pre-Mississippian unconformity, since the Endicott is offset (cross sections D and E).

STRUCTURE IN THE MISSISSIPPIAN TO TRIASSIC ROCKS

A regional angular unconformity at the base of the Mississippian rocks is a horizon of major stratigraphic and structural importance. Below the unconformity, the thick pre-Mississippian carbonates and volcanic rocks behave as structurally competent units. Above the unconformity and at the base of the cover sequence, the Mississippian Endicott Group is relatively thin, consisting largely of shales, and behaves as a structurally incompetent unit. The second decollement horizon is located in the Lower Mississippian Endicott Group and probably in the Kayak Shale due to its mechanically incompetent nature. Northward displacement along the Kayak Shale detachment surface has resulted in structural duplication of Lisburne through Sadlerochit Group rocks over an oblique ramp at Mt. Copleston (cross section C).

Beneath the thrust fault, a series of asymmetric folds and fault-propagation folds occur, as seen on the north nose of Mt. Copleston (cross section C). These structures either formed prior to the formation of the oblique ramp and were further tightened during the breakthrough, or formed in response to displacement over the ramp.

Structures in the Franklinian and Ellesmerian rocks are disrupted by several N-trending, down-to-the-west, high-angle oblique-slip faults, possibly tear faults. These occurred either during or after the formation of the range-front fault, since all of the stratigraphic units are cut by these faults. Two such faults exist in the northern portion of the study area.

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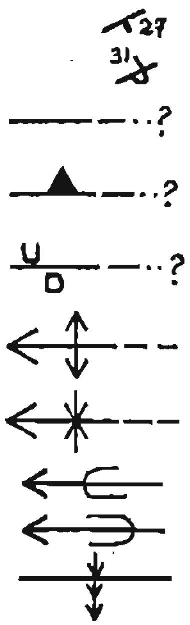
GEOLOGIC MAP SYMBOLS



Strike and dip of bedding

Strike and dip of overturned bedding

Contact: solid where known, dashed where approximately located, dotted where covered, queried where questionable

Thrust fault: solid where known, dashed where approximately located, dotted where covered, queried where questionable

Fault: solid where known, dashed where approximately located, dotted where covered, queried where questionable

Strike of the axial trace and plunge of the axis of a large anticline: solid where known, dashed where approximately located

Strike of the axial trace and plunge of the axis of a large syncline: solid where known, dashed where approximately located

Axial trend of a small anticline

Axial trend of a small syncline

Trend of axial surface of flexure where dip changes degree but not direction

GEOLOGIC MAP UNITS

TKc **CANNING FORMATION**

The Canning Formation (Molenaar, Bird, and Kirk, 1987) is present along the northern flank of the study area and typically only outcrops in drainages. The stratigraphic nomenclature and age determinations are based on Robinson et al. (1987).

Gray to brown and black, very fine- to medium-grained, thin- to thick-bedded, interbedded lithic sandstone, siltstone, shale, and minor tuff and bentonite. The unit is recessive.

uKs **HUE SHALE**

The Hue Shale (Molenaar et al, 1987) is present along the northern flank of the study area and outcrops along drainages. The stratigraphic nomenclature and age determinations are based on Robinson et al. (1987).

Multi colored (typically shades of red, orange, and maroon) organic-rich shale, siltstone, tuff, and bentonite forming low relief exposures.

SADLEROCHIT GROUP

The Sadlerochit Group (Detterman et al., 1975) is divided into two formations, the Ivishak and Echooka formations (Keller et al., 1961). The Ivishak Formation is the younger formation and is divided into three formal members, the Fire Creek Siltstone, the Ledge Sandstone, and the Kavik Shale. The Fire Creek Siltstone is absent in the study area. The Ledge Sandstone conformably underlies the Fire Creek Siltstone and the Kavik Shale conformably underlies the Ledge Sandstone. The Echooka Formation conformably to disconformably underlies the Kavik Shale member of the Ivishak Formation. The Echooka Formation has been subdivided into two members, the younger Ikiakpauruk member and the basal Joe Creek member. Stratigraphic nomenclature and age determinations for the Sadlerochit Group are based on Detterman et al. (1975), Keller et al. (1961), and Robinson et al. (1987).

