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# PRELIMINARY GEOLOGIC MAP OF FRANKLIN MOUNTAINS BETWEEN FORKS OF THE CANNING RIVER, ARCTIC NATIONAL WILDLIFE REFUGE, NORTHEASTERN BROOKS RANGE, ALASKA

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This report contains preliminary information on the bedrock geology and structure of the Franklin Mountains between the forks of the Canning River within the Arctic National Wildlife Refuge. All data were collected during the 1987 field season while participating in the Brooks Range Research Program being conducted by the Department of Geology and Geophysics, University of Alaska-Fairbanks. This report consists of a preliminary geologic map and three accompanying schematic cross-sections of the Franklin Mountains.

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# INTRODUCTION

## Regional Perspective

The regional structure of the northeastern Brooks Range is dominated by several major east-trending anticlinoria. The study area is located on the north flank of one such anticlinorium. Fault-bounded structural-stratigraphic packages of poly-deformed and weakly metamorphosed pre-Mississippian shales, volcanic rocks, and cherts core this anticlinorium. A major angular unconformity places Mississippian and younger rocks of the Ellesmerian sequence in apparent depositional contact with the underlying pre-Mississippian rocks of the structural basement. The basement anticlinorium, as well as folds and faults in Ellesmerian sequence rocks, are a consequence of crustal shortening during Late Mesozoic - Cenozoic (Brookian) deformation of the northeastern Brooks Range.

## Objectives

Field-oriented structural analysis in the Canning River-Marsh Fork region of the Franklin Mountains of the Arctic National Wildlife Refuge (ANWR) emphasized the characterization of deformational history and structural style of both pre-Mississippian and Ellesmerian sequence rocks with particular focus on (1) the response of a well-defined structural stratigraphy to deformational events, (2) the mode of basement involvement and nature of structural-stratigraphic control of cover rock deformation, and (3) basement - cover relationships.

# PRELIMINARY FINDINGS

## Deformational History

(A) Pre-Mississippian deformation (D1) is expressed by overturned, tight to isoclinal folds with a pervasive, E-W-trending, nearly bed-parallel slaty cleavage with moderate to steep south dips.

(B) Late Mesozoic - Cenozoic deformation (D2) of the Ellesmerian sequence is characterized by ENE-trending disharmonic folds and local thrust and normal faults. Those faults which sole within the Ellesmerian sequence probably are the product of space problems in short wavelength folds.

(C) D2 structures in pre-Mississippian rocks include both S- and N-dipping thrust faults and an ENE-trending crenulation cleavage with moderately N-dipping axial surfaces.

(D) D3 produced a subvertical, N-trending spaced cleavage in both pre-Mississippian and Ellesmerian rocks.

Structural Stratigraphy of the Ellesmerian Sequence

Structural style in the Ellesmerian sequence is stratigraphically influenced (from bottom to top): (1) mylonitic fabric, tectonic brecciation, imbrication, and extension fractures normal to bedding within the thin Kekiktuk Conglomerate suggest that deformation was distributed across, rather than at, the unconformity surface; (2) intensely flow-folded Kayak Shale, with a minimum of 25-30% internal shortening, served as a major detachment horizon; (3) competent Lisburne Group limestone determined the wavelength of D2 similar folds as reflected in overlying Sadlerochit Group clastic rocks.

Pre-Mississippian Basement Involvement in Brookian Deformation

Recent models and retrodeformable cross sections of the northeastern Brooks Range invoke a north-vergent hinterland-dipping duplex thrust system which served to uplift the characteristic anticlinoria as fault-bend folds (Namson and Wallace, 1986) and produce the shortening observed in Ellesmerian cover rocks (Leiggi, 1987; Kelley and Foland, 1987; Namson and Wallace, 1986; Kelley and Molenaar, 1985; Leiggi and Russell, 1985; Rattey, 1985). Versions of this duplex model place a floor thrust in pre-Mississippian rocks at depth and a roof thrust variably (1) in the Mississippian Kayak Shale (Namson and Wallace, 1986; Rattey, 1985),

(2) stepping down from the Kayak Shale to the base of the Mississippian Kekiktuk Conglomerate (Rattey, 1985), (3) locally at the Mississippian unconformity (Leiggi, 1987; Kelley and Molenaar, 1985), (4) in structurally uppermost pre-Mississippian rocks (Leiggi, 1987), or (5) a subsidiary duplex with a roof thrust in the Kayak Shale and a floor thrust along the unconformity surface beneath the Kekiktuk Conglomerate (Lallemant et al, 1987, Oldow et al, 1987, 1986).

