"Kan82a" F-11

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEDIMENTOLOGY AND STRATIGRAPHY OF THE KANAYUT CONGLOMERATE, CENTRAL AND WESTERN BROOKS RANGE, ALASKA--REPORT OF 1981 FIELD SEASON

By

Tor H. Nilsen and Thomas E. Moore

Open-File Report 82-674

1982

This report is preliminary and
has not been reviewed for conformity
with U.S. Geological Survey editorial
standards and stratigraphic nomenclature.

Contents

Illustrations

Tables

ABSTRACT

The Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate forms a major stratigraphic unit along the crest of the Brooks Range of northern Alaska. It crops out for an east-west distance of about 900 km and a north-south distance of about 65 km. The Kanayut is wholly allochthonous and has probably been transported northward on a series of thrust plates.

The Kanayut is as thick as 2,600 m in the east-central Brooks Range. It thins and fines to the south and west. The Kanayut forms the middle part of the allochthonous sequence of the Endicott Group, an Upper Devonian and Mississippian clastic sequence underlain by platform limestones of the Baird Group and overlain by platform limestone, carbonaceous shale, and black chert of the Lisburne Group. The Kanayut overlies the marine Upper Devonian Noatak Sandstone or, where it is missing, the marine Upper Devonian Hunt Fork Shale. It is overlain by the marine Mississippian Kayak Shale. The Kanayut Conglomerate forms the fluvial part of a large, coarse-grained delta that prograded to the southwest in Late Devonian time and retreated in Early Mississippian time.

Four sections of the Kanayut Conglomerate in the central Brooks Range and five in the western Brooks Range were measured in 1981. The sections from the western Brooks Range document the presence of fluvial cycles in the Kanayut as far west as the shores of the Chukchi Sea. The Kanayut in this area is generally finer grained than it is in the central and eastern Brooks Range, having a maximum clast size of 3 cm. It is probably about 300 m thick. The upper and lower contacts of the Kanayut are gradational. The lower Kanayut contains calcareous, marine-influenced sandstone within channel deposits, and the upper Kanayut contains probable marine interdistributary-bay shale sequences. The members of the Kanayut Conglomerate cannot be differentiated in this region.

In the central Brooks Range, sections of the Kanayut Conglomerate at Siavlat Mountain and Kakivilak Creek are typically organized into fining-upward fluvial cycles. The maximum clast size is about 3 cm in this area. The Kanayut in this region is 200-500 m thick and can be divided into the Ear Peak, Shainin Lake, and Stuver Members. The upper contact of the Kanayut with the Kayak Shale is very gradational at Kakivilak Creek and very abrupt at Siavlat Mountain.

Paleocurrents from fluvial strata of the Kanayut indicate sediment transport toward the west and south in both the western and central Brooks Range. The maximum clast size distribution generally indicates westward fining from the Shainin Lake region.

INTRODUCTION

We have presented stratigraphic and sedimentologic data collected from the fluvial Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate and associated units of the central and eastern Brooks Range during the 1978-1980 field seasons in a series of open-file reports (Nilsen and others, 1980b, 1981b, 1982). This report presents data collected during a shorter 1981 field season in the eastern, central, and western Brooks Range (figs. 1 and 2). Moore spent one month in the field at Crevice Creek in the central Brooks Range. Subsequently, Nilsen and Moore worked together for 4 days from the

Lisburne Well site in the west-central Brooks Range and 6 days from Driver's Bar, located about 30 km east-northeast of Kivilina in the western Brooks Range. As a result, one section of the Kanayut Conglomerate was measured at Till Creek north of Crevice Creek, two sections south of the Lisburne Well site, and four partial sections northeast of Driver's Bar. In addition, one new pebble count was obtained and additional maximum clast size measurements and paleocurrent determinations were acquired and are reported herein.

Our previous work was confined to the central and eastern Brooks Range, between the Alaska-Yukon Territory border and the Kuna River, where the Kanayut Conglomerate has been mapped in considerable detail (Brosge and Reiser, 1962, 1964, 1965, 1969, 1971; Reiser and others, 1971, 1974; Brosge and others, 1976, 1979a, 1979b; and Nelson and Grybeck, 1980). Brosge and others, (1982) present a geologic map of the central and eastern Brooks Range that shows the distribution of members of the Kanayut Conglomerate and the location of major thrust faults within the outcrop belt. Paleocurrent maps for the Kanayut Conglomerate and associated units, based on field work in 1978 and 1979, have also been released (Nilsen and others, 1980a). A generalized facies model for the Kanayut Conglomerate has been presented by Nilsen and others (1981a). Stratigraphic nomenclature for the Kanayut Conglomerate has been revised by Nilsen and Moore (1982a).

The Kanayut Conglomerate forms part of the Endicott Group, a thick sequence of Upper Devonian and Lower Mississippian clastic units bounded below by platform carbonates of the Baird Group and above by platform carbonate, carbonaceous shale, and black chert of the Lisburne Group (Tailleur and others, 1967). The Endicott Group in the central part of the Brooks Range consists in ascending order of the marine Hunt Fork Shale, marine Noatak Sandstone, nonmarine Kanayut Conglomerate, and marine Kayak Shale (Bowsher and Dutro, 1957; Chapman and others, 1964; Porter, 1966). This sequence of strata forms a series of allochthonous thrust plates thought to have been transported northward during orogenesis in the late Mesozoic (Mull and others, 1976; Mull and Tailleur, 1977; Roeder and Mull, 1978).

A second sequence of the Endicott Group is autochthonous or parautochthonous and may underlie the allochthonous sequence of the Endicott Group. The autochthonous sequence consists primarily of the Kekiktuk Conglomerate and Kayak Shale (Brosge and others, 1962; Reed, 1968; Martin, 1970; Ellersick and others, 1979), which rest unconformably on deformed and intruded pre-Upper Devonian metasedimentary and metavolcanic rocks (fig. 3). The autochthonous sequence crops out in the Brooks Range to the south, east, and northeast of the allochthonous sequence, and underlies parts of the North Slope and Arctic Foothills north of the allochthonous sequence. Relations between the allochthonous and autochthonous sequences of the Endicott Group, are not completely clear, and depend on the nature of palinspastic reconstruction both within the Brooks Range and between the Brooks Range and other circum-Arctic orogenic belts (Nilsen, 1981).

The Kanayut Conglomerate in the central and eastern Brooks Range consists of three members, in ascending order: (1) the Ear Peak Member, as thick as 1160 m, consisting chiefly of fining-upward cycles thought to have been deposited by meandering streams; (2) the Shainin Lake Member, as thick as 530 m, consisting chiefly of conglomerate-sandstone couplets thought to have been deposited by braided streams; and (3) the Stuver Member, as thick as 1300 m, consisting chiefly of fining-upward cycles thought to have been deposited by meandering streams. Because our previous open-file reports describe the general geology, setting, biostratigraphy, lithostratigraphy, and previous work, we will not repeat this information here.

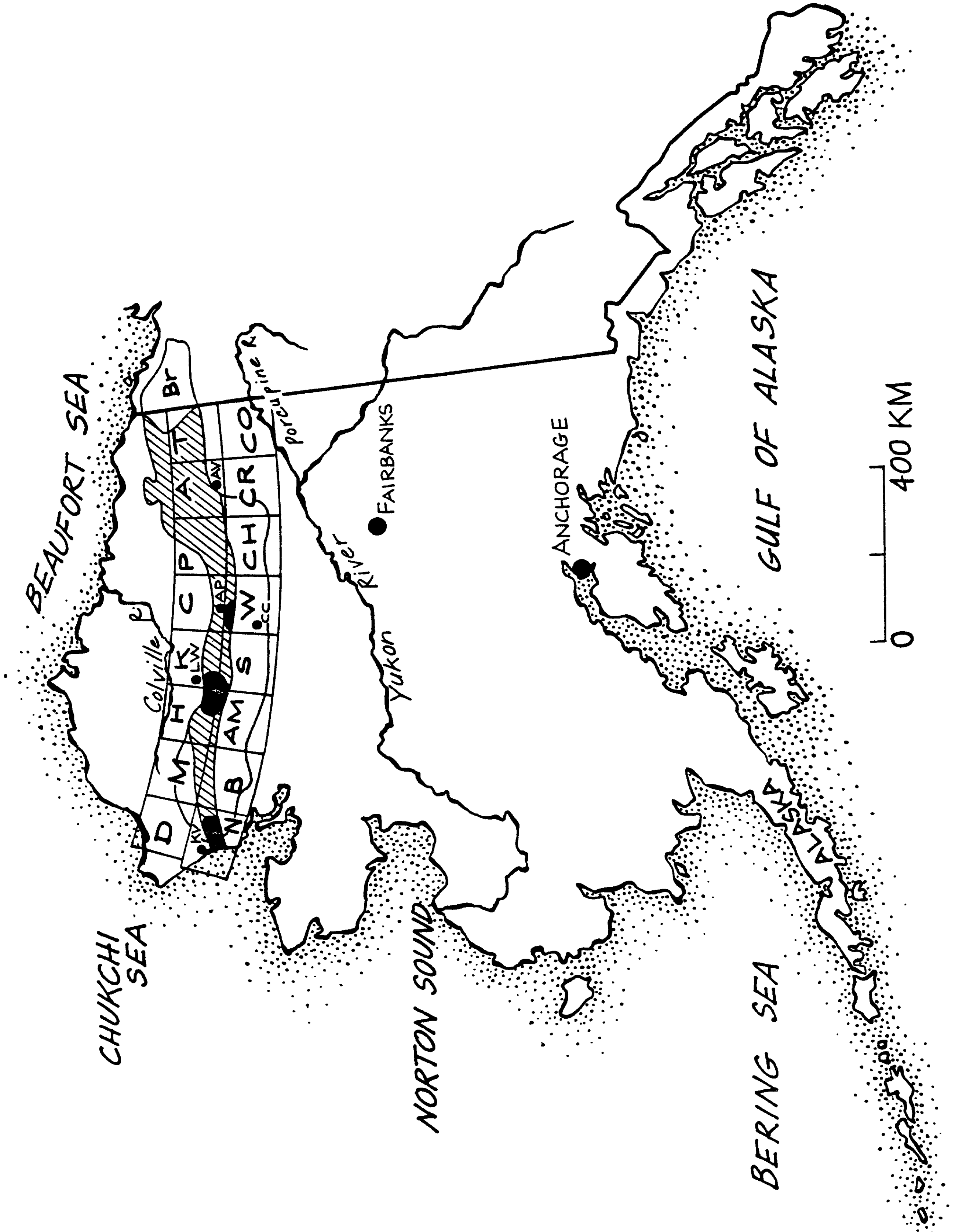
Our 1981 field work provided us with the opportunity to examine outcrops of the Kanayut Conglomerate in the western Brooks Range, as far west as the coast of the Chukchi Sea near Kivalina (fig. 1). The Kanayut Conglomerate had been previously mapped in the western Brooks Range by Mayfield and Tailleur (1978) and Mayfield and others (1978). However, because (1) the quality of outcrops diminishes markedly as the Brooks Range becomes progressively lower topographically to the west, (2) the Kanayut is less easily distinguishable to the west from stratigraphically related clastic units, and (3) the Kanayut contains smaller amounts and finer sizes of conglomerate toward the west, the positive recognition of fluvial facies remained uncertain. In addition, it appeared on the basis of regional stratigraphic relations (Dutro, 1953b) that the Kanayut passed laterally southwestward into the Noatak Sandstone, a marine clastic unit that underlies the Kanayut Conglomerate in the central and eastern Brooks Range, but was thought to be the only unit in the westernmost Brooks Range.

Our work in the Mulgrave Hills region and "Husky" Mountains of the westernmost Brooks Range establishes the presence of the Kanayut Conglomerate in the same relative stratigraphic position that it occupies in the central and eastern Brooks Range (Nilsen and Moore, 1982a). It consists of well-defined fining-upward fluvial cycles with interbedded floodplain deposits that contain plant debris and paleosols. It rests gradationally on the Noatak Sandstone and is overlain gradationally by the Kayak Shale.

ACKNOWLEDGMENTS

We are indebted to W. P. Brosge, C. G. Mull, and I. L. Tailleur for supporting most of our work during the summer of 1981. They provided helicopter access that permitted the measurement of stratigraphic sections and collection of other field data. Discussions with them and C. F. Mayfield and I. Ellersick in the field provided a helpful focus for our work. We also gratefully acknowledge the help of R. L. Detterman who helped measure the Till Creek section.

Figure 1.--Index map of Alaska and adjacent areas showing location of study areas. The Brooks Range and British Mountains (Br) are outlined by a solid line. The ruled areas show the approximate outcrop extent of the Endicott Group. The location of the 1981 field study areas is shown by a dark pattern. Abbreviations: AP, Anaktuvuk Pass; AV, Arctic Village; CC, Crevice Creek; KV, Kivalina; LW, Lisburne Well site. Quadrangle names are designated by initial letters, from west to east: D, De Long Mountains; N, Noatak; M, Misheguk Mountain; B, Baird Mountains; H, Howard Pass; AM, Ambler River; K, Killik River; S, Survey Pass; C, Chandler Lake; W, Wiseman; P, Philip Smith Mountains; CH, Chandalar; A, Arctic; CR, Christian; T, Table Mountain; and CO, Coleen.


BEAUFORT SEA
CHUKCHI SEA
NORTON SOUND
BERING SEA
GULF OF ALASKA
FAIRBANKS
ANCHORAGE
Colville R
Yukon River
Porcupine R
ALASKA
D
M
H
K
C
P
A
T
Br
N
B
AM
S
W
CH
CR
CO
LW
AP
AV
CC
0
400 KM

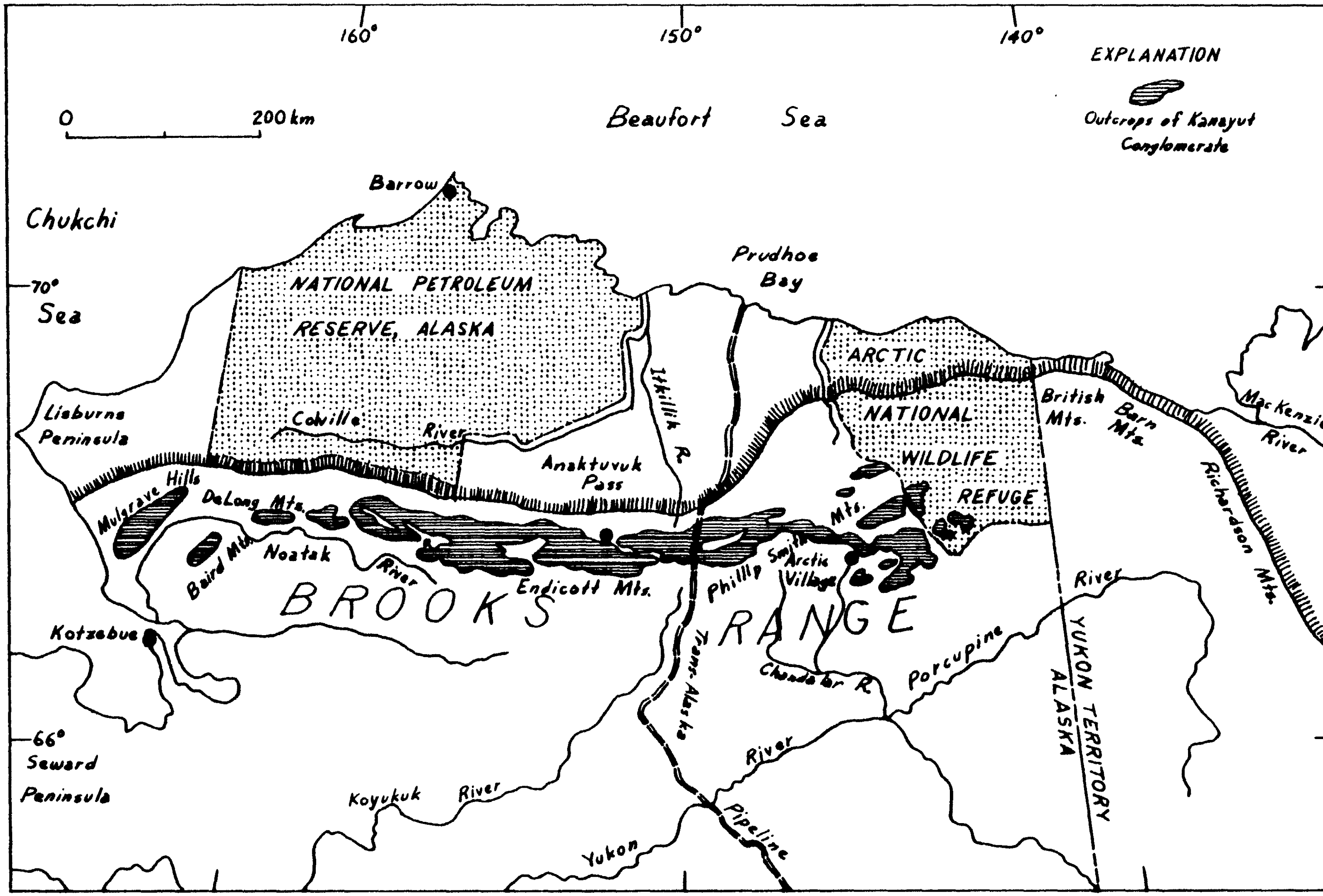


Figure 2.--Index map of northern Alaska showing distribution of Kanayut Conglomerate. Hachured line shows northern edge of Brooks Range. Abbreviations: AP, Anaktuvuk Pass; AV, Arctic Village; AWR, Arctic Wildlife Refuge; NPRA, National Petroleum Reserve, Alaska; SL, Shaninin Lake.

SEDIMENTARY FACIES
General

The Kanayut Conglomerate and associated units in the Brooks Range contain a variety of sedimentary facies deposited in fluvial and marine environments. The upper part of the Hunt Fork Shale records shoaling marine conditions as it grades upward into the shallow-marine deposits of the Noatak Sandstone. The overlying Ear Peak Member of the Kanayut Conglomerate records progradation of fluvial sediments over the Noatak Sandstone, culminating in deposition of the coarser grained fluvial Shainin Lake Member of the Kanayut. The successively overlying fluvial Stuver Member, basal shallow-marine sandstone of the Kayak Shale, and shale of the Kayak Shale record major retrogradation of the Kanayut depositional system (fig. 3). Thus, the entire sequence records outbuilding of a major fluvial system, most probably a large delta, out into a marine basin during Late Devonian time.

Earlier episodes of clastic deposition, recorded by conglomerate and sandstone within the Beaucoup Formation and lower Hunt Fork Shale (Dutro and others, 1979; Nilsen and others, 1980b), may not be related genetically to the Kanayut onlap-offlap cycle. These less-well understood depositional events may be related more to local uplifts and restricted sedimentation.

Hunt Fork Shale

Shale deposited in low-energy and probably deep-marine (at least below wave base) settings forms most of the lower member of the Hunt Fork Shale (fig. 3). It is as thick as 700 m in the Philip Smith Mountains quadrangle (Brosge and others, 1979a). It is typically black- or brown-weathering and unfossiliferous except for trace fossils. The shale contains thin turbidite interbeds that increase in abundance upward and locally contain fossil debris and shale rip-up clasts. The thin-bedded turbidites form graded beds, generally less than 5 cm thick, that may contain parallel stratification or current-ripple laminae. Other graded beds commonly are internally structureless, reflecting probable vertical settling from storm-generated overflows or interflows within the water column rather than bottom-flowing turbidity currents. The shale member is thought to have been deposited on the floor of a relatively deep marine basin.

The overlying wacke member of the Hunt Fork Shale consists mostly of shale and shaley siltstone with interbedded fine- to medium-grained sandstone. It is as thick as 700 m in the Philip Smith Mountains quadrangle (Brosge and others, 1979a). Ferruginous lenses contain abundant brachiopod fossils, and plant fossils and marine burrows are common. The beds of sandstone are commonly flat-stratified or cross-stratified, reflecting deposition by marine traction currents. The wacke member is thought to have been deposited in a marine slope to outer-shelf setting.

Noatak Sandstone

The Noatak Sandstone, previously mapped as the basal sandstone member of the Kanayut Conglomerate (Brosge and others, 1979a,b) in the central and eastern Brooks Range, consists of calcareous sandstone interbedded with black shale. The type section is in the western Brooks Range, in the southern DeLong Mountains adjacent to the Noatak River (fig. 2). There, it is several

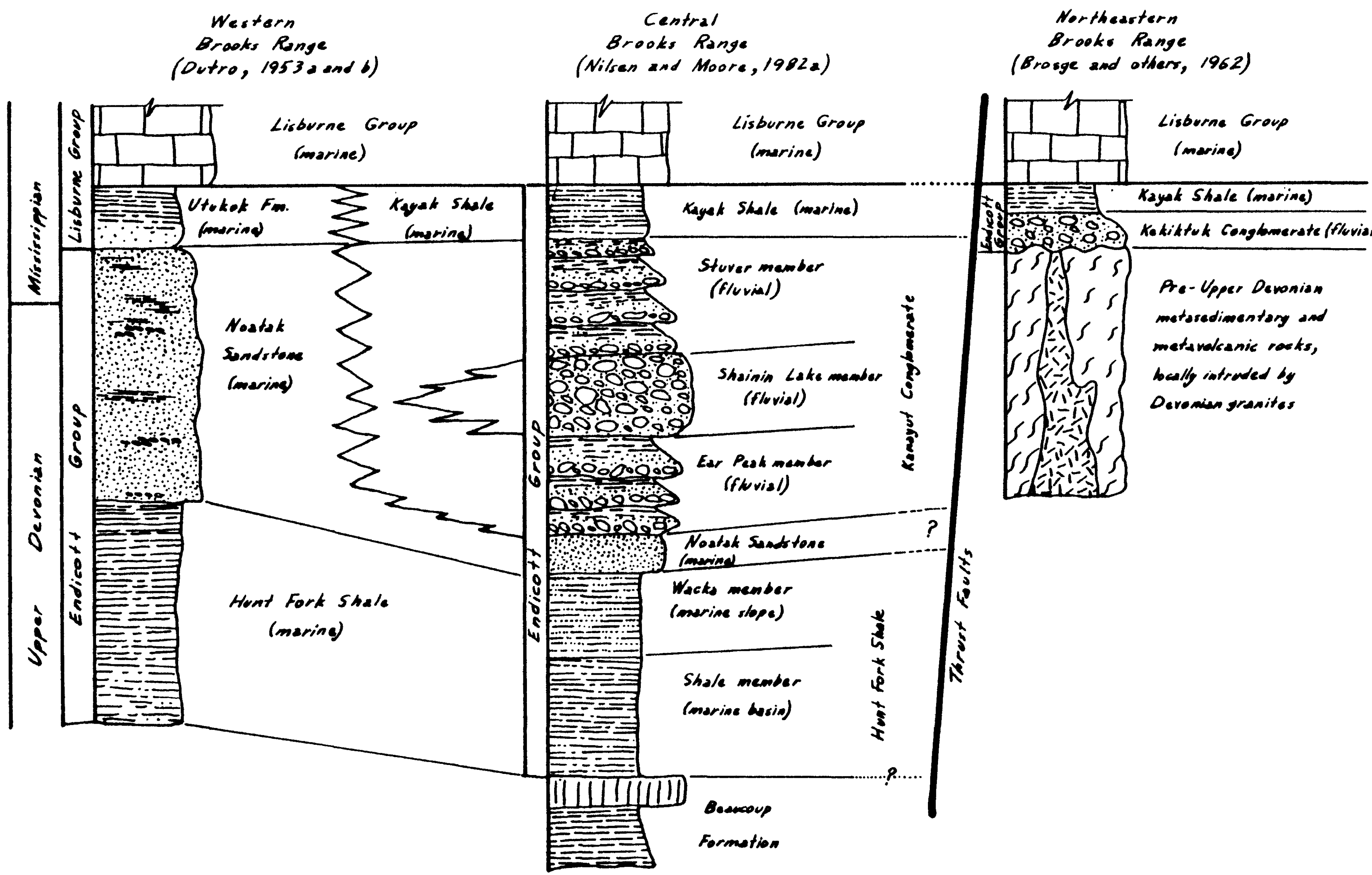


Figure 3.--Columnar sections and inferred depositional environments of the Endicott Group in the western, central, and eastern Brooks Range.

hundred meters thick and consists mostly of quartzitic sandstone that is locally fossiliferous (Dutro, 1952, 1953a, b). The Noatak is locally conglomeratic and contains marine megafossils in many places. It is as thick as 1,000 m in the western Brooks Range (Tailleur and others, 1967) and 600 m in the Philip Smith Mountains quadrangle (Brosge and others, 1979a).

In the central and eastern Brooks Range, the sandstone strata most typically form thickening- and coarsening-upward cycles deposited in delta-front settings, probably most commonly as channel-mouth bars. The cycles record progradation of the delta over underlying marine slope and outer-shelf deposits. Other sandstone bodies, characterized throughout by medium- to large-scale cross-strata that have consistent orientation, may represent offshore bars or spits that formed on the margins of the delta. Variable paleocurrent directions from the shallow-marine sandstone bodies reflect currents generated by waves, winds, tides, and longshore drift.

In the Mulgrave Hills area, the Noatak Sandstone interfingers with the lower part of the Kanayut Conglomerate. Fining-upward fluvial cycles of the Kanayut Conglomerate in this region contain interbedded calcareous sandstone and conglomeratic sandstone that are probably marine in origin and resemble the Noatak Sandstone.

Kanayut Conglomerate

The Ear Peak Member (formerly the lower shale member) and Stuver Member of the Kanayut Conglomerate are interpreted to have been deposited by meandering streams on a floodplain. The members consist of a series of thinning- and fining-upward cycles similar to those described from many modern meandering rivers. Detailed analysis of the cycles may permit determinations in the future of the sizes of the rivers, their discharges, and temporal or geographical variability of the streams within the depositional basin.

The meandering-stream cycles characteristically commence at their base with erosional truncation of underlying shale or paleosols by thick beds of conglomerate or sandstone. The amount of downcutting observed varies from several cm to as much as 5 m. However, if viewed on a large enough scale, each fluvial cycle probably downcuts approximately the thickness of the individual cycle, inasmuch as the cycle is a preserved record of filling of the individual river channel. The basal beds typically consist of massive or crudely parallel-stratified conglomerate or conglomeratic sandstone containing abundant rip-up clasts of shale, siltstone, and paleosol material.

Overlying the basal conglomeratic beds are parallel-stratified beds of sandstone that are in turn overlain by trough-cross-stratified beds of sandstone. Trough amplitudes gradually decrease upward in the cycles concomitantly with decreasing grain size of the sandstone. The trough axes have variable attitudes, but generally plunge toward the southwest. These deposits represent fill of the channel by transverse and longitudinal bars that migrate downchannel as the stream channel gradually shifts and migrates laterally by the meander process.

The upper part of the cycles consists of thinly bedded current-ripple-marked fine-grained sandstone with thin shale interbeds. These ripple-marked sandstones contain abundant mica, clay, and carbonaceous material. Climbing ripples are locally common in these deposits, as well as plant fossils and root impressions. These thin beds of sandstone are interpreted to be levees deposited on the inner parts of meander loops by overbanking processes during flood stages.

The uppermost part of the cycles consists of interchannel and floodplain shale and siltstone containing prominent local paleosols. The shale varies from reddish brown to black in color, probably depending upon the amount of exposure to the atmosphere. Red shale probably was deposited chiefly on higher ground of the floodplain and black shale in lower, swampy areas. Many cycles contain red shale directly over the sandy levee facies, succeeded upward by black shale. Both red and black shale contain abundant fossil plant debris, much of it in situ. Mudcracks, raindrop imprints, and features that might represent burrows but are more likely root casts from plants are common. The lower shale member locally contains very thick sections of reddish-brown shale, particularly in the eastern Brooks Range. These deposits may represent large floodplain areas traversed by few river channels. In these areas, shale deposited by major floods probably accumulated to substantial thicknesses.

A characteristic feature of the cycles is long inclined surfaces that cut across the vertical sequence (epsilon cross-stratification). These surfaces are thought to be the original inclined surfaces of the inner parts of meander loops or point-bar surfaces.

Cycles of sandstone not characterized by fining- and thinning-upward trends accumulated in parts of the meandering stream facies. These bodies of sandstone are locally channelized, may form symmetrical vertical cycles, and characteristically contain abundant rip-up clasts and fragments of levee, interchannel, and floodplain facies. The bodies may be crevasse-splay deposits formed where levees have been broken through during large floods.

The Shainin Lake Member (formerly the middle conglomerate member) of the Kanayut Conglomerate consists of interbedded conglomerate and sandstone thought to have been deposited by braided streams. The characteristic feature of these deposits is the vertical stacking of fining-upward couplets of conglomerate and sandstone, with the erosional base of each conglomerate bed truncating the underlying sandstone. In some sections, conglomerate rests on conglomerate to form amalgamated beds, with sandstone absent either as a result of nondeposition or erosion.

The conglomerate-sandstone couplets are thought to represent deposition of various kinds of bars within a braided stream complex. Sandstone is deposited on the flanks, tops, and downstream edges of gravel bars as thin but wide lens-shaped bodies characterized generally by parallel stratification, low-angle trough cross stratification, or very low-angle inclined tabular cross stratification. The sandstone probably accumulates during waning stages of floods and on the protected downstream margins of bars.

The largest conglomerate clasts are found in the Shainin Lake Member. The conglomerate is typically well imbricated and characterized by a closed framework with a sandstone or pebbly sandