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GEOLOGIC MAP, CROSS SECTION, AND STRUCTURAL GEOLOGY OF AN AREA SOUTHWEST OF BATHTUB RIDGE, NORTHEASTERN BROOKS RANGE, ALASKA

by

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ABSTRACT

The hindward- and south-dipping Drain Creek duplex is exposed southwest of Bathtub Ridge in the northeastern Brooks Range. East-plunging structures in the study area expose the two lowest and farthest forward horses in the duplex. The 2 km-long horses are defined by north-vergent hangingwall anticlines and footwall synclines separated by south-over-north thrust faults. The folds are formed in competent carbonates of the Carboniferous Lisburne Group above a detachment in the structurally incompetent Mississippian Kayak Shale. The Kayak Shale is significantly thickened in anticlines, suggesting the folds are detachment folds. Thrust faults cut up from a flat either in or below the Kayak Shale, through the Lisburne Group and shales and sandstones of the Permian-Triassic Sadlerochit Group, and into a roof thrust in the Jurassic-Lower Cretaceous Kingak Shale. A smaller, secondary duplex is formed between a detachment within the Sadlerochit Group (in the Echooka Formation), and the roof thrust in the Kingak Shale. Both duplexes display a progressive northward transition from strongly asymmetric thrust-truncated folds in the duplex, to more open and upright, unfaulted folds north of the duplex. This transition in space suggests that as shortening increased, detachment folds formed, increased in asymmetry, and eventually broke through to form thrust faults.

Beneath the Kayak Shale, the Mississippian Kekiktuk Conglomerate unconformably overlies previously deformed pre-Mississippian rocks. The form-surface defined by the Kekiktuk Conglomerate and the unconformity displays broad, thrust-truncated anticlines that correspond roughly with anticlines above the Kayak Shale. This relationship, and the occurrence of both the Kekiktuk Conglomerate and pre-Mississippian rocks as a thrust slice structurally above the Kayak Shale, suggest the possibility that pre-Mississippian rocks are involved in the Drain Creek duplex. However, a direct connection between thrust faults above and below the Kayak Shale has yet to be demonstrated. If pre-Mississippian rocks are involved, then the floor thrust of the Drain Creek duplex is in pre-Mississippian rocks rather than in the Kayak Shale, as has been interpreted previously.

INTRODUCTION

Purpose, Methods, and Previous Work:

This report briefly discusses the geometry and the development of the structures in an area south and west of Bathtub Ridge (Fig. 1). The purpose of this report is fourfold: (1) to describe the lithologies in the area in the context of their structural significance; (2) to describe the geometry of structures south and west of Bathtub Ridge; (3) to suggest a kinematic model for the development of these structures; and (4) to point out the regional tectonic significance of the development of these structures.

The methods used in this study include geologic field mapping (1:25,000 scale; conducted over a period of 7 weeks during the summer of 1990), analysis of aerial photographs, and computer-aided cross section balancing.

The Bathtub Ridge area was originally mapped in reconnaissance by Reiser and others (1980), and part of the area was mapped in greater detail by Camber and Mull (1986). The Drain Creek duplex was recognized by Wallace and others (1988). Anderson (1991) is currently conducting stratigraphic and structural studies in the area directly south and west of this study area.

Geologic Setting:

The study area covers approximately 30 square miles immediately south and west of Bathtub Ridge (Fig. 1). The ridge is a local topographic high corresponding with Bathtub syncline, a major structural low that lies in parts of the Demarcation Point A-3 and A-4 Quadrangles in the northeastern Brooks Range.

The stratigraphy in the northeastern Brooks Range can be broadly divided into three sequences (Fig. 2)(in ascending order): the pre-Cambrian(?)-Devonian Franklinian sequence, a deformed and weakly metamorphosed heterogeneous assemblage of sedimentary and volcanic rocks; the middle Devonian(?)-Lower Cretaceous Ellesmerian sequence, a series of carbonate and clastic rocks derived from the north; and the Lower Cretaceous-present Brookian sequence, a southerly-derived succession of clastic rocks.

Each of these sequences is represented in the study area in an outcrop pattern which generally exposes progressively younger rocks eastward toward Bathtub Ridge. This pattern is the result of an eastward plunge of structures throughout the area. The Franklinian sequence (here referred to as "pre-Mississippian rocks") has undergone at least two periods of deformation (Wallace and Hanks, 1990) and is separated from the Mississippian Kekiktuk Conglomerate by a regional angular unconformity in the western part of the study area. The Mississippian Kayak Shale is also exposed in the west, along the Aichilik River. The Carboniferous Lisburne Group occurs at the surface north, south, and west of "Bathtub valley", clearly defining the Bathtub syncline. Rocks of the Permian-Triassic Sadlerochit Group are exposed in "Bathtub valley", west of Bathtub Ridge ("Bathtub valley" and Bathtub Ridge are topographic features along the axial trace of Bathtub syncline). Brookian sequence rocks occur only at Bathtub Ridge in the northeast. The stratigraphy of the area is summarized in the Appendix and in Figure 2.

The area can be divided into three general structural domains which roughly correspond with stratigraphic sequences: (1) Bathtub syncline: The Brookian sequence rocks above the Jurassic-Cretaceous Kingak Shale are only broadly folded in the gentle, upright Bathtub syncline; (2) Drain Creek duplex: The stratigraphy from the Kayak Shale up through the Sadlerochit Group is folded and faulted as part of the south-dipping Drain Creek duplex south of "Bathtub valley". The Drain Creek duplex, first described by Wallace and others (1988), structurally repeats this stratigraphy in a series of kilometer-wavelength horses; (3) Regional anticlinorium: The pre-Mississippian rocks and the Kekiktuk Conglomerate are folded into a regional anticlinorium that is exposed in the western part of the study area (Wallace and Hanks, 1990).

STRUCTURAL GEOMETRY

Major Folds (see Fig. 3):

Several major folds are recognized in the study area. All fold axes trend southeast. The Bathtub syncline dominates the northern part of the area and is easily seen on aerial photographs of the area. The part of the Bathtub syncline below the middle part of the Kingak Shale is highly deformed while the section above the lower part of the Kingak Shale is only gently folded.

Angular, parallel folds with wavelengths of approximately one to two kilometers are defined best in the upper Lisburne Group rocks, the dominate structurally competent member in the study area. These folds demonstrate a transition from tight, asymmetric (north-vergent), overturned, thrust-truncated anticlines in the south to open, symmetric, and upright anticlines in the north. There are four major folds observed in the Lisburne Group rocks, three are south of Bathtub syncline (referred to as "the footwall syncline", the "Aichilik forks fold", and "the hangingwall anticline") and one is north of Bathtub syncline.

The southernmost fold in Lisburne Group rocks, "the footwall syncline", is an overturned syncline positioned directly beneath the Pugutak thrust fault. The fold is tight, asymmetric, and steeply overturned. This fold represents a classic example of a footwall syncline and is best exposed in the southernmost east-trending valley and adjacent ridges at the southwest corner of the study area.

The "Aichilik forks fold" is an overturned anticline best observed on the cliff faces east of the Aichilik River. Beds in "the footwall syncline" can be traced into this fold indicating both folds are in the footwall of the Pugutak thrust fault. The overturned limb of the "Aichilik forks fold" defines the southern margin of "Bathtub valley", where it dips beneath Sadlerochit Group rocks. The fold plunges eastward at about 15 degrees and thus, is also manifest up-section in rocks of the Sadlerochit Group, which are truncated by the Pugutak thrust fault. The outcrop pattern of the Sadlerochit Group (which generally corresponds with the tundra-covered regions) in the central part of the study area wraps around the plunging anticline. The Kayak Shale and middle Lisburne carbonates are significantly thickened in the core of this fold. Up-plunge, to the west, of the core of this fold are imbricated antiforms (approximately 50-

100 meters between traces of adjacent imbricate faults) involving pre-Mississippian rocks, Kekiktuk Conglomerate, and the "Endicott siltstone".

The third major fold displayed in the upper Lisburne Group south of Bathtub syncline is an overturned anticline about 5 kilometers southwest of the western peak of Bathtub Ridge in the northeastern part of the study area. The overturned limb of this fold, termed "the hangingwall anticline", is truncated by the Pugutak thrust fault. The overturned limb of this classic hangingwall anticline probably represents the fault-truncated, along-strike equivalent of the overturned limb of "the footwall syncline".

Folds north of Bathtub syncline, in the competent rocks of the upper Lisburne Group also display angular and parallel geometry. In contrast to those south of Bathtub syncline, however, these folds are generally upright, open, symmetric, and are not associated with a thrust fault. Immediately north of Bathtub syncline, south-dipping beds in the upper Lisburne Group roll over northward to form a gentle anticline which defines the north flank of "Bathtub Valley". Erosion has cut only as deep as the middle part of the Lisburne Group in the core of this kilometer-wavelength anticline.