IVISHAK FORMATION

lTrl **Ledge Sandstone Member**

Light gray to brown sandstone weathering to rusty brown and orange, medium- to coarse-grained, thin- to thick-bedded (.1 - 1 m) and massive. A clean, well sorted, mature quartz arenite with abundant local pyrite blobs (generally 5 mm in diameter) and diseminated concretions. Highly fractured and resistant forming hogback ridges.

lTrk **Kavik Shale Member**

Dark reddish-brown to black and brown shale with hematite staining and weathering to a yellowish-orange. Very fine-grained, thin- laminated, thin-bedded, silty shale and noncalcareous siltstone with minor argillaceous sandstone. Nonresistant saddle and slope former.

ECHOOKA FORMATION

Pei Ikiakpauruk Member

Dark-brown, fine-grained quartz arenite with subrounded to subangular quartz grains, silica cement, and abundant Zoophycus trace fossils. Interbedded with a black, very fine-grained, moderately-bedded (.1 - .3 m) siltstone and shale with a fetted odor.

Pej Joe Creek Member

Calcareous pebble conglomerate with black, gray, and white chert pebbles. Weathers to a rusty orange and commonly channels into the underlying Wahoo Formation.

Pe ECHOOKA UNDIFFERENTIATED

Unit mapped where the Ikiakpauruk and Joe Creek members are too thin to be represented separately at this map scale.

LISBURNE GROUP

The Lisburne Group is formally subdivided into two formations, the younger Wahoo Limestone and the basal Alapah Limestone. The upper contact of the Wahoo Limestone (Brosge et al., 1962) is a channelized unconformity with the overlying Joe Creek Member of the Echooka Formation. The Alapah Limestone is subdivided into two members, the upper Alapah Limestone and the lower Alapah Limestone. The upper contact of the upper Alapah Limestone is conformable with the Wahoo Limestone and marks the boundary between the Missisippian and Pennsylvanian. The basal contact of the upper Alapah Limestone is gradational with the lower Alapah Limestone and the basal contact of the lower Alapah Formation is gradational with the underlying Kayak Shale. Stratigraphic nomenclature and age determinations for the Lisburne Group are based on Schrader (1904), Leffingwell (1919), Bowsher and Dutro (1957), Brosge et al. (1962), Armstrong et al. (1970), Sable (1977), and Imm (1986).

Pw WAHOO LIMESTONE

Light- to medium-gray and weathers locally to orange, medium- to coarse-grained, thin- to massive-bedded (2 cm - 15 m), with tan, thin- laminated dolomite layers occurring locally. Mudstone, packstone, and bioclastic grainstone with local black and dark gray chert nodules predominantly running parallel to bedding. Interbedded shale and shaley limestone at the top. Rich in jasperized crinoid stems, bryozoans, and brachiopods near the top. Resistant unit forming massive cliffs.

ALAPAH LIMESTONE

Mau Upper Alapah Limestone

Dark- to medium-gray weathering to buff and light gray. Thin- to medium-bedded with interbedded lime mudstones that weather into sharp, platy, shard-like pieces. Forms distinct talus aprons beneath the Wahoo Limestone.

Mal Lower Alapah Limestone

Medium light-gray to black limestone weathering to a medium- to dark-gray. Carbonaceous limestone with a fetid odor, well-defined thin- to massive-bedding (1 to 10 m), finely crystalline, pelletoidal packstone and grainstone. Slightly fossiliferous with some horn corals and small nodular chert locally. Near the base a distinct clastic sequence is present with sandy and silty lime mud and large sand dominated forset cross-beds. Resistant unit forming cliffs.

ENDICOTT GROUP

The Endicott Group lies in depositional and unconformable contact with the underlying Katakturuk Dolomite and Nanook Limestone, and grades conformably into the overlying Lisburne Group.The unit behaves as a major detachment horizon, thus is typically highly fractured and sheared and contains several celavage directions. Stratigraphic nomenclature and age determinations are based on Leffingwell (1919), Brosge et al. (1962), Bowsher and Dutro (1957), Dutro et al. (1962), Armstrong and Mamet (1975), and Robinson et al. (1987).

IMeky **KAYAK SHALE**

Black to dark-gray shales, claystones, and siltstones weathering to red, orange, gold, and yellow with some local pyrite. Very fine- to fine-grained with abundant organic debris and typically bedding is covered with shiny plant fragments. Breaks into thin plates and chips, but becomes more calcareous and competent near the contact with the Lower Alapah. Thin-bedded (2.5 - 7.5 cm), well-foliated chevron- to asymmetrically-folded and highly-faulted with several strong cleavage directions present. Non-resistant and typically forms benches and swails.

IMek **KEKIKTUK CONGLOMERATE**

White quartzite with gray streaks and very fine-grained, light-gray, clean quartz arenites weathering to rusty-reddish-brown due to presence of iron. Bedding 30 - 80 cm with planar beds and massively outcropping. Local small cross-beds. Quartz arenites are interbedded with black siltstones and shales, very fine- grained, planar-laminated, and friable. Several cleavage directions present and slickenslides common.

IMe **ENDICOTT UNDIFFERENTIATED**

Unit mapped where the Kayak Shale and the Kekiktuk Conglomerate formations are too thin to be represented separately at this map scale or have totally different character due to extreme deformation.

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 and disconformably underlies rocks of the Endicott Group. The formation is divided into six members. The unit ranges in age from mid–Upper Cambrian through Devonian in age (Blodgett et al., 1986). Stratigraphic nomenclature is based on Dutro (1970) and Robinson et al. (1987).

lPznl **Upper Limestone**

Medium dark-gray to gray and buff, fine- to medium-grained, thin- to thick- bedded and massive, pelletoidal, limy mudstone. Minor amount of fossil debris present, including, inarticulate brachiopods and trilobites. Unit 8 of Dutro (1970).

lPznld **Upper Limestone and Dolomite**

Light- to medium-gray, fine- to medium-grained, thick-bedded to massive, limy mudstone above a medium gray, medium-grained, massive, vuggy dolomite that forms cliffs. Unit 7 and 6 of Dutro (1970).

lPznv **Vuggy Dolomite**

Medium-gray to buff and tan dolomite weathering to medium gray. Fine- to medium-grained, thick-bedded (1 m, with algal laminations)to massive, siliceous dolomite that contains abundant quartz-filled vugs and secondary open- space filling type quartz veinlets. Resistant unit forming cliffs. The base of the unit contains a dark-gray to black, thin bedded, limestone that conformably underlies the vuggy dolomite. Unit 5 and 4 of Dutro (1970).

lPznw **White Dolomite**

White to very light-gray dolomite weathering to gray. Fine-grained, algal-laminated dolomite that occurs in massive layers to 10 m thick. Locally fractured with closely spaced jointing and consistent parting. A resistant cliff former which forms a distinctive horizon above the massive gray limestone. Unit 3 of Dutro (1970).

lPzng **Gray Limestone**

Medium-gray limestone weathering to a light-gray and brown, fine-grained, well-defined bedding (1 - 5 cm in 20 - 30 cm packages) to massive (ranging up to 2 m thick). Veining prevolent and filled with spary calcite. Weathering to angular, flat, irregular shards. Unit 2 of Dutro (1970).

lPznt **Limestone Turbidites**

Medium-gray and light-brown limestone and dolomite weathering to a medium-gray to orange-yellow, fine-grained and crystalline, thin-bedded (1 cm - 10 cm), thin-laminated, limestone turbidites. Interbedded 5mm - 1 cm laminated brown shale with organic limestone laminations. Locally faulted and fractured. Unit 1 of Dutro (1970).

KATAKTURUK DOLOMITE

The Katakturuk Dolomite unconformably underlies rocks of the Nanook Limestone and Endicott Group. The Katakturtuk Dolomite is considered to be older than mid-Upper Cambrian and probably is Proterozoic in age (Robinson et al., 1987). It has been divided into 11 members in this study area. Stratigraphic nomenclature and age determinations are based on Dutro (1972), Robinson et al. (1987), and Blodgett et al. (1986).

pCkp **Pink Dolomite**

Medium-gray, pink, and buff dolomite weathering to a distinctive pinkish-gray color and alternating with gray beds averaging 5 m thick. Medium- to coarse- grained, cross-bedded to massive grainstone with ooids and algal-mat debris.

pCkuc **Upper Craggy Dolomite**

Medium dark-gray to gray, fine- to coarse-grained, thick-bedded, coarsely cross-bedded dolomite weathering to a light gray. Ooids and algal-mat rip- up clasts, parallel to bedding, are common. Minor columnar stromatolites present. Resistant ridge former.

pCka **Algal Dolomite**

Dark-gray to gray dolomite weathering to shades of light gray and dark brownish-gray. Thin-bedded, thin-laminated horizons containing algal mats and stromatolites. Speleothems with isopachous rims are common, which are either calcite–filled or void. Unit is locally recessive.

pCklc **Lower Craggy Dolomite**

Medium- to dark-gray dolomite weathering to dark-gray and black. Fine- to medium-grained, sugary, crystalline appearance on fresh surface. Thick- to massive-bedded, with coarse, cross- and parallel-bedded rip– up clasts of algal debris and ooids, columnar and digitate stromatolites, and carbonate mud cracks. Forms prominent ledges due to its resistant nature.

pCkw **White Marker**

Upper portion contains interbedded, light-brown to brown, fine- to medium- grained, thin- to medium-bedded, sandy dolomite; and dark-gray to black, thin-laminated, recessive weathering, dolomite. Polygonal mudcracks, small collapse breccias and speleothem infillings common. An irregular shear fabric is present with high-angle fractures. Lower portion comprised of light gray dolomite weathering to yellowish-tan and very light-gray. Abundant cryptalgal-laminated dolomitic mudstone with stromatolites ranging from columnar to hemispheroid to elongated. Unit is resistant.

pCkso **Silicified Oolite**

Light- to dark-gray dolomite weathering to light-gray. Fine- to very coarse- grained, thin-laminated to cross- bedded, massive, thick, and resistant oolitic dolomite interbedded with light- gray, thin-bedded, silicified oolitic and stromatolitic dolomite. Zone of stromatolites at 30 m below the top of the unit with columnar and "rabbit-ear" forms and massive festoon cross-beds. Abundant silicified ooids and algal debris present. Top of the unit contains a layer of thick pisolitic dolomite, while the base of the unit is marked by a thin- to thick-bedded, thin-laminated, medium-gray dolomite weathering to brownish-gray, containing black chert spheroids up to 2 cm in diameter in lenticular channels. Unit is recessive.

pCkc **Cobweb Dolomite**

Gray- to medium dark-gray dolomite weathering to light-gray and orange. Fine- to medium-grained, thin-bedded to massive, with planar, algal-laminations (1 mm to 10 cm) to flat pebble conglomeratic dolomite. Dolomite conglomerate consists of debris flow with clasts possibly derived from underlying pCv. Local brecciation is either depositional or structural with minor faulting and folding at wavelengths of approximately 4 m. A dense network of white and tan-weathering quartz and calcite veinlets is common. Unit is resistant and forms cliffs that appear banded. The top of the unit contains a medium-gray dolomitic mudstone weathering to an orangish-tan to red which is thin-bedded (1 to 10 cm), and has a well-developed cleavage. Interbedded with the siltstone is a black to dark-gray fissile shale weathering to gray and tan. This upper section is chevron folded and highly fractured in Nanook Creek and is recessive on slopes.

pCkv **Variegated Dolomite**

Light-gray silty dolomite and silty limestone weathering to orange, fine- to medium-grained, 10 - 15 cm thicks interbedded with a brown to black, thin-bedded, thin-laminated, calcareous shale in packages 10 cm thick. Dolomite layers contain planar laminations and some minor chert layers near the top. Thicker beds of dolomite contain a network of white quartz veinlets.

pCkz **Zebra Dolomite**

Brown- to brownish-gray weathering to white and orange, fine-grained, thin- to medium-bedded (.2 - .5 m), thin-laminated, containing irregular, silicified vugs and solution cavities in a grid-like pattern along with chert bands. Quartz veins run perpendicular to laminae and are mm thick and occur every 2 - 3 cm giving the weathered surface a striped appearance. Unit is locally brecciated, faulted, and highly fractured. Unit is resistant.

pCks **Spire Dolomite**

Medium light-gray to gray, thick-bedded to massive, cross-bedded, pisolitic to faintly laminated dolomite containing a fine network of thin quartz veinlets. Weathers oomoldic and contains large dolomite crystals. Unit is resistant.

pCku **UNDIFFERENTIATED**

Undifferentiated units of the Katakturuk Dolomite and areas where high degrees of deformation have altered the lithology.

pCkgn **MAFIC VOLCANICS**

Dark green, maroon, and black mafic volcanics weathering to orange, brown, and dark green. Highly altered and weathered to smooth or blocky surfaces. Fine- to coarse-grained with a microlitic groundmass (.5 - 1 mm), granular, and plagioclase microlites present. A variety of textures is present from aphanitic to porphyritic. Typically amygdaloidal with vesicles ranging in size from 2 mm - 2 cm and in shape from round to oblate to irregular. Locally show a crude preferred orientation aligned with the local flow direction. Vesicles filled with calcite, chlorite, epidote, or red, green, or white silica. Veins (1 mm - 7 cm wide) form a random network and are comprised of calcite or epidote. Massive volcanics contain rounded xenoliths up to 10 cm. Locally brecciated in rounded to tabular blocks (10 - 20 cm) and floating in an irregular and altered matrix. Occurs in massive to well- layered sequences defined by amygdule size and percentage and groundmass grain size. Slickenslides, jointing, and a random shear and fracture pattern are present. Pillow structures vary in size from 2 cm - 1 m. Pahoehoe structures exist in 1 - 10 m cycles for over 100 m. The top surface is fan-shaped with concentric wrinkles exhibiting no apparent flow direction. The top is oxidized, glassy, and red underlain by a layer of spherical amygdules (.1 - 1 cm in diameter), followed by an amygdule- free layer and terminated by a basal layer of (4 - 8 cm long) escape vesicles pointing toward the top of the flow and filled with calcite and silica. At the top of the volcanic sequence a (6 m) clastic layer is present composed of maroon, green, and white interbedded calcareous sandstones, siltstones, shales, quartzites, and slates. Some sandstones show a significant volcanic component and are believed to be locally-derived. Bed parallel mylonitic banding is present, and faulting, small scale folding, and a strong cleavage is present. Some locally-derived, graded layers are present that are cyclical, sedimentary breccias up to 10 cm thick with (.5 - 3 cm) angular volcanic and sedimentary clasts.

REFERENCES CITED

Armstrong, A.K., and Mamet, B.L., 1975, Carboniferous biostratigraphy, northeastern Brooks Range, Arctic Alaska: U.S. Geological Survey Prof. Paper 884, 29p.

Armstrong, A.K., Mamet, B.L., and Dutro, J.T., 1970, Foraminiferal zonation and carbonate facies of Carboniferous (Mississippian and Pennsylvanian) Lisburne Group, central and eastern Brooks Range, Arctic Alaska: Am. Assoc. Petrol. Geol. Bull., v. 54, p. 687–698.