The following observations were made concerning the style of pre-Mississippian basement involvement in Late Mesozoic - Cenozoic deformation of the cover rocks:

(A) Mapping at a scale of 1:25,000 defined an antiformal axis within pre-Mississippian rocks. These rocks have been thrust northward over a small anticline containing the Kekiktuk Conglomerate which appears to depositionally overlie a package of pre-Mississippian rocks (illustrated in cross sections B - B' and C - C'). Best seen in the pre-Mississippian shale unit (pMsh), the antiformal axis could be interpreted to be a fault-bend fold of a south-dipping horse in a duplex. Fold limb attitudes and fold plunges for the overthrust antiform and the underlying Kekiktuk anticline differ significantly, perhaps suggesting that both antiforms were not formed synchronously.

Note that the north-dipping thrust which emplaces pre-Mississippian rocks over the lower Kekiktuk Conglomerate-capped anticline is interpreted in cross sections B - B' and C - C' to be north-directed. Alternatively, it is possible to model a south-directed thrust which climbs through the structurally highest pre-Mississippian rocks, probably merging into the proposed roof thrust described below.

(B) The thin sheet of Kekiktuk Conglomerate capping the upper antiform appears to be in depositional contact with pre-Mississippian rocks comprising the thrust package referred to in (A). To the SW, it is possible that the Kekiktuk Conglomerate and the pre-Mississippian chloritic phyllite unit (pMc) are in fault contact with underlying pre-Mississippian rocks. The unconformity surface does not appear to have served as a shear zone. For the duplex horse proposed in (A), these observations would suggest a roof thrust lying above the Kekiktuk Conglomerate or locally within a pre-Mississippian phyllite immediately beneath the unconformity surface.

(C) The Kayak Shale which overlies the Kekiktuk Conglomerate of (B) shows extensive flow folding and substantial internal shortening. Disharmonic variable-wavelength folding of the Mississippian - Pennsylvanian Lisburne Group limestones above the broadly folded Kekiktuk Conglomerate suggests that the intervening Kayak Shale served as a detachment horizon and potential roof thrust zone for effecting shortening of the overlying Ellesmerian sequence. An example of a structure formed by detachment folding of cover rocks above the Kayak Shale is the prominent overturned anticline of cross section A - A' which is cored by short wavelength disharmonic folds in the lower Alapah Limestone.

(D) Thrust faults soled in the Kayak Shale displace folded Ellesmerian sequence rocks (cross sections A - A', B - B", and C - C'), pressumably relieving space constraints imposed by folds generated in (C).

## Equating Crustal Shortening and Strain Across a Major Unconformity

Poly-deformed and weakly metamorphosed pre-Mississippian basement rocks are more highly strained than Ellesmerian cover rocks, a result of Brookian structures being superimposed on existing pre-Mississippian penetrative structures. Study of the pre-Mississippian rocks focused on distinguishing between structures of pre-Mississippian age and those resulting from involvement of the basement in Late Mesozoic - Cenozoic deformation of cover rocks. D1 slaty cleavage is not seen in the Ellesmerian sequence and is interpreted to be a product of pre-Mississippian deformation. D2 and D3 structures are common to both basement and cover and, as such, are inferred to be signatures of Brookian deformation. Thus, structural analysis should enable comparison of Brookian strain states across the Mississippian angular unconformity.