<u>Major Thrust Faults (see Fig. 3)</u>:

Three major south-dipping, south-over-north thrust faults are present in the area. These faults are discussed in order of their structural position, from lowest to highest (and in reverse order of their interpreted development - see Kinematic Model section).

The structurally lowest major thrust fault in the area is, perhaps, the most significant. This fault (the "lower thrust"), exposed well only in the northwest part of the study area, separates Kekiktuk Conglomerate in the hangingwall from overturned Kayak Shale and the Lisburne Group in the footwall. Unfortunately, timing restrictions allowed only distant observation of this structure. The "lower thrust " fault can be traced east only into a high tundra-covered valley in the western part of the area. In this same area imbricated antiforms of pre-Mississippian rocks, Kekiktuk Conglomerate, and "Endicott siltstone" are exposed. These imbrications are in the structural position of the core of the "Aichilik forks fold". These relationships suggests that the imbrications and the "lower thrust" are related to each other or even that the antiformal imbrications are the eastward continuation of the "lower thrust". Since the "Aichilik forks fold" is not truncated by a fault along the Aichilik River and its nearby (2 km to west of the Aichilik River) equivalent is truncated by the "lower thrust", it is likely that the "lower thrust" accommodates progressively less displacement eastward toward the Aichilik River. This fault is interpreted to represent the lowest and farthest forward linking thrust fault in the Drain Creek duplex.

Since the Kekiktuk Conglomerate structurally overlies the Kayak Shale and Lisburne Group in some places, the pre-Mississippian unconformity is either truncated or served as the basal detachment surface for the "lower thrust". The unconformity surface, where observed, does not show evidence of shear or decoupling. This suggests that the pre-Mississippian unconformity *is* truncated by the "lower thrust" and that pre-Mississippian rocks are, at least locally, involved in the formation of the Drain Creek duplex. This suggestion is also supported by the occurrence of Kekiktuk Conglomerate and pre-Mississippian rocks in the fault zone of the Pugutak thrust fault.

The most prominent thrust fault in the study area is the south-southeast dipping Pugutak thrust fault, which strikes northeast and cuts progressively up-section (with respect to both the footwall and the hangingwall) to the northeast. The entire range of stratigraphy from the Kayak Shale up through the "e member" of the Ivishak Formation can be seen occupying hangingwall positions. Likewise, a complete stratigraphic section from the Kayak Shale through the Kingak Shale is exposed in the footwall position at various localities along the strike of the fault. At the apparent southwestern termination of the fault, rocks of the Kayak Shale form both the hangingwall and the footwall. In this area, due to the present topographic geometry, the fault is a thrust zone whose trace is approximately 0.5 kilometers wide. The thrust zone is locally complicated by slices of pre-Mississippian rocks and Kekiktuk Conglomerate. At the northeastern termination of the Pugutak thrust fault (at the south face of Bathtub Ridge), north-dipping rocks of the "e member" of the Ivishak Formation are in the hangingwall and incompetent rocks of the Kingak Shale form the footwall. Approximately 4 kilometers southwest of Bathtub Ridge, the thrust truncates the Sadlerochit Group rocks at the crest of the "Aichilik forks fold", which forms the footwall beneath "the hangingwall anticline" fold. In the central part of the study area there is a complicated geometry associated with both hangingwall and footwall splays of the Pugutak thrust fault. This fault is interpreted as the structurally second lowest and second farthest forward linking fault of the Drain Creek duplex. Rocks between the "lower thrust" and the Pugutak thrust represent the lowest and farthest forward horse of the Drain Creek duplex. Linkage between these faults has not been demonstrated.

In the southeast part of the field area another southeast-dipping thrust fault, the "upper thrust", separates upper and middle Lisburne Group rocks (hangingwall) from Sadlerochit Group rocks (footwall). This, the "upper thrust", is structurally higher than the Pugutak thrust fault and only appears to involve these rocks. However, extrapolation of both structures and stratigraphy to depth (via cross section balancing) probably will suggest a similarity, in terms of overall structural and stratigraphic geometry, between this fault and the Pugutak thrust fault. The "upper thrust" fault is also related to well-defined structures of the upper parts of the Drain Creek duplex southeast of the study area (Wallace and others 1988). Thus, it can be inferred that this is the next (third) highest linking fault in the Drain Creek duplex.

"Bathtub Valley Duplex":

The Sadlerochit Group rocks in Bathtub syncline are folded and faulted in a manner similar, but with smaller folds and closer fault-spacing, to that described above. Two faults cut up through the entire Sadlerochit Group in Bathtub syncline and flatten in the overlying Kingak Shale. The two faults represent the floor thrust and the single linking fault of this minor (1-2 kilometer-length) duplex. The floor thrust is a flat in the lower Echooka Formation and the roof thrust is in the Kingak Shale (shared with the roof thrust of the Drain Creek duplex). Folds in Sadlerochit Group rocks on the south limb of the syncline are tight, overturned, thrust-truncated, asymmetric, and north-vergent. The folds gradually become more upright, symmetric, and open northward across the hinge zone of Bathtub syncline (see Kinematic Model section). This northward transition is similar to the transition in the geometry of the folds of the Drain Creek duplex displayed in the Lisburne Group rocks.

KINEMATIC MODEL

The structural geometry in the south and central part of the study area approximates well the geometry of a simple hindward-dipping, forward-propagating duplex. This conforms with the "forward-propagating" model of thrust systems (Boyer and Elliot, 1982) that is generally accepted in the literature. The important difference between the Boyer and Elliot (1982) model and the model proposed for the structures in this study area is that here the folds apparently formed before the faults (suggested by the existence of footwall synclines), while in the Boyer and Elliot (1982) model, the faults form first.

The floor thrust of the Drain Creek duplex is not exposed, but either lies at depth in the pre-Mississippian sequence or in the Kayak Shale. The roof thrust, in either case, is a zone of deformed lower Kingak Shale. Rocks above the lower part of the Kingak Shale are only very broadly folded. The linking faults, listed in order from highest to lowest, farthest hindward to farthest forward, from south to north (map view), and in probable order of formation (based on the model of Boyer and Elliot, 1982) are: the "upper thrust", the Pugutak thrust fault, and the "lower thrust".

The folds in the upper Lisburne are classic examples of detachment folds (Jamison, 1987). They are formed in a structurally rigid beam with folding accommodated by thickness changes in the underlying incompetent unit (the Kayak Shale). If they are not constrained by other structures, detachment folds tend to become more asymmetric with increased shortening. Much like a folded carpet, shortening and asymmetry of folds in fold trains increase toward an impinging buttress. Here, the buttress is to the south in the form of an orogenic wedge strengthened by deformation. The most asymmetric folds finally fail by faulting when the rupture strength of the material is met. After the competent Lisburne Group strata responded to this northward displacement by folding as much as possible, the southernmost folds failed and were truncated by thrust faults, while the northernmost folds remained relatively open, upright and symmetric.

This pattern is repeated on a smaller scale within Bathtub syncline, between the lower Echooka Formation and the lower Kingak Shale. These structures probably formed in response to slip on the linking faults of the Drain Creek duplex and/or out-of-syncline faulting in the core of Bathtub syncline.

Summarizing the major events in order of their occurrence:

1) The unnamed thrust cuts up section and flattens in the Kingak Shale.
2) The unnamed thrust becomes locked and detachment folds form in its footwall above the Kayak Shale.

3) The detachment folds in the Lisburne Group increase in asymmetry and are truncated by a fault cutting up section from at least as deep as the Kayak Shale. This is the Pugutak thrust fault.
4) The Pugutak thrust fault flattens up section in the Kingak Shale, thus completely bounding a package of rock with faults and forming the second-most forward horse of the Drain Creek duplex. Thickening in the duplex contributes to the uplift of the south limb of Bathtub syncline (Wallace, 1990).
5) The Pugutak thrust fault becomes locked and the "lower fault" steps up from a flat in the pre-Mississippian rocks or in the Kayak Shale, carrying at least the western part of the Drain Creek duplex in its hangingwall. This contributes to formation of the "Bathtub valley duplex" in the Sadlerochit Group rocks within Bathtub syncline.

REGIONAL IMPLICATIONS

There are two significant implications of this study. The first, and best established, is that the lowest and most forward parts of the Drain Creek duplex in this area involve rocks from at least as deep as the Kayak Shale through the Kingak Shale, which accomodates the roof thrust. Rocks above the Kayak Shale were deformed by detachment folding, then truncated by thrust faults as the Drain Creek duplex evolved.