Blodgett, R.B., Clough, J.G., Dutro, J.T., Ormiston, A.R., Palmer, A.R., and Taylor, M.E., 1986, Age revisions of the Nanook Limestone and Katakturuk Dolomite, northeastern Brooks Range, Alaska: in Bartsch–Winkler, S., and Reed, K.M., eds., Geologic studies in Alaska by the U.S. Geological Survey during 1985: U.S. Geological Survey Circular 978, p. 5–10.

Bowsher, A.L., and Dutro, J.T., 1957, The Paleozoic section in the Shainin Lake area, central Brooks Range, northern Alaska: U.S. Geological Survey Prof. Paper 303–A, 39p..

Brosge, W.P., Dutro, J.T., Mangus, M.D., and Reiser, H.N., 1962, Paleozoic sequence in eastern Brooks Range, Alaska: Am. Assoc. Petrol. Geol. Bull., v. 46, n. 12, p. 2174–2198.

Detterman, R.L., Reiser, H.N., Brosge, W.P., and Dutro, J.T., 1975, Post–Carboniferous stratigraphy of northeastern Alaska: U.S. Geological Survey Prof. Paper 886, 46p.

Dutro, J.T., 1970, Pre–Carboniferous carbonate rocks, northeastern Brooks Range: in Adkison, W.L., and Brosge, M.M., eds., Proceedings of the Geological Seminar on the North Slope of Alaska: Am. Assoc. Petrol. Geol. Pacific Section Meeting, Los Angeles, p. M1–M8.

Imm, T.A., 1986, Preliminary detailed stratigraphic sections and bedrock maps of the Lisburne Group, Mt. Michelson C–3, and C–4 quadrangles, western Sadlerochit Mountains and northwestern Shublik Mountains, Northeastern Alaska: ADGGS Public–Data File 86–86e.

Keller, A.S., Morris, R.H., and Detterman, R.L., 1961, Geology of the Shaviovik and Sagavanirktok Rivers region, Alaska: U.S. Geological Survey Prof. Paper 303–D, p. 169–222.

Leffingwell, E. de K., 1919, The Canning River Region, northern Alaska: U.S. Geological Survey Prof. Paper 109, 251p.

Molenaar, C.M., Bird, K.J., and Kirk, A.R., 1987, Cretaceous and Tertiary stratigraphy of northeastern Alaska: in Tailleur, I.L., and Weimer, P. eds., Alaskan North Slope Geology: Pacific Section, SEPM V. 1, p. 513–528.

Reiser, H.N., Brosge, W.P., Dutro, J.T., and Detterman, R.K., 1971, Preliminary geologic map of the Mt. Michelson Quadrangle, Alaska: U.S. Geological Survey Open–File Report 71–237, scale 1:200,00.

Reiser, H.N., Dutro, J.T., Brosge, W.P., Armstrong, A.K., and Detterman, R.L., 1970, Progress map, geology of the Sadlerochit and Shublik Mountains, Mt. Michelson C–1, C–2, C–3, and C–4 quadrangles, Alaska: U.S. Geological Survey Open–File Report 70–273, scale 1:63,360.

Robinson, M.S., Decker, J., Clough, J.G., Reifenstuhl, R.R., Bakke, A., Smith, T.E., Pessel, G.H., Imm, T.A., Meigs, A.J., and O'Sullivan, P., 1987, Bedrock geology of the Mt. Michelson C–4 quadrangle, Arctic National Wildlife Refuge, Northeastern Alaska: ADGGS Public–Data File 87–27a.

Sable, E.G., 1977, Geology of the western Romanzof Mountains, Brooks Range, Alaska: U.S. Geological Survey Prof. Paper 897, 84p.

Schrader, F.C., 1904, Geological studies of the Rocky Mountains in northern Alaska: Geol. Soc. Am. Bull., v. 13, p. 238–252.