Recent structural analysis in the Franklin Mountain region led Oldow et al (1987) to conclude that the amount of Brookian shortening seen in pre-Mississippian rocks and in the Mississippian Kayak Shale and younger rocks did not appear to be obvious in the Kekiktuk

Conglomerate. Oldow et al (1987) and Lallemant et al (1987) suggest that the apparent difference in crustal shortening between the Kekiktuk Conglomerate and underlying pre-Mississippian rocks can be accounted for if there are zones of decoupling both above and below the Kekiktuk Conglomerate. On the basis of their observations, Oldow et al (1987) and Lallemant et al (1987) propose that imbrication and shortening of the Kekiktuk Conglomerate between a floor thrust along the unconformity and a roof thrust in the Kayak Shale have resulted in Brookian shortening comparable to that seen in under- and overlying rocks.

In the Canning River - Marsh Fork region of the Franklin Mountains, field observations relating to the accommodation of Brookian shortening by the Kekiktuk Conglomerate suggest that

(A) In most instances, the Kekiktuk Conglomerate overlying the unconformity surface does not appear to have undergone significant penetrative deformation. Pebble- and cobble-conglomerate horizons show no obvious, consistent pattern of tectonic flattening or preferred orientation of clasts. Thin section study and the application of center-to-center techniques of strain measurement to quartz grains within oriented samples of the Kekiktuk Conglomerate will supplement mesoscopic observations.

(B) Pre-Mississippian rocks underlying the Kekiktuk Conglomerate display the characteristic D1 slaty cleavage and do not appear to have undergone substantial shear along a D2 decoupling horizon coinciding with the unconformity surface. However, invoking a model of south-directed thrusting along the north-dipping thrust fault in the pre-Mississippian chloritic phyllite unit (pMc) shown in cross sections B - B' and C - C' could support the existence of at least a local decoupling horizon within structurally highest pre-Mississippian rocks.

(C) Locally, always where pre-Mississippian rocks overlie the Kekiktuk Conglomerate in thrust contact with it, there is significant tectonic brecciation and imbrication of the Kekiktuk Conglomerate. Angular clasts of pre-Mississippian rock are included in the tectonic breccia and it is pervasively cut by quartz-filled extension fractures which show chocolate tablet structure. Imbricates of the Kekiktuk Conglomerate are discontinuous pods up to several meters thick, bound by carbonaceous black shale which may be either the Kayak Shale or a pre-Mississippian shale.

(D) NNW- to NNE-trending quartz-filled extension fractures oriented perpendicular to bedding are common in the Kekiktuk Conglomerate, compatible with roughly E-W maximum longitudinal strain related to D2. Localized normal faulting along NW- to NE-trending andS-dipping planes may be related to D3 N-trending spaced cleavage, both types of pressumably late-formed structures being indicative of N-S maximum longitudinal strain.

## CONCLUSION

Field-oriented structural analysis identified three deformational events, D1 seen only in pre-Mississippian rocks, and D2 and D3 observed in both pre-Mississippian and Mississippian and younger rocks. D2 corresponds to the main phase of Late Mesozoic - Cenozoic Brookian deformation. The structural style of D2 folds and faults within the Ellesmerian sequence is stratigraphically influenced.

Preliminary interpretations suggest a northward-propagating basement duplex model similar to that proposed by Namson and Wallace (1986) for the involvement of pre-Mississippian rocks in Late Mesozoic-Cenozoic (Brookian) deformation in which (1) the antiformal axis identified in cross sections B - B' and C - C' is interpreted to be a fault-bend fold of a south-dipping duplex horse; (2) the main roof thrust of the duplex thrust system lies within the Mississippian Kayak Shale; (3) a local zone of decoupling may exist within structurally uppermost pre-Mississippian rocks, helping to explain the apparent lack of obvious penetrative strain within the Kekiktuk Conglomerate; and (4) disharmonic folding and local thrust faulting within the Ellesmerian sequence overlying the Kayak Shale detachment horizon.

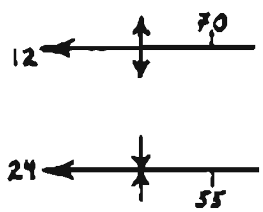
<u>GEOLOGIC MAP SYMBOLS</u>


Strike and dip of beds

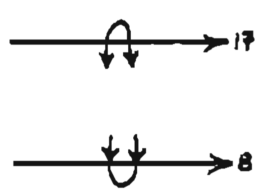

Strike and dip of bedding; uncertain

Strike of vertical bedding


Strike and dip of foliation



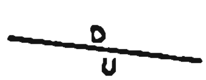

Anticline (top) and syncline, showing trace and dip of axial surface and plunge of axis; dashed where approximately located




Overturned anticline (top) and overturned syncline, showing trace of axial surface and plunge of axis; dashed where approximately located

Contact; solid where known, dashed where approximately located, dotted where inferred

Thrust fault; solid where known, dashed where approximately located, dotted where inferred, sawteeth on upper plate (Note: Also used to delineate a map unit which acts as a detachment horizon or is extensively brecciated)




Fault (D, downthrown side; U, upthrown side)

## DESCRIPTION OF MAP UNITS

### Sadlerochit Group

Stratigraphic nomenclature and age determinations for the Sadlerochit Group are based on Keller et al. 1961, and Detterman et al. 1975. Map units of the Ivishak Formation are similar to those of Reed, 1968.

lTriu Lower Triassic upper Ivishak Formation (Sandstone-Siltstone Unit)

Medium- to fine-grained, thin-bedded and tabular, sometimes convolute-bedded, light to medium dark gray, olive gray to rusty weathering, pyritic quartz sandstone. Fine-grained, dark gray, gray to olive brown weathering, laminated and cross-bedded in tabular sets 0.5-1.0 meters thick, quartz sandstone and dark gray siltstone with thinly interbedded dark gray shale. Orange-brown weathering secondary cleavage surfaces are common. Outcrops as low resistant ridges and forms small rectangular blocks. Medium-grained, medium-bedded, dark gray, brown to dark gray weathering, quartz sandstone. Thin, discontinuous quartz veins commonly intersect bedding. Cream-colored calcite stains on secondary cleavage surfaces are characteristic. Fine- to medium-grained, laminated to thick-bedded with normal graded interbeds of dark gray siltstone and shale, tabular, light brown to medium gray, gray to olive brown weathering, resistant, mature quartz sandstone.

lTril Lower Triassic lower Ivishak Formation (Shale Unit)

Fine-grained, dark gray to black, buff weathering, shale and silty shale, flaky, well-developed slaty cleavage, poorly exposed.

Pe Permian Echooka Formation

Medium-grained, gray, rusty to cream weathering, massive, calcarenite with thin, discontinuous secondary quartz veins and medium-grained, dark gray to black, tan to red weathering with limonite stains, medium-bedded to massive, cherty quartz arenite interbedded with dark gray to black, rusty weathering shale. Locally, thin intervals of coarse-grained, buff to orange weathering fossiliferous calcarenite or calcareous white and dark gray chert pebble conglomerate occur near the base of the sequence. Thin basal gray calcarenite or calcareous shale is in disconformable contact with the underlying Wahoo Limestone.

## Lisburne Group

Stratigraphic nomenclature and age determinations for the Lisburne Group are based on Brosge et al, 1962, Armstrong et al, 1970, and Sable, 1977.

Pw Pennsylvanian Wahoo Limestone

Fine- to medium-grained, medium to dark gray, light gray to buff weathering, thin- to massive-bedded, interbedded lime mud and bioclastic grainstone. Irregular-shaped nodules and discontinuous lenses of dark gray to black chert are common; abundantly fossiliferous with fauna including crinoids, bryozoans, and brachiopods. Outcrops as a resistant, cliff-forming unit.

Mau Mississippian upper Alapah Limestone

Fine-grained, light to medium gray, buff to light gray weathering, thin- to medium-bedded, limestone; forms distinctive talus aprons beneath the Wahoo Limestone.

Mal Mississippian lower Alapah Limestone

Fine- to medium-grained, light to medium gray, gray to tan weathering, thin- to massive-bedded, limestone; outcrops as cliff-former below the Upper Alapah Limestone.

