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FRANKLINIAN LITHOTECTONIC DOMAINS, NORTHEASTERN BROOKS RANGE, ALASKA

by

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ABSTRACT

The Franklinian Sequence of the eastern Brooks Range, composed of low rank metasedimentary and metavolcanic rocks and three plutonic bodies, is divided into 5 lithotectonic domains. A lithotectonic domain is here defined as an apparent stratigraphic sequence or plutonic body that on a regional scale is characterized by a dominant structural style. Most of these domains record a late Proterozoic and early Paleozoic continental margin that was deformed by a compressional orogenic event of probable late Early Devonian age, accompanied by emplacement of plutonic rocks. The top of the Franklinian sequence is a major regional unconformity overlain by Middle Devonian and Lower Mississippian clastic rocks of the Ellesmerian sequence. These rocks, and those of the Ellesmerian sequence and overlying Brookian sequence were then subsequently affected by Cenozoic deformation.

The region has yielded very limited fossil age control. The age assignment of many of the stratigraphic units is based on possible lateral correlation with the few fossiliferous units, and upon the apparent superposition of units at presumed depositional contacts. However, our reconnaissance studies suggest that some of the inferred stratigraphic contacts of Reiser and others (1980) may be thrust faults rather than depositional contacts and that several of the units may be younger than previously inferred.

INTRODUCTION

The rock record of the eastern Brooks Range has been divided into three unconformity- bounded megasequences: Franklinian, Ellesmerian, and Brookian (Lerand, 1973). The Franklinian sequence consists of pre-Middle Devonian rocks that are widespread in the Mt. Michelson and Demarcation Point quadrangles (1:250,000 scale) of the northeastern Brooks Range. These rocks were deformed by at least one contractional event prior to deposition of the Middle Devonian to Early Cretaceous Ellesmerian sequence, which contains the record of deposition on a south-facing passive continental margin. In Arctic Canada this event has been called the Innuitian or Ellesmerian orogeny. The sub-Ellesmerian unconformity is a regionally significant angular unconformity. In the north, the unconformity is sub-Mississippian, but to the south it is sub-Middle Devonian (Anderson and Wallace, 1990). Rocks of the Early Cretaceous and younger Brookian sequence overlie the Ellesmerian sequence, were derived from the south, and are the depositional record of the Brooks Range orogeny. This orogeny affected all of northeastern Alaska, deformed the rocks of the Ellesmerian sequence, and resulted in an additional generation of deformation of the Franklinian sequence.

Rocks assigned to the Franklinian sequence in the northeastern Brooks Range are extensively exposed in the cores of regional anticlinoria formed during the Brookian orogeny. They have been mapped only in reconnaissance fashion (Reiser and others, 1971, 1980) and are poorly understood. Over 30 mappable units have been delineated in the Franklinian rocks, but complex structure and lack of good age control have presented a major obstacle to understanding the regional stratigraphic history and structural relationships. Two plutonic bodies have been dated by radiometric methods, but only four of the stratigraphic units have yielded datable fossil material (Dutro and others, 1972, Lane and others, 1991, Blodgett and others, 1986). In the Demarcation Point quadrangle, Reiser and others (1980) inferred that most of the units here considered to be Franklinian sequence, are Ordovician, Cambrian, or Proterozoic in age based upon two fossil collections, which consist of Ordovician graptolites and Late Cambrian trilobites and brachiopods.

Most of the units mapped in the Demarcation Point quadrangle by Reiser and others (1980) are dated only by their apparent stratigraphic position relative to the dated units. However, our reconnaissance studies suggest that some of the inferred stratigraphic contacts of Reiser and others (1980) may be thrust faults rather than depositional contacts and that several of the units may be younger than previously inferred.

Many of these stratigraphic units are present in the Mt. Michelson quadrangle, which also contains an Ordovician graptolite (Moore and Churkin, 1984) and an Early Cambrian trilobite collection (Dutro and others, 1972). In addition to the fossils from the metasedimentary rocks, an unmetamorphosed unit of dominantly carbonate rocks in the northern part of the Mt. Michelson quadrangle has yielded Early Devonian, Ordovician, and Cambrian fossils.

This evaluation of the Franklinian rocks in the northeastern Brooks range is based primarily upon detailed observations by Anderson in the southwestern Demarcation Point quadrangle (1988, 1989, 1990), regional reconnaissance studies by Mull in the Demarcation Point and Mt. Michelson quadrangles (1971, 1976, 1980, 1988, 1989), and evaluation of the published maps of these quadrangles by Reiser and others (1971, 1980). These observations suggest that the rocks of the Franklinian sequence in the northeastern Brooks Range can be grouped into 5 lithotectonic domains (Plate 1). A lithotectonic domain is here defined as an apparent stratigraphic sequence that on a regional scale is characterized by a dominant structural style. Although some of the domain boundaries are clearly thrust faults, at least one of the boundaries is equivocal and could be either a thrust fault or a steeply dipping stratigraphic contact between units of marked competency contrast.

From south to north, the domains on Plate 1 are numbered I through V. These domains coincide in part with six sequences into which Dutro and others (1972) grouped the Franklinian rocks in the northeastern Brooks Range. However, our interpretation of a possible major thrust fault within one of the sequences results in some significant differences in the interpretation of the stratigraphy and tectonic evolution of the area.

Regional structural relationships indicate substantial amounts of total shortening of the Franklinian rocks in the northeastern Brooks Range; the range in magnitude of this shortening is quantified by Hanks (1990) and Wallace and Hanks (1990). The regional data indicate that shortening by thrust faulting occurred both during the pre-Middle Devonian orogenic event (Ellesmerian or Innuitian?) and during the Mesozoic-Tertiary (Brookian) event, but the magnitude of deformation associated with each of these events has proven to be difficult to assess. In some areas, brittle deformation accompanying Brookian thrusting may have reactivated earlier Innuitian faults, but in other areas some thrust faults are clearly post-Mississippian in age. Ductile deformation has also affected some of the Franklinian rocks, but the magnitude of this deformation has proven to be more difficult to quantify (Hanks, in preparation).

LITHOTECTONIC DOMAINS

DOMAIN I

Stratigraphic sequence and distribution

Domain I contains two distinct lithologic packages (designated IA and IB) (fig. 2) that are closely associated and are present for over 125 km as regional anticlinorium that extend through the high Romanzof Mountains in the southern Mt. Michelson quadrangle and southwestern Demarcation Point quadrangle (fig. 1). This domain coincides with Sequence A of Dutro and others (1972). The rocks of Domain I have been subjected to multiple deformation; structural relationships are complicated. Domain IB is also present in the British Mountains of the eastern Demarcation Point quadrangle, but Domain 1A is not present. In the Romanzof Mountains rocks of Domain I are overlain with major angular discordance by basal Ellesmerian Early Mississippian terrigenous clastic rocks, which locally truncate the entire section.

Domain IA (fig. 2) consists of a limestone unit or units overlain by thick volcanic and volcaniclastic rocks, and red and green phyllite. The volcanic rocks range from 700 to 1300 m thick (Reiser and others, 1980) and stratigraphically overlie dark gray fine grained limestone that is less than 200 m thick. The volcanic rocks also contain interbedded or structurally interleaved limestone that is similar to the limestone at the base.

In most places in the southern Romanzof Mountains, the volcanic rocks, limestone, and maroon and green phyllite of Domain IA appear to be structurally interleaved or intricately infolded. In general, in the southern Romanzof Mountains, Domain IA is overlain by Domain 1B at a thrust fault. However, in some places, relatively thin limestone and volcanic

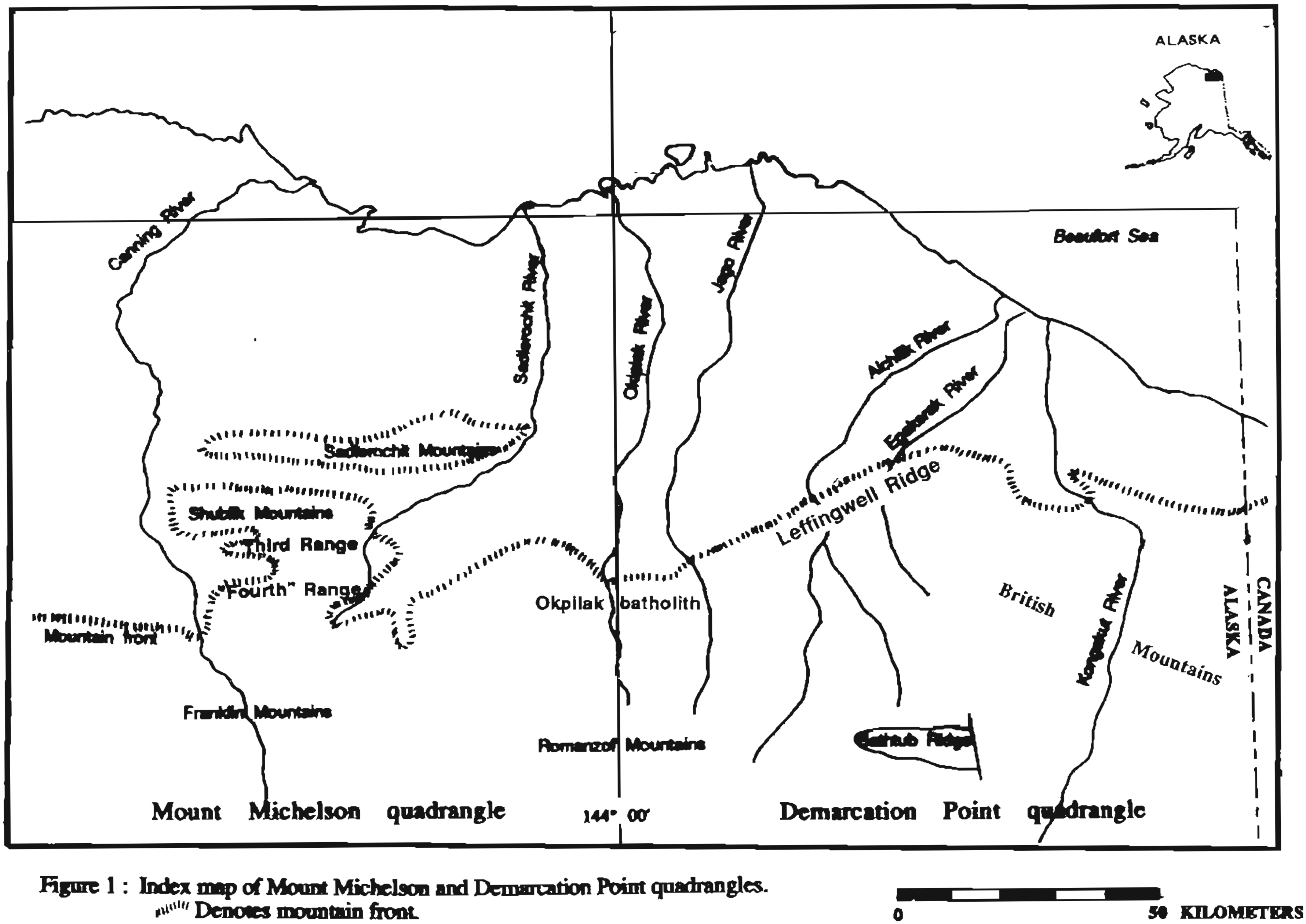
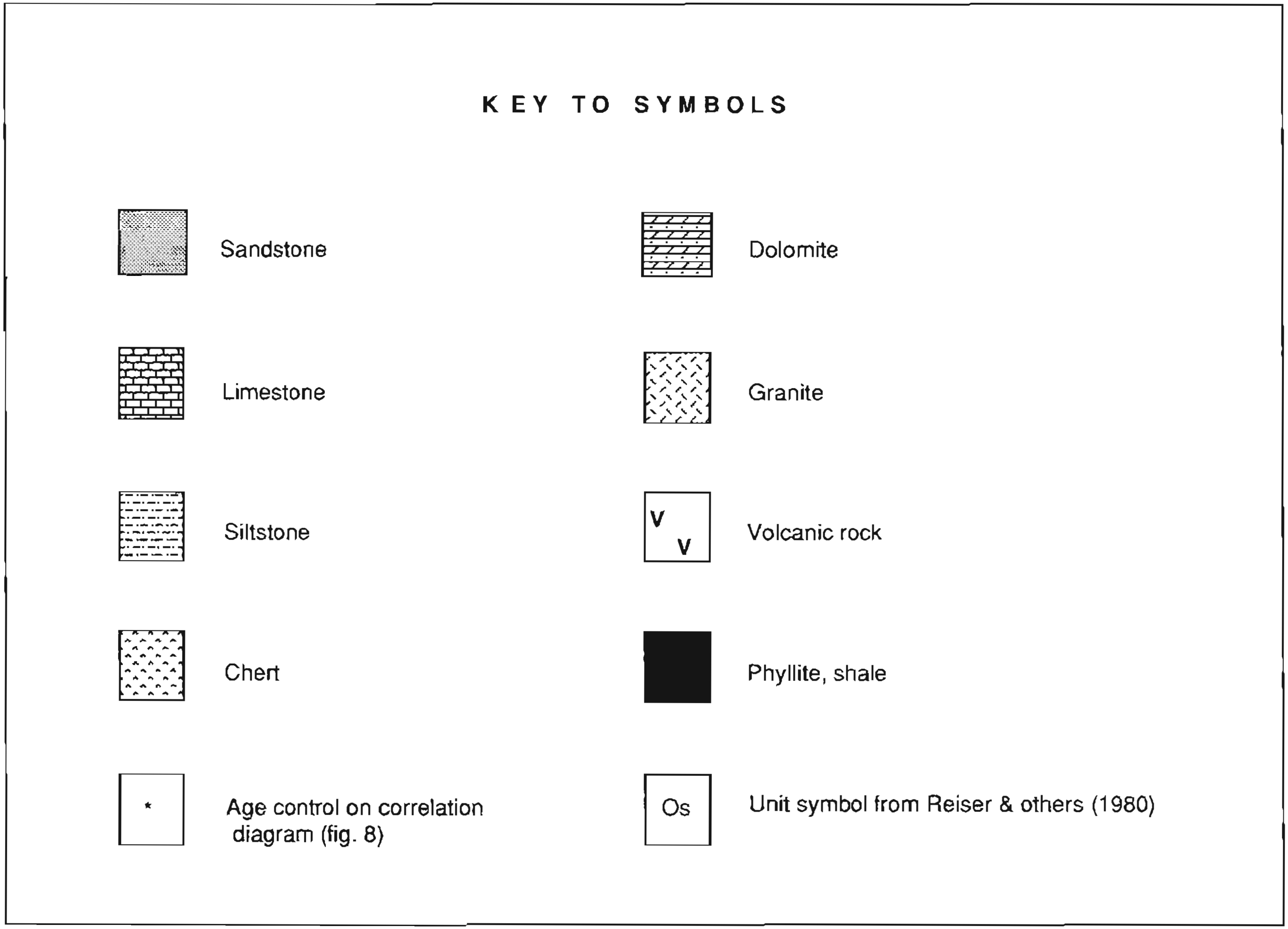


Figure 1 : Index map of Mount Michelson and Demarcation Point quadrangles.
Denotes mountain front.


KEY TO SYMBOLS
Sandstone
Dolomite
Limestone
Granite
Siltstone
Volcanic rock
V
V
Chert
Phyllite, shale
*
Age control on correlation diagram (fig. 8)
Os
Unit symbol from Reiser & others (1980)

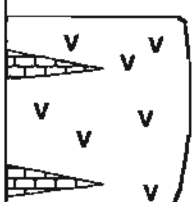
FRANKLINIAN SEQUENCE LITHOTECTONIC DOMAINS

DOMAIN I

ORDOVICIAN

CAMBRIAN

Sequence A



Mafic volcanics with interlayered limestone: Includes Whale Mountain volcanics (informal name) in east-central Demarcation Point quadradrangle. Medium to thick-bedded limestone with minor conglomeratic sandstone. (€l, €v)
Thickness: 700-1300 m
AGE: Early and Late Cambrian trilobites.. (Reiser et al., 1980; Dutro, et al., 1971).

ORDOVICIAN

CAMBRIAN

Sequence B

Chert and phyllite: (Romanzof Chert, new name). Chert crops-out as large resistant units in dark gray phyllite showing strong cleavage. Original depositional relationship between chert and phyllite unclear. (O€cp).
AGE: Ordovician graptolite (Moore & Churkin,1983).

STRUCTURE: Complex deformation prior to deposition of Middle Devonian Ulungarat Formation (new name) and Mississippian Kekiktuk Conglomerate. Chert of sequence B subvertical at time of Kekiktuk deposition.

Figure 2

rocks may be structurally interleaved within areas of Domain IB; these areas have not been mapped in detail and the possibility that the volcanic rocks and limestone are interbedded with the overlying Domain IB cannot be precluded.

In the British Mountains of the southcentral Demarcation Point quadrangle, the limestone, volcanic rocks, and red and green phyllite of Domain IA appear to be a gradational stratigraphic succession in many places. The volcanic rocks of this succession are informally known as the Whale Mountain volcanics. These rocks were considered part of sequence C by Dutro and others (1972). Rocks of Domain 1B are not present in the British Mountains.

Domain 1B (fig. 2) consists of massive and bedded chert units in a phyllite matrix informally named the Romanzof Chert (Anderson, 1991). Chert units or groups of units define mappable linear features that extend for kilometers in an east-west orientation. Individual chert lenses crop out on a scale of 100's of meters and are laterally discontinuous. The nature of the contacts between the chert and phyllite units is unknown, but the section probably represents intense imbrication of a few chert and phyllite units. Bedding and cleavage in the cherts are steep to subvertical. The cherts display at least two generations of tight to isoclinal folds with variably plunging refolded axes. Where examined in detail in the area of the upper Aichilik and upper Kongakut Rivers, the axial surfaces of the folds and associated thrust faults were rotated to steep to sub-vertical dips prior to development of the overlying regional unconformity. Elsewhere in the Romanzof Mountains,dip in Domain I appears to be steeply to the south relative to the basal Mississippian deposits.

The Mississippian Kekiktuk Conglomerate rests depositionally on the unconformity surface and has remained attached to the underlying Romanzof chert and phyllite so that the two units deformed as a single structural unit during Brookian deformation. The unconformity surface and overlying Kekiktuk Conglomerate define the geometry of Brookian age structures. On the south side of the southernmost anticlinorium, the basal rocks of the Ellesmerian sequence are the Middle Devonian and younger(?) Ulungarat Formation (Anderson, 1991) and the unconformably overlying Kekiktuk Conglomerate. The Ulungarat Formation lacks the strong deformational overprint that characterizes the underlying Franklinian rocks. and is considered to be the earliest deposits of the Ellesmerian sequence. (Anderson, 1991).

Age of stratigraphic units

In the southern Romanzof Mountains, the limestone unit that is apparently at the base of the volcanic rocks contains Early Cambrian trilobites (Dutro and others, 1972, and Reiser and others, 1971). In the British Mountains, Late Cambrian trilobites are reported from the limestone at the base of the volcanic rocks (Dutro and others, 1972; Reiser and others, 1980). In view of the Late Cambrian age of the limestone at the base of Domain 1A in the British Mountains, it seems likely that the volcanic rocks and red and green argillite of Domain IA may range into the Ordovician.

The Romanzof chert and phyllite (Domain 1B) is of Ordovician-Cambrian age (Reiser et al., 1980). This age assignment is based upon graptolites from presumably equivalent rocks along strike to the southwest in the Arctic quadrangle (Moore and Churkin, 1984).

Domain I boundaries and structural style

The volcanic and carbonate rocks of Domain IA dominate the northern part of Domain I. In the Romanzof Mountains, the northern limit is mapped in most places by Reiser and others (1971, 1980) as a thrust fault that emplaces Domain IA over rocks of Domain II. The chert and phyllite of Domain IB dominate the southern part of the domain and overlie Domain IA at an apparent regional thrust fault. However, slivers of Domain 1A appear locally to be structurally interleaved with Domain IB. Although they have been intensely folded and faulted, thrust contacts of Domain 1A and 1B both appear to have a steep regional south dip. The age of these faults is unclear, but an argument can be made that some of them pre-date the sub-Ellesmerian unconformity.

In the Romanzof Mountains, Domain I is unconformably overlain by Middle Devonian to Mississippian rocks of the basal deposits of the Ellesmerian sequence. The top of Domain IA in the British Mountains is a Holocene erosion surface, but as part of the Franklinian sequence, the domain regionally underlies the sub-Ellesmerian unconformity although no contacts between the domain and the basal Mississippian clastic rocks are known. In the British Mountains, the limestone, volcanic rocks, and phyllite of Domain IA form a long narrow syncline (informally known as the Whale Mountain syncline) trending WNW-ESE for over 60 km. into the Yukon Territory. These rocks were interpreted by Dutro and others (1972) and Reiser and others (1980) to depositionally overlie a thick black phyllite unit that is here interpreted to form the top of Domain II. However, our reconnaissance studies indicate that this contact is probably a folded thrust fault marked by scattered slivers of limestone, and suggest that the limestone, volcanic rocks and argillite of Domain IA form a klippe that overlies Domain II.

Field studies in 1991 are reported to have yielded additional conflicting data concerning the interpretation of this fault.

<u>Age of bounding faults</u>

Mapping by Reiser and others (1980) in the southeast Romanzof Mountains near the headwaters of the west fork of the Aichilik River indicates that the basal Mississippian Kekiktuk Conglomerate of the Ellesmerian sequence truncates the thrust faults that juxtapose Domain IB with Domain IA and Domain IA with Domain II. This evidence suggests that the major thrust juxtaposition of different rock units in this part of the Romanzof Mountains was pre-Mississippian in age. However, the area has not been mapped in detail and the possibility that the thrusts are related to the Brookian orogeny and sole out into a roof thrust at the base of the Mississippian section cannot be precluded. In the Romanzof Mountains at the headwaters of the Jago River, Reiser and others (1980) map a local area of possible Kekiktuk overlain by the thrust fault at the base of Domain 1A; if confirmed, this relationship is indicative of Brookian thrusting.

Field studies in 1991 are reported to have yielded additional conflicting data concerning the interpretation of this fault.

In the British Mountains, the northern boundary of the Whale Mountain syncline is mapped by Reiser and others (1980) as a west northwest trending thrust fault that juxtaposes the limestone and volcanic rocks of Domain IA, and a narrow band of the underlying rocks here considered to be the top of Domain II, over rocks of Domain II and over rocks of the Ellesmerian sequence. This apparent Brookian age fault is discussed in greater detail in a later part of this report. The probable thrust fault at the base of the carbonate and volcanic rocks of Domain IA generally overlies phyllite of Domain II, but at one locality a relatively small mass (a tectonic sliver) of crinoidal limestone resembling the Mississippian and Lower Pennsylvanian Lisburne Group is present beneath Domain IA (Mull, unpublished 1976 field notes). If this body is confirmed as Lisburne Group, the relationship is indicative of substantial Brookian age thrusting in the British Mountains.