The second implication is that the pre-Mississippian rocks may be involved in the formation of the Drain Creek duplex. Because the Drain Creek duplex was first recognized in areas geographically removed from pre-Mississippian outcrop, previous work suggests that the floor thrust lies in the Kayak Shale (Wallace, 1990; Wallace and others, 1988). The Kayak Shale accommodates a significant flat which may be the floor thrust of the Drain Creek duplex. If the floor thrust is in the Kayak Shale, it suggests that involvement of pre-Mississippian rocks might only be a local occurrence, resulting from interaction of lower thrust faults with the duplex. In the scenario, the slices of pre-Mississippian rocks in the Pugutak thrust zone may be the result of fault-truncation and transportation of a local paleo-topographic high in the pre-Mississippian sequence.

This study suggests that the floor thrust of the Drain Creek duplex may actually lie at depth in the pre-Mississippian sequence, suggesting contemporaneous deformation in both the pre-Mississippian rocks and the Ellesmerian sequence of the duplex. If this is true, then other structures in Ellesmerian sequence rocks in the northeastern Brooks Range may have formed contemporaneously with structures in the pre-Mississippian rocks. Unfortunately, this study does not conclusively establish the location of the floor thrust (and hence the amount and mode of interaction between Ellesmerian sequence rocks and pre-Mississippian rocks) of the Drain Creek duplex because data from lower levels in the pre-Mississippian rocks were unavailable in the study area.

APPENDIX

LOCAL STRATIGRAPHY- MAP UNIT DESCRIPTIONS

KJk- Jurassic-Lower Cretaceous Kingak Shale:

Black fissile shale with centimeter to 10s of centimeter-thick interbeds of micritic limestone. Camber and Mull (1986) determined the Kingak Shale to be 150 m at Bathtub Ridge. The Kingak Shale occurs in isolated outcrops in

"Bathtub valley" and in continuous outcrop at the base of Bathtub Ridge. Deformation decreases markedly from the base to the top of the unit.

TrPsi - Permian- Triassic Ivishak Formation (probably including equivalents of the Shublik Formation):

TrPsie- Ivishak "e member": White-gray, medium-grained quartz arenite. This unit is approximately 11 meters thick and forms resistant, linear ridges in "Bathtub valley". The unit serves as a structurally competent horizon and deforms by parallel folding and thrust faulting. This unit is probably the same as the "camp sandstone" of Camber and Mull (1986) and therefore is probably a Shublik Formation equivalent. Biostratigraphic work needs to be completed before this can be confirmed.

* a 2.5 meter interval of black/orange shale occurs at this position and serves as a local detachment *

TrPsid- Ivishak "d member": Interbedded cross-laminated siltstone and shale make up this 40 meter-thick unit. The unit deforms primarily by bed-parallel shortening and kink folding in the more fine-grained and laminated horizons and by small-scale thrust duplication in the more coarse-grained and massive horizons. Although correlation is hampered by poor exposure, Camber and Mull (1986) recovered Shublik Formation fossils from what may be the local equivalent of this unit (Mull, pers. comm., 1990). If this is confirmed by biostratigraphic data from this study, the Shublik-Ivishak contact should be drawn within or below the TrPsid unit of this study.

TrPsic- Ivishak "c member": Cross-bedded sandstone and siltstone, upward coarsening and thickening. The unit is approximately 30 meters thick and displays a gradational lower contact and an abrupt upper contact. Ripple marks and laminations occur in the upper, meter-thick beds. The unit acts as a structurally rigid horizon which deforms by angular, parallel folding and thrust faulting.

TrPsib- Ivishak "b member": Interbedded cross-laminated gray siltstone and shale with an approximate thickness of 230 meters. Thickness and stratigraphic position are the most effective means to distinguish this unit from the Ivishak "d member". Kink-style deformation dominates in this unit, which is bounded on both sides by gradational contacts.

TrPsia- Ivishak "a member": This is a black and orange shale, 3-5 meters thick. This unit behaves incompetently between the two adjacent, more competent units.