## Endicott Group

Stratigraphic nomenclature and age determinations for the Endicott Group are based on Brosge et al. 1962, Dutro et al. 1972, and Armstrong and Mamet, 1975.

### Mississippian Kavak Shale and Kekiktuk Conglomerate

Mky Mississippian Kavak Shale

Black, orange weathering, laminated to thin-bedded, fissile, carbonaceous shale; thin- to medium-interbeds of argillaceous limestone near the contact with the overlying lower Alapah Limestone; prevalent thin, secondary quartz veining parallel to and cross-cutting bedding near the contact with the underlying Kekiktuk Conglomerate; poorly exposed, typically tundra-covered.

Mkt Mississippian Kekiktuk Conglomerate

Medium-grained, light to medium gray quartzite with basal 0.2-0.4 meter thick interbeds of gray and white chert pebble- and cobble-conglomerate with secondary quartz veins perpendicular to bedding. Where in fault contact with pre-Mississippian rocks, the Kekiktuk Conglomerate frequently forms discontinuous, 0.25-2.5 meter thick lens-shaped imbricates bound by dark gray to black shale.

### Pre-Mississippian Rocks

Depositional relationships within and between pre-Mississippian map units are difficult to infer due to deformational overprints such as isoclinal folding and thrust faulting. Map units are grouped into three fault-bounded structural-stratigraphic packages.

pM Pre-Mississippian Undifferentiated

Pre-Mississippian rocks, unexposed or outside limits of study area

Pre-Mississippian Upper Structural-Stratigraphic Package

pMb Pre-Mississippian Brecciated Unit

Tan-greenish phyllite, tectonically brecciated, commonly with thin- to medium-interbedded dark gray chert (sometimes faulted on a small-scale) and discontinuous lenses of more massive dark gray chert with quartz-filled extension fractures; confined to footwall where the phyllitic unit is thrust over the chloritic phyllite unit or the Kekiktuk Conglomerate.

pMv Pre-Mississippian Volcanic Unit

Fissile, carbonaceous black shale interbedded with tectonically (?) brecciated limestone outcropping as tan weathering, resistant towers, orange weathering dolostone, basalt and greywacke (sometimes with flute casts); orange weathering, vesicular basalt with pillow structures and mafic volcanic breccia; greenish-brown weathering massive volcanic breccia and brown weathering greenstone.

pMc Pre-Mississippian Chloritic Phyllite Unit

Tan to greenish-tan, chloritic phyllite with quartz stringers and stretched pebbles along the primary foliation; sometimes appears to be mylonitic, frequently found in contact with the Kekiktuk Conglomerate; lenses of dark gray metaquartzite and metaconglomerate with quartz-filled extension fractures normal to foliation.

Pre-Mississippian Middle Structural-Stratigraphic Package

pMcg Pre-Mississippian Chert-Greenstone Unit

Discontinuous lenses of massive dark gray chert, commonly cross-cut by prominent quartz-filled extension fractures, and tan-orange weathering massive greenstone with intercalated black shale; resistant unit upholding the higher, precipitous peaks.

pMsh Pre-Mississippian Shale Unit

Gray to black shale and gray phyllite, with interbedded orange weathering dolostone, fine-grained olive-brown weathering sandstone, orange to tan weathering greenstone, and thin- to medium-bedded dark gray chert. Interbeds are less than 25 meters thick and vary in degree of continuity along strike.

dss Dolostone/Sandstone

gs Greenstone

ch Chert

pMp Pre-Mississippian Phyllite Unit

Purple, green, and gray phyllite with minor interbedded dark gray chert, fissile, foliation surfaces sometimes spotted with magnetite grains. Repetition of this unit within the field area is interpreted to be due to faulting.

Pre-Mississippian Lower Structural-Stratigraphic Package

pMsv Pre-Mississippian Slate-Volcanic Unit

Tan weathering volcanic rocks, some being andesitic; red slate with interbedded, gray weathering, massive white to red chert.

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