DOMAIN II

Stratigraphic sequence and areal distribution

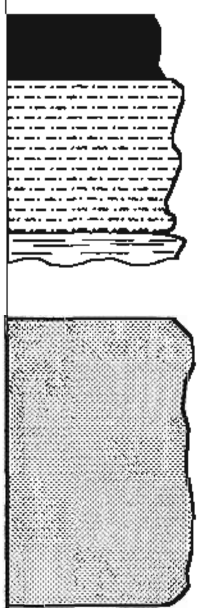
Domain II (fig. 3) consists of four major rock units that are well exposed in the southern part of the Demarcation Point quadrangle, where they are in apparent stratigraphic succession and form a regional east plunging anticlinorium north of Bathtub Ridge. The domain is also widespread in the Mount Michelson quadrangle, where it forms the high peaks of the Romanzof Mountains and appears to be more intensely deformed than in the Demarcation Point quadrangle. In the British Mountains, Domain II coincides with the lower part of Sequence C of Dutro and others (1972); in the Romanzof Mountains, it coincides with Sequence B of Dutro and others.

In the British Mountains the lower part of the sedimentary succession that forms Domain II is a thick section (>1700 m. thick) of dominantly quartzose wacke and semischist; this unit was originally named the Neruokpuk Schist by Leffingwell (1919) and the usage was continued by Reiser and others (1980). The quartz wacke and semischist unit is probably unconformably overlain by a thin and possibly discontinuous chert and phyllite unit that is overlain by a section of distinctive reddish brown weathering calcareous and micaceous siltstone and sandstone beds that is apparently between 700 and 1300 m thick (Reiser and others, 1980). This unit is particularly widespread in the area of the Aichilik River and is here informally named the Aichilik Formation. It is also found in the Romanzof Mountains in the Mount Michelson quadrangle and in the Echooka anticlinorium at the west edge of the map area (plate 1). This unit contrasts markedly with the underlying quartz wacke, and the contact may be an unconformity. Where examined near the Jago

FRANKLINIAN SEQUENCE LITHOTECTONIC DOMAINS

DOMAIN II

NO AGE CONTROL



Black phyllite: Black, dark gray, and greenish gray phyllite. Reported by Reiser (1980) to intertongue with and contain lenses of the Cambrian limestone unit. Unit is here interpreted as a detachment horizon containing tectonically emplacedslivers of limestone.

Calcareous siltstone and sandstone: very thin bedded, cross-bedded calcareous micaceous sandstone; local limestone and graywacke weathers distinctive reddish brown. Aichilik Formation (new name) (€ss).
Thickness: 700 - 1300 meters. Age: Undated Echinoderm debris indicates Paleozoic age.

Chert and phyllite: (€cp). Thickness less than 100 meters.

Possible unconformity

Quartz wacke: Massive quartz wacke, thin to thick bedded, with interbedded semischist, phyllite and agrillite; weathers greenish to brownish gray. (p€n)
Thickness: more than 1700 m

AGE: No age control

STRUCTURE: Clastic rocks form major regional anticlinorium in southcentral Demarcation Point quadrangle. Aichilik Formattion and chert-phyllite unit apparently truncated by Mississippian Kekiktuk Conglomerate in southern part of anticlinorium. Forms generally south dipping mountains in Mt. Michelson quadrangle with quartz wacke thrust over Aichilik Formation in northern part of domain.

Figure 3

River, the contact of the Aichilik Formation and underlying quartz wacke is apparently marked by a thin chert pebble conglomerate, shows no evidence of structural complication, and appears to be an unfaulted stratigraphic succession (Mull, unpublished field notes, 1988).

Regionally, the Aichilik Formation is overlain by a unit up to 1300 m thick (Rieser and others, 1980) composed dominantly of black phyllite and shale. This interval appears to be the top of the Domain II sedimentary sequence, and we interpret it as a detachment horizon upon which the carbonate and volcanic rocks of Domain I were emplaced. Limestone bodies interpreted by Reiser and others (1980) as lenses within the phyllite are here interpreted as tectonic slivers of Domain I within the incompetent phyllite. In contrast to this interpretation, Dutro and others (1972) and Reiser and others (1980) interpreted the black phyllite unit to be in stratigraphic continuity with the overlying volcanic and carbonate unit, although they recognized that the volcanic and carbonate rocks are in fault contact with the phyllite in the upper Hulahula River area of the Romanzof Mountains (Dutro and others, 1972, p.809).

Field studies in 1991 are reported to have yielded additional conflicting data concerning the interpretation of this fault.

In the Mt. Michelson quadrangle, only local detailed mapping has been carried out within the pre-Mississippian rocks (Reed, 1968) and most of the rocks of Domain II are known only from reconnaissance mapping. However, Domain II apparently consists mostly of the quartz wacke and semischist unit that is much more complexly deformed than to the east, and appears to be bounded by thrust faults at its base. Mapping by Reed (1968) (1:63,360 scale) and Reiser and others (1971) (1:200,000 scale) suggest that regional dip in this area is to the south although intense tight folding is evident in some areas.

Age of stratigraphic units

The age of the rocks in Domain II is not well constrained. The only fossils reported are unidentifiable echinoderm columnals recovered from the rocks here called the Aichilik Formation (Dutro and others, 1972; Reiser and others, 1980). They inferred a Cambrian age for the chert-phyllite, the Aichilik Formation, and the black phyllite, presumably based upon the apparent stratigraphic position of these units below the Upper Cambrian limestone that is associated with the volcanic rocks of the Whale Mountain syncline in Domain IA. However, our observations suggesting that Domain I structurally overlies Domain II cause us to question the inferred Cambrian age of the Aichilik Formation and overlying black phyllite. Adding to the uncertainty in inferring a Cambrian age for the calcareous siltstone of the Aichilik Formation and the black phyllite unit in Domain II is the fact that these units are lithologically dissimilar to any of the dated Cambrian and Ordovician units in the Franklinian sequence. It is thus difficult to infer facies changes in proposing a correlation of Domain II with any of the rock units in either Domain I or Domain III.

The quartz wacke and semischist unit that forms the apparently stratigraphically lowest part of Domain II was inferred by Reiser and others (1980) to be Precambrian in age. Based upon its apparently greater degree of deformation and metamorphism, we believe that this unit may be the oldest rocks exposed in the northeastern Brooks Range.

Domain II boundaries and structural style

The nature of the base of Domain II in the British Mountains is uncertain and what rock types underlie it is unknown. The most extensive and least structurally disrupted exposures of the entire stratigraphic succession of

Domain II are exposed in the regional anticlinorium north of Bathtub syncline; here the quartz wacke-semischist unit underlies the entire crestal portion of the anticlinorium, and no obvious base to the succession is known.

The northern part of Domain II is marked by a regional south dipping high angle reverse fault that is well defined north of the Whale Mountain syncline near the Alaska-Yukon boundary (Reiser and others, 1980) this fault is here called the Whale Mountain fault. This fault can be traced westward for nearly 100 km. to the upper Jago River; it juxtaposes Domain II with Mississippian rocks of the Ellesmerian sequence that unconformably overlie a narrow belt of Domain II to the north. Between the Aichilik River and the middle reaches of the Jago River, similar quartz wacke is present north of the Whale Mountain fault, and although not mapped as such by Reiser and others (1980), on the northern side of this outcrop belt we map an inferred thrust fault that juxtaposes the quartz wacke of Domain II over rocks of Domain III. However, available mapping is not adequate to preclude the possibility that the northern edge of this belt of quartz wacke is an overturned depositional contact.