Pe - Permian Echooka Formation:

The 93 meter-thick Echooka Formation in "Bathtub valley" is divided into an upper and lower member. The resolution on the 1:25,000 scale field map did not allow for contacts to be accurately represented on the map. The upper member consists of 45 meters of massively-bedded orange, white, and black chert, and tan, fossiliferous limestone which act as competent structural beams. The lower member is a 48 meter-thick black and orange shale resting unconformably (?) on the upper Lisburne Limestone. The lower member serves as a detachment horizon.

uPMl - Pennsylvanian -Mississippian upper Lisburne Group:

Massive tan and gray grainstones and wackestones comprise this approximately 360 meter-thick unit. This is the probable equivalent of the Wahoo Formation. The unit behaves as the major structurally competent unit in the study area, deforming primarily by angular, parallel detachment folds. The unit is truncated by several thrust faults (representing kilometer-scale horizontal displacement), and forms prominent hangingwall anticlines and footwall synclines with respect to these faults.

mPMl - Mississippian middle Lisburne Group:

This is a dark gray platy wackestone that is approximately 195 meters thick. The abundance of mud in this unit causes it to behave incompetently. It is thickened in anticlines and thinned in fold limbs. The unit forms dip slopes and outcrop is limited. This is the likely equivalent to the Alapah Formation.

lPMl - Mississippian lower Lisburne Group:

150 meters of interbedded black chert, bioclastic wackestones, and shale make up the lower part of the Lisburne Group. The lower contact with the Mississippian Kayak Shale is ill defined but was placed at the position of the first occurrence of substantial chert beds. The unit displays a wide range of deformation styles due to its vertical and lateral lithologic heterogeneity. Where shale dominates, the unit displays features indicative of structurally incompetent material and where bedded chert dominates, the unit displays brittle deformation features. This may be the equivalent of the Wachsmuth Formation.

Mk - Mississippian Kayak Shale:

The total thickness of the Kayak Shale in this area is currently undetermined. The Kayak Shale is a black and orange shale with at least one 20-25 meter-thick bioclastic limestone bed near the top. This bed gives way to black chert and shale as the Kayak grades into the lower part of the Lisburne Group. The Kayak Shale serves as a major detachment horizon in the area. Shortening is taken up by flowage of material, layer-parallel slip, angular parallel folding (in the competent carbonate horizons), and minor thrust faulting.

Mes - Mississippian "Endicott Siltstone":

This unit of undetermined thickness represents a transition between the Kekiktuk Conglomerate and the Kayak shale. It consists of gray and orange cleaved siltstone and is exposed, only sparsely, west of the Aichilik River in the western part of the study area. This unit is grouped with the Kayak Shale on the cross section.

Mkt - Mississippian Kekiktuk Conglomerate:

Dark gray siltstone and sandstone immediately overlie the sub-Mississippian unconformity at two localities. The Kekiktuk Conglomerate shows channelized chert-pebble conglomerates where it outcrops in the tundra west of the Aichilik River and in steeply dipping beds in the westernmost part of the study area. Discontinuous outcrop prevented an accurate estimate of the thickness of the Kekiktuk Conglomerate. The Kekiktuk Conglomerate is thrust-imbricated and is complexly juxtaposed with the "Endicott siltstone" and the pre-Mississippian rocks west of the Aichilik River. The unit also appears as a thrust-bounded slice along with pre-Mississippian rocks in the Pugutak thrust zone in the southwest part of the study area. The Kekiktuk Conglomerate is also observed to lie structurally above the Kayak Shale and the Lisburne Group in the.northwest corner of the study area. The unit dominantly behaves as a competent horizon.

OCcp - Cambrian-Ordovician (?) chert and phyllite (pre-Mississippian rocks):

An undetermined thickness of orange and white bedded chert occurring in a matrix of deformed phyllite make up the pre-Mississippian stratigraphy in the area. The beds are 10s of centimeters thick and appear to behave as a structurally competent unit. Theses rocks have locally been thrust over the Kekiktuk Conglomerate and the "Endicott siltstone" and occur within the Pugutak thrust zone. The overall geometry defined by the unit is that of an east-plunging antiform whose wavelength is several kilometers across.

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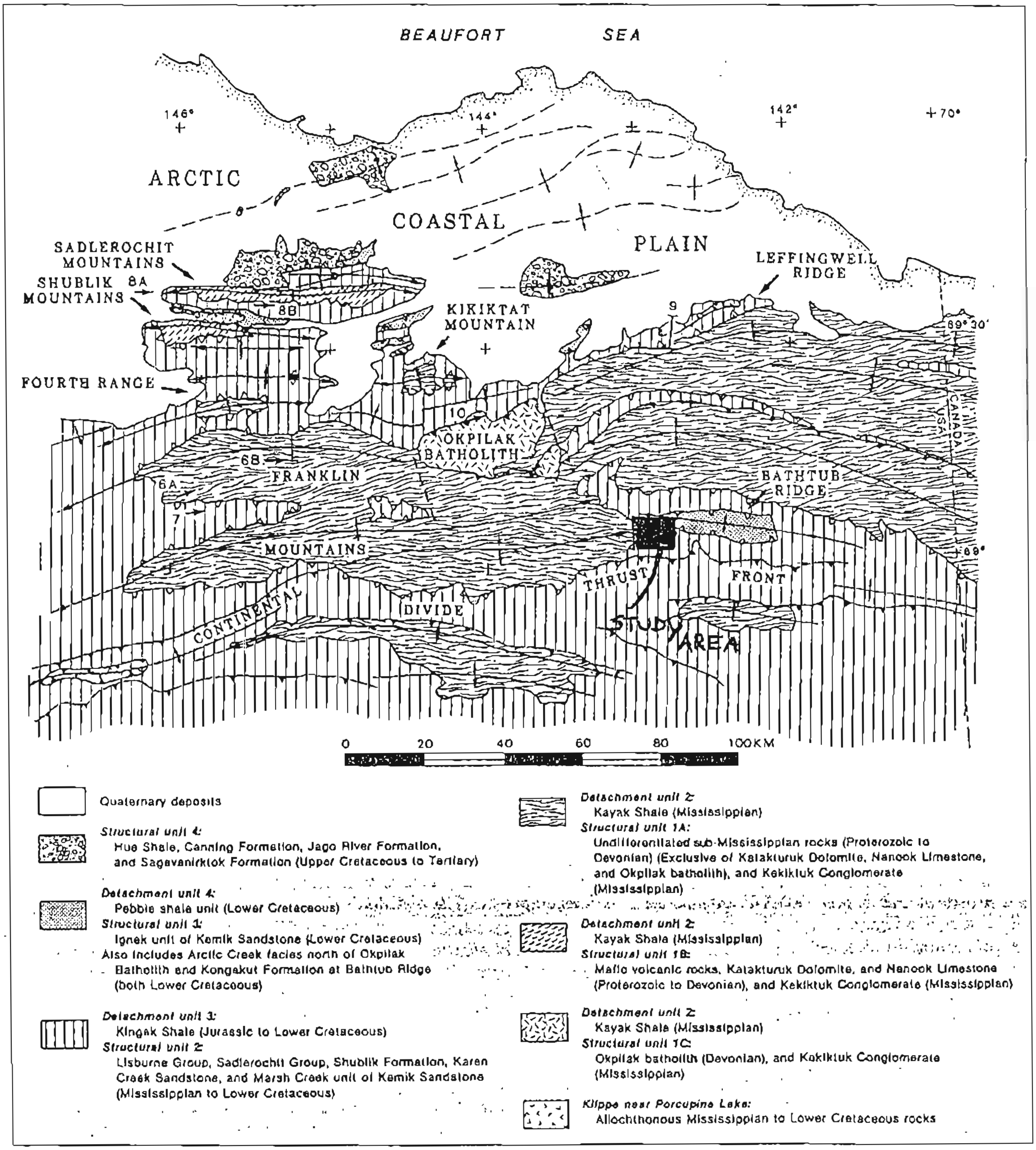

Figure 3—Generalized tectonic map of the northeastern Brooks Range showing the distribution of the major structural stratigraphic units and structural features (modified from Brosgé and Reiser, 1965; Brosgé et al., 1976; Bader and Bird, 1986; Clough et al., 1987). Structural and stratigraphic units are as identified in Figure 4. Solid teeth on thrust faults indicate older-over-younger thrust faults that duplicate stratigraphic section; open teeth indicate detachment surfaces along which there has been slip but no disruption of the normal stratigraphic succession.

FROM WALLACE AND HANKS, 1990

FIG. 1

Sequence	STRATIGRAPHY			
	Age	Symbol	Unit Name	Detachment Layers
Brookian	Cretaceous/ Jurassic	KJk	Kingak Shale	
Ellesmerian		ŦPsi	undivided Ivishak Fm.	
	Triassic	ŦPsie	Ivishak "e" member	
		ŦPsid	Ivishak "d" member	
		ŦPsic	Ivishak "c" member	
		ŦPsib	Ivishak "b" member	
		ŦPsia	Ivishak "a" member	
	Permian	Pe	Echooka Fm.	
	Penn	uIPMl	upper Lisburne Limestone	
	Miss	mIPMl	middle Lisburne Limestone	
		lIPMl	lower Lisburne Limestone	
		Mk	Kayak Shale	
		Mes	"Endicott Siltstone"	
	pMu	Mkt	Kekiktuk Conglomerate	
Franklinian	pre-Miss ?	□Ecp	pre-Mississippian Cherts and Phyllites	? ?

Fig. 2

SCHEMATIC CROSS SECTION OF AREA SOUTHWEST OF BATHTUB RIDGE (UPPER LISBURNE SHADED)

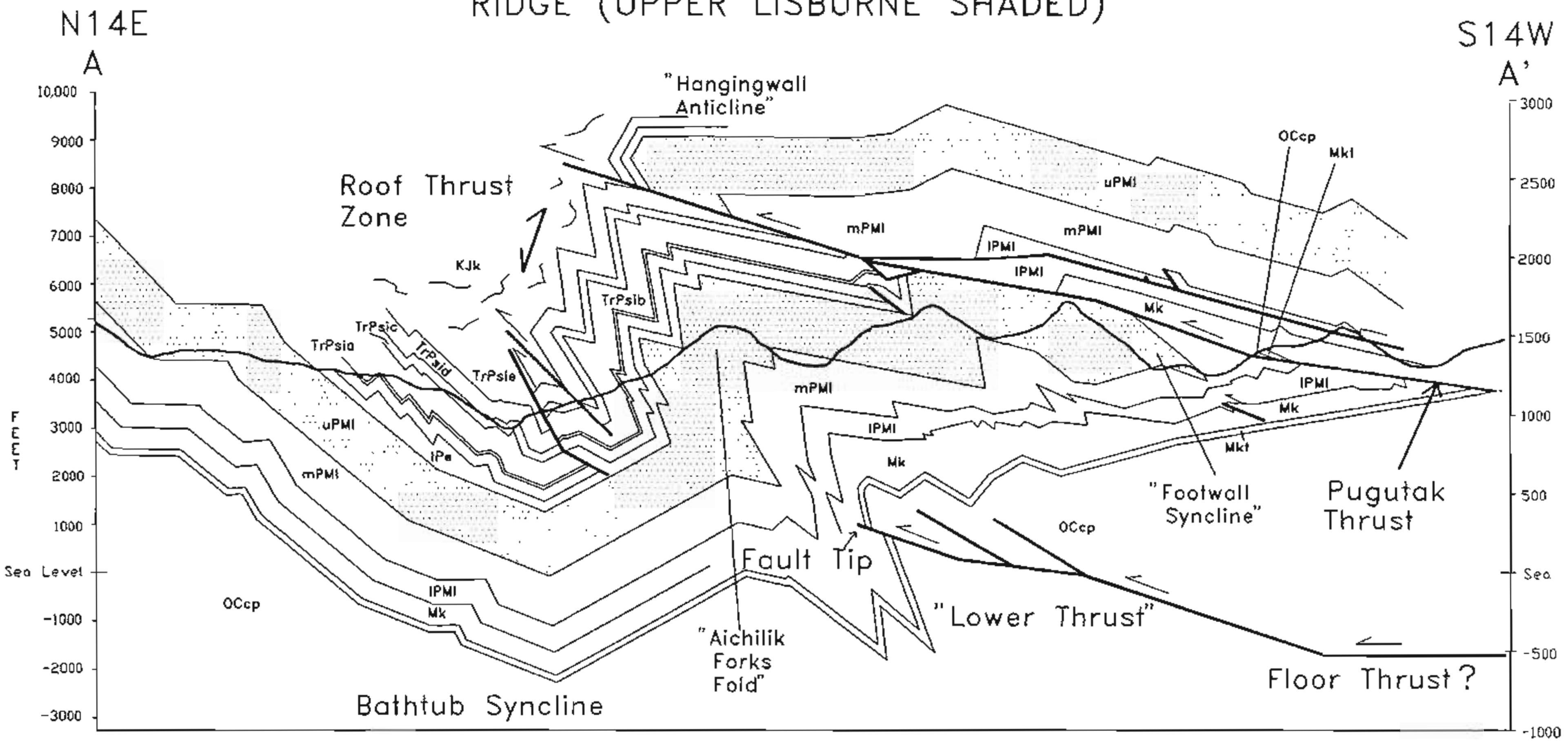

Figure 3 – Schematic down-plunge section
Section shows floor thrust in pre-Mississippian rocks
Plane of section dips 80 degrees west