All units in Domain II are unconformably overlain and truncated by the Kekiktuk Conglomerate, which forms the base of the Ellesmerian sequence in most of the British and Romanzof Mountains. The truncation is well exhibited on a regional scale in the mapping of Reiser and others (1980) along the south flank of the regional anticlinorium in the south-central Demarcation Point quadrangle north of Bathtub Ridge; it is also well exhibited between the Jago and Aichilik Rivers.

Age of bounding faults

In the British Mountains, thrust juxtaposition of Domain II over the Ellesmerian sequence indicates that major brittle deformation here occurred during the Brookian orogeny. Alternatively, however, this relationship can be interpreted as reactivation of a pre-Mississippian fault or an out-of-sequence fault that cuts a pre-existing thrust fault.

Within Domain II between the Jago and Aichilik Rivers, at least one apparent thrust fault appears to be truncated by the base of the Ellesmerian sequence (Reiser and others, 1980). In addition, we interpret the northern boundary of the quartz wacke unit in this area as a thrust fault; these faults thus appear to represent pre-Mississippian deformation. As in other areas, presently available mapping is insufficiently detailed to preclude the possibility that the faults are Cenozoic age and die out into a sole fault at the base of the Ellesmerian sequence.

DOMAIN III

Stratigraphic sequences and distribution

Domain III is widespread in the anticlinorium that forms the northern British Mountains in the central Demarcation Point quadrangle and in the anticlinorium south of Ikiakpuk Valley in the Mt. Michelson quadrangle; this anticlinorium is here called the Ikiakpuk anticlinorium and is in the area that is sometimes informally known as the Fourth Range. The domain includes rocks of Sequences D and E of Dutro and others (1972).

Domain III is composed of three apparent stratigraphic sequences (figs. 4 & 5) that were probably parts of a formerly continuous depositional succession before being disrupted and juxtaposed by thrusting. In general,

FRANKLIAN SEQUENCE LITHOTECTONIC DOMAINS

DOMAIN III

NO AGE CONTROL

Sequence A

<u>Dark gray to black platy limestone</u>: Ikiakpuk Formation (new name) (p€l, p€bl)

<u>Phyllite and argillite</u>: Gray, green, and red argillite and phyllite; some thin-bedded limestone and chert; relatively thin unit. (p€pa, p€al).
AGE: No age control.

<u>Quartz wacke</u>: Fine- to coarse-grained; rounded quartz grains common. Includes siltstone, red, green, and black phyllitic slate, and rare limy beds. (p€n).
AGE: No age control.

NO AGE CONTROL

Sequence B

<u>Dark gray to black platy limestone, phyllite, and calcareous sandstone</u>: (Ikiakpuk Formation, new name). To east limestone is thicker bedded, pisolitic, pelletoidal, contains rounded quartz grains, and locally grades to coarse-grained calcareous sandstone and grit conglomerate (p€ls, p€s, p€lr, p€l).
Age: No age control
Thickness: less than 300 m

<u>Phyllite, quartzite, and dolomite</u>: Fine-grained, lamellar to thin-bedded sandstone and quartzite. Phyllite dominates lower part of unit. (p€pq, p€sd).
Age: No age control.
Thickness: Greater than 200m.

<u>STRUCTURE</u>: Intense deformation and imbrication before deposition of Ellesmerian sequence suggested by appartent truncation of anticlinal nose in T1N, R36 & 37E developed in Domain III-B. Ellesmerian rock is deposited on flanks of regional anticlimorium and appear to not be involved in the imbrication. Imbrication of Ikiakpuk Formation before Ellesmerian deposition suggested by regionally south dipping section in Ikiakpuk anticlinorium (Fourth Range, Mt. Michelson quadrangle) truncated by Kekiktuk Conglomerate.

Figure 4

FRANKLINIAN SEQUENCE LITHOTECTONIC DOMAINS

DOMAIN III

ORDOVICIAN

CAMBRIAN

NO AGE CONTROL

<u>Sequence C</u>

<u>Slate and argillite</u>: black and greenish gray to black phyllite and chert. Lithic wacke and sandstone, volcanic clast conclomerate, and limestone, Volcanic clasts similar to volcanics in Domain I-A. Closely associated with and may stratigraphically overlie unit ph of Reiser & others, 1980). (Os, Opc, sc).

Age: Black slate contains Late Ordovician graptolite.

<u>Phyllite</u>: red, green and gray with minor chert. (ph)
Age: Early Cambrian Oldhamia in red argillite (Lane and others, 1991).

<u>Dark gray to black limestone and phyllite</u> (pЄl, pЄls).
Ikiakpuk Formation (new name).

<u>STRUCTURE</u>: Imbrication of Sequence B with Sequence C before deposition of Ellesmerian Sequence suggested by folded thrust fault apparently truncated by Mississippian rocks in T2N, R40E.

Figure 5

the rocks of Domain III are more thinly bedded and less competent than the rocks of Domains I and II. Owing to the relatively incompetent nature of many of the units and the intense deformation to which they have been subjected, the nature of the contacts between mapped units and the stratigraphic succession is uncertain in many areas. The sequences discussed below are based upon recognition of common associations of some of the lithologic units in areas in which the direction of dip is evident. However, the presence of unrecognized thrust faults through incompetent intervals may have resulted in erroneous interpretations of these sequences.

Sequence A is composed of quartz wacke to lithic graywacke that is locally gritty or conglomeratic. The unit is apparently overlain by a section of gray, green, and red argillite and phyllite, which may be succeeded upward by a unit of black limestone and phyllite. In the Demarcation Point quadrangle, sequence A is exposed dominantly in the eastern half of the central part of the quadrangle. Sequence A is also present locally in the core of the eastern Sadlerochit Mountains in the Mount Michelson quadrangle. The wacke unit constitutes the northernmost exposures of the Neruokpuk Schist of Leffingwell (1919).

Sequence B is a heterogeneous unit that consists of dark gray to black, thick to medium bedded recrystallized limestone, phyllite, and calcareous sandstone. The limestone commonly contains floating quartz grains; it is probably correlative with the limestone unit that may form the top of sequence A. This unit is here informally named the Ikiakpuk Formation for its widespread exposures in the Ikiakpuk anticlinorium south of Ikiakpuk Valley in the central Mount Michelson quadrangle. It is overlain by a unit that consists of platy to thin bedded silty limestone and calcareous sandstone. To the east, near the Alaska-Yukon border, the limestones apparently grade locally to coarse grained calcareous sandstone and grit conglomerate. In the Mount. Michelson quadrangle, the Ikiakpuk Formation is exposed only in the Ikiakpuk anticlinorium and in the eastern end of the Third Range.

Sequence C is exposed only in the northeastern part of the British Mountains, in the eastern Demarcation Point quadrangle. It consists of dark gray to black limestone and phyllite (similar to the Ikiakpuk Formation of Sequences A and B) overlain by a section of dominantly red, green, and gray argillite. This section is overlain by a 40 to 70 m thick succession of lithic wacke and sandstone, mudstone, volcanic clast conglomerate, tuff, and minor limestone, with interbedded dark gray argillite and chert. Black slate and argillite, and greenish gray to black phyllite and chert form the top of the sequence (Lane and others, 1991).

Age and correlation of stratigraphic units

Most of the stratigraphic units in Domain III have not yielded identifiable fossil material and are dated only by their apparent stratigraphic position relative to the few dated units and by analogy to similar units elsewhere in the northeastern Brooks Range. Sequences A and B in Domain III have not yielded fossil material; diagnostic fossils have been found only in sequence C. Lane and others (1991) report discovery of Oldhamia, a distinctive Early Cambrian trace fossil, at three localities in the red argillite near the Alaska-Yukon border. And, a Late Ordovician graptolite is reported by Reiser and others (1980) from the black slate in the top of the sequence (as here defined) in the same area. These fossils confirm an apparent stratigraphic sequence that can be interpreted by the mapping of Reiser and others in the northeastern part of the Franklinian outcrop belt near the Alaska - Yukon border.

Lane and others (1991) report that volcanic clasts in sequence C of Domain III (as here defined) are indistinguishable from the much thicker volcanic rocks of Domain IA exposed in the Whale Mountain syncline (discussed above).

Domain III boundaries and structural style

In the Demarcation Point quadrangle, the broad anticlinorium in which Domain III crops out is defined by opposing dips in the overlying Ellesmerian sequence. In this anticlinorium the domain is characterized by faulted and isoclinally folded relatively incompetent rocks. The southern boundary of Domain III is probably a thrust fault that juxtaposes the quartz wacke of Domain II over Domain III (Reiser and others, 1980). In the Mt. Michelson quadrangle, the anticlinoria in which Domain III is exposed from the Third Range and "Fourth Range"; both structures are defined by opposing dips in the Ellesmerian sequence, which truncates the rocks of Domain III. Wallace and Hanks (1990) interpret the anticlinoria in both the Demarcation Point and Mt. Michelson quadrangles as major horses in duplex systems formed during Brookian deformation.

In the Demarcation Point quadrangle, the northern limit of Domain III in the surface exposures is an angular unconformity overlain by the Kekiktuk Conglomerate, which forms the base of the Ellesmerian sequence. The northern limit of the domain in the subsurface north of the mountain front is unknown. However, in the Mt. Michelson quadrangle, the inferred northern limit of Domain III is partly constrained by exposures in the Shublik Mountains, 8 km. north of the Third Range. The rocks of Domain III in the Third and "Fourth" Ranges are markedly different than the rocks of Domain V in the Shublik Mountains (discussed below). Wallace and Hanks (1990) infer that the northern limit of Domain III in the subsurface is a regional thrust fault that is the sole thrust of a duplex system, with its leading edge located between the Third Range and Shublik Mountains. In view of the marked contrast in lithology of at least partly coeval Franklinian rocks between the Third Range and Shublik Mountains, we infer large displacement on this thrust, possibly on the order of 10's of kilometers, which resulted in juxtaposition of the diverse lithologic assemblages.

Domains III A, B, and C are at least locally juxtaposed by clearly defined thrust faults that have been mapped or can be inferred in the mapping of Reiser and others (1980). The quartz wacke at the base of Domain III-A is thrust over the black limestone of Domain III-B at several localities east of the Kongakut River. Black sandy limestone of Domain III-B is superimposed over the Cambrian to Ordovician argillite, slate, and chert of Domain III-C by a folded thrust fault that can be traced for over 50 km. between the Ekaluakat River and the Alaska-Yukon boundary.

Elsewhere between the Aichilik and Kongakuk Rivers, lateral tracing of apparent stratigraphic sections suggests that some of the more resistant lithologic units of Domain III-A are overturned on the flanks of long narrow tightly folded anticlines that may in some cases be developed in folded thrust sheets. In addition, Lane and others (1991) report upright to north verging isoclinal folds and thrust faults near the Alaska-Yukon international boundary at the east edge of Demarcation Point quadrangle. Although the absence of sedimentary features or well defined stratigraphy in many places makes it difficult to determine which rocks may be overturned, tight open to isoclinal folds and folded thrust sheets appear to be the dominant structural style in Domain III.

In addition to the apparent isoclinal folds and thrust faults, at least one broad open upright structure is present in the rocks of the Franklinian sequence. On the south side of Leffingwell Ridge, west of the Aichilik River, a west plunging anticlinal nose developed in the black sandy limestone of Domain III-B is truncated by the overlying basal clastic rocks of the Ellesmerian sequence (Kekiktuk Conglomerate).

Age of deformation

The apparent truncation of major structures in Domain III by the base of the Ellesmerian sequence suggests that major deformation and large scale telescoping of these rocks occurred before Mississippian time. The large west plunging anticlinal nose in Domain III-B west of the Aichilik River is clearly truncated by the unconformity at the base of the Ellesmerian sequence that forms Leffingwell Ridge (Reiser and others, 1980). A similar relationship is suggested by the trend of the rock units and the folded thrust fault that juxtaposes Domains III-B and -C east of the Egaskrak River. Between the Jago and Aichilik Rivers, on the south side of the anticlinorium, the sub-Ellesmerian unconformity apparently truncates the thrust fault that juxtaposes Domains II and III. In addition, the presence of thrust faults and large scale folds truncated by the sub-Ellesmerian unconformity suggests that isoclinal folding within the Domain III Franklinian rocks may also have occurred before Mississippian time, although this relationship has not been demonstrated.

The interpretation of major pre-Middle Devonian juxtaposition of rock units contrasts with the interpretation of Wallace and Hanks (1990) who infer that the majority of the deformation of the Franklinian sequence probably occurred during the Brookian orogeny. We do not dispute the interpretation of major Brookian deformation and thrusting, but believe that some of this occurred by reactivation of major pre-Mississippian structural units. However, separation of these two generations of deformation based solely upon megascopic map criteria is difficult. The magnitude of Brookian deformation in the northeastern Brooks Range is under detailed study by C. Hanks (in preparation).

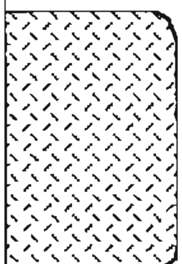
DOMAIN IV

Granite of the Okpilak batholith, the Jago stock and an unnamed smaller stock to the south comprise Domain IV (fig. 6). These intrusive bodies appear to intrude rocks of Domain II and III and suggest that these domains had been juxtaposed by Devonian time; this relationship is relatively well exposed west of the Jago River. The Okpilak batholith is considered by Newberry and others (1986) to have compositional and mineralogical similarities to Sn-type granites and has been dated as 380 Ma (Dillon and others, 1987). Sable (1977) concluded that the batholith cooled in the mesozone. Deep levels of erosion of the batholith prior to Mississippian time is suggested by the absence of fine -grained porphyritic phases, indicating removal of the cupola portion of the granitic body (Newberry and others, 1986). Thus, a minimum of 6 km must have been eroded before the basal Ellesmerian clastic rocks were deposited on the eroded surface of the batholith. West of the Okpilak batholith, the basal Mississippian Kekiktuk Conglomerate contains clasts with tourmaline-quartz and heavy minerals believed to have been derived from the batholith (Reed, 1968).

Recent mapping and studies by Wallace and Hanks (1990) indicates granite thrust over Ellesmerian rocks on the north flank of the Okpilak batholith and suggest that the batholith is detached at depth and thrust a minimum of several kilometers northward by Brookian deformation.

FRANKLINIAN SEQUENCE LITHOTECTONIC DOMAINS

DOMAIN IV	DEVONIAN



Granite and quartz monzonite: Okpilak Batholith and Jago stock.

Age: 380 +/- 10 Ma (Dillon et al., 1987)

STRUCTURE: Compositional and mineralogical similarities to Sn-type granites (Newberry et al., 1986). Cooled in the mesozone (Sable (1977), but overlying deposits were eroded prior to deposition of the Early Mississippian Kekiktuk Conglomerate on the eroded surface of the batholith.

Figure 6

DOMAIN V

Stratigraphic sequence and distribution

Domain V is exposed only in the Mt. Michelson quadrangle, in the Sadlerochit and Shublik Mountains, and in the axis of the Kikiktat Mountain anticline. The domain consists dominantly of thick massive carbonate rocks and minor amounts of mafic igneous rock (fig. 7). The sequence includes, in ascending order, the Katakturuk Dolomite, Nanook Limestone, and Mt. Copleston Limestone (new name, J. Clough, personal comm.).

The Katakturuk Dolomite (Dutro, 1970) consists of over 2500 m of massive dolomite and is comprised of cyclic shallowing-upward sequences of subtidal to intertidal carbonate. A vertical succession of similar distinctive carbonate facies is present in the Katakturuk in both the Shublik and Sadlerochit Mountains. The Katakturuk Dolomite contains thin interstratified volcanic rocks near its base in the Shublik Mountains. An angular unconformity of 3 to 5 degrees separates the dolomite from the overlying Nanook Limestone (Dutro, 1970) which is exposed mostly in the central Shublik Mountains. A disconformity separates the overlying Mt. Copleston Limestone from the underlying Nanook Limestone. In contrast to the Franklinian rocks of Domains I, II, and III, which exhibit a prominent structural fabric and can generally be described as low- grade metamorphic rocks, the limestones and dolomites of Domain V are undeformed and show no effects of metamorphism.

Age of stratigraphic units

Invertebrate fossils of late Early Devonian age have been recovered from the top of the Mt. Copleston Limestone (J. Clough, personal

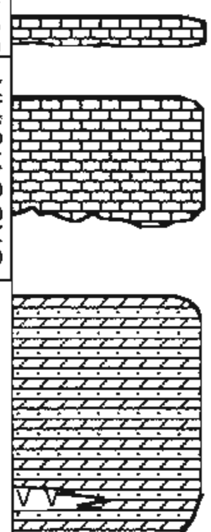
FRANKLINIAN SEQUENCE LITHOTECTONIC DOMAINS

DOMAIN V

EARLY DEVONIAN

CAMBRIAN-ORDOVICIAN

PRECAMBRIAN



Limestone: (Mt. Copleston Limestone).
Thickness: 72 m
Age: Late Early Devonian at top (J. Clough, personal communication).

Limestone and dolomite: (Nanook Limestone).
Thickness: 1700 m
Age: Upper middle to Late Cambrian through Ordovician, based on fossils (Blodgett and others, 1986)

Angular unconformity, 3 to 15 degrees.

Dolomite: (Katakturuk Dolomite) Stromatolitic, oolitic, cross-bedded; cycles of shallowing-upward sequences of subtidal to intertidal carbonates; intertonguing mafic volcanics.
Thickness: 2500 meters
Age: 700 - 800 Ma on volcanics. (Clough, 1990).

STRUCTURE: Low angle discordance between Kakakturuk Dolomite and Nanook Limestones. Units dip south below basal Ellesmerian truncation. Angular unconformity approximately 15 - 30°. Units are not thrust imbricated and are unmetamorphosed.

Figure 7

communication). The Nanook Limestone contains a scattered invertebrate fauna of late Middle to Late Cambrian through Ordovician age (Dutro 1970; Blodgett and others, 1986). The Katakturuk Dolomite is unfossiliferous and because of its stratigraphic position underlying dated Middle Cambrian rocks of the Nanook, is thought to be Proterozoic age (Blodgett and others,1986). The mafic volcanic rocks interstratified with the Katakturuk Dolomite have yielded radiometric dates of 700 - 800 Ma. (J. Clough, 1990).

The fossils recovered from the Nanook Limestone indicate that it is coeval with at least some of the units of Domain III-C and with the volcanic and limestone unit of Domain I-A. Other than a superficial similarity of the limestone in Domain I-A to limestone in the Nanook Limestone, no significant lithologic similarities between the Nanook and other units in the Franklinian sequence in northern Alaska have been noted. This absence of any lithologic comparison with other units suggests that the Nanook Limestone and Katakturuk Dolomite were separated by a substantial distance from the remainder of the rocks of the Franklinian sequence in northern Alaska prior to deformation. However, alternatively, the lack of lithologic similarity with rocks to the south could be the result of very rapid facies changes and does not necessarily require major structural juxtaposition of contrasting facies.

Domain V boundaries and structural style

The Katakturuk Dolomite and Nanook Limestone in both the Sadlerochit and Shublik Mountains have relatively uniform south dip that ranges from about 20° to 60°. Only minor bedding parallel faults and a few cross faults have been mapped (Robinson and others (1989). The angular unconformity at the base of the overlying Ellesmerian sequence ranges up to about 20° and truncates down northward to progressively lower levels of the

Nanook and Katakturuk. In the eastern end of the Sadlerochit Mountains, the unconformity has truncated the entire Nanook and Katakturuk section and truncates quartzite, phyllite, schist, and mafic igneous rocks that are probably part of Domain III-A underlying the Katakturuk.

The base of the Katakturuk Dolomite is a south- dipping thrust fault that is exposed in the eastern end of the Sadlerochit Mountains (Reiser and others, 1972; Robinson and others, (1989). This south-dipping thrust juxtaposes the Katakturuk with more steeply south-dipping to nearly vertical quartzite and associated rocks of the underlying Domain III. A highly vesicular zone in a basalt interval within these beds suggests that tops are to the south. If this interpretation is valid, the fault at the base of the Katakturuk appears to cut downsection to the north in the underlying rocks of the footwall.

The northern limit of the Katakturuk Dolomite in both the western Sadlerochit and western Shublik Mountains are south dipping high angle reverse faults that Wallace and Hanks (1990) interpret as sole thrusts at the base of horses in a duplex system.

Age of faulting

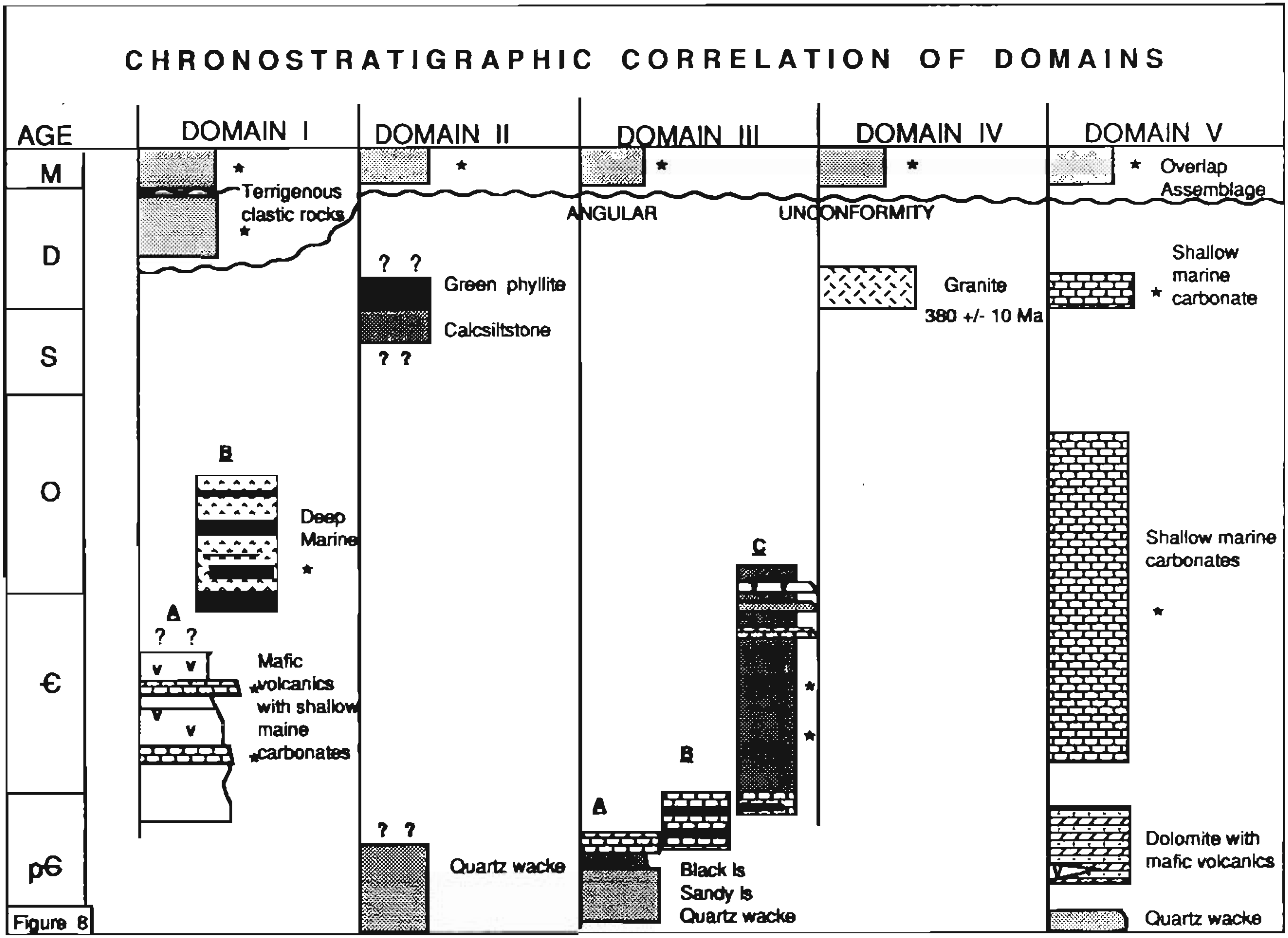
The major deformation that uplifted the Katakturuk Dolomite and Nanook Limestone in the Sadlerochit and Shublik Mountains is interpreted by Wallace and Hanks (1990) and other workers as resulting from the Brookian orogeny. Evidence from study of Quaternary deposits in the area suggests that some of the uplift may be as young as Pleistocene (R.A. Combellick, personal communication).

However, in addition to the evidence for Brookian deformation, there is also evidence for substantial pre-Mississippian deformation. Detailed mapping in the eastern Sadlerochit Mountains (Reiser and others, 1980, Robinson and others, 1989; Mull and Mangus, 1972) shows that the fault that juxtaposes the Katakturuk Dolomite with the underlying rocks of Domain III in the eastern Sadlerochit Mountains is clearly truncated by the overlying basal Ellesmerian deposits. In addition, there is also evidence that a large pre-Mississippian fault separated the Katakturuk Dolomite and Nanook Limestone in the Sadlerochit Mountains from the Katakturuk and Nanook in the Shublik Mountains. As discussed above, the pre-Mississippian truncation in the Shublik Mountains ranges up to about 20°, truncating down section to the north in the Nanook and Katakturuk; the angular relationship is similar in the Sadlerochit Mountains. If the rate of truncation in the Shublik Mountains continued unbroken to the north, the entire Katakturuk and Nanook section in the Sadlerochit Mountains should have been removed by the pre-Mississippian unconformity. This evidence suggests that the Katakturuk and Nanook in the two ranges were separated by a major fault before truncation by the pre-Mississippian unconformity. Inasmuch as there is no evidence for major fault offsets within the Katakturuk and Nanook in either the Sadlerochit or Shublik Mountains, we infer that the pre-Mississippian fault probably trended east-west. We are aware of no evidence for its direction of dip; although we favor the interpretation of a south-dipping high angle reverse or thrust fault, it could have been a north-dipping normal fault. A major fault of either orientation probably provided a zone of weakness that controlled the location of the Brookian faulting at the north flank of the Shublik Mountains. A similar pre-Mississippian fault probably controlled the location of the high angle reverse fault along the north flank and center of the Sadlerochit Mountains.

DISCUSSION

Regional mapping shows that Domains I through V are exposed as coherent east-west trending belts (plate 1). A chronostratigraphic diagram (fig. 8) compares the relative position in time and space of these belts and suggests a correlation of rock units. Because of the lack of fossil control in many of the rock units, correlation of some of the stratigraphic successions is difficult and should be considered tentative. The assignment of a Silurian-Early Devonian age for the phyllite and calcsiltstone of Domain II is speculative. In the absence of any paleontologic control, the lack of similarity to any other dated units in the area coupled with less apparent deformation leads one of the authors (Mull) to suggest that these rocks could be Silurian-Devonian age.

In summary, from the available paleontologic control, parts of Domains I, III, and V appear to span a similar time interval ranging from the Cambrian into the Ordovician. The Cambrian and Ordovician rocks of Domain V in the north consist dominantly of platform carbonate rocks and appear to have been a tectonically stable element. Domain V rocks do not share the complex sub-Ellesmerian deformational history of other Franklinian domains. Apparently coeval rocks of Domain III seem to be deep marine deposits consisting of argillite, slate, chert, and some volcaniclastic rocks. To the south, the Cambrian and probable Ordovician rocks of Domain I-A consist of a thick succession of dominantly volcanic rocks with minor limestone, overlain by marine argillite. Lane and others (1991) report that the volcanic clast conglomerate here considered part of Domain III-C contains clasts that are identical to some of the Whale Mountain volcanic rocks to the south, which are


CHRONOSTRATIGRAPHIC CORRELATION OF DOMAINS
AGE
DOMAIN I
DOMAIN II
DOMAIN III
DOMAIN IV
DOMAIN V
M
D
S
O
€
pЄ
Terrigenous clastic rocks
Overlap Assemblage
ANGULAR UNCONFORMITY
Green phyllite
Calcsiltstone
Granite
380 +/- 10 Ma
Shallow marine carbonate
B
Deep Marine
A
Mafic volcanics with shallow maine carbonates
C
Shallow marine carbonates
B
A
Quartz wacke
Black ls
Sandy ls
Quartz wacke
Dolomite with mafic volcanics
Quartz wacke
Figure 8

here considered part of Domain I-A. This lithologic correlation is consistent with the sparse fossil data that link the two domains.

Vergence of the late Early Devonian compressional event is unclear. Detailed field studies in the southwest Demarcation Point quadrangle (Anderson, 1989, 1991) show that Domain I rocks were orientated steep to sub-vertical relative to the sub-Ellesmerian unconformity surface. No clear sense of vergence has been determined. Work by Lane et al. (1991) and regional relationships reported throughout this paper suggest north vergence. Oldow et al. (1987) concluded south vergence. This is a question that needs to be addressed through a regional study.

Based on lithologic similarities and the available paleontologic control, the following elements of a geologic history are suggested for the domains presently juxtaposed below the sub-Ellesmerian unconformity.

1. The apparently oldest stratigraphic unit to crop out is the quartz wacke of presumed Precambrian age. This indicates continental influence as the oldest tectonic element present. The quartz wackes present at the base of Domains II, III, and IV may or may not be coeval.
2. Cambrian volcanism is recorded in Domains I-A and III-C, suggesting a spatial relationship between the two domains.
3. Ordovician rocks indicate a marine environment deep enough to permit deposition of radiolarian chert.
4. The Okpilak batholith and related stocks (Domain IV) were intruded by Middle Devonian time into the stratigraphic succession of Domains II and III and stitch them together.

5. Most of the Ordovician, Silurian, and Early Devonian depositional record was removed by erosion following the late Early Devonian compressional event.

6. The Middle Devonian to Mississippian basal Ellesmerian terrigenous clastic rocks are an overlap assemblage on the angular unconformity at the top of the Franklinian Sequence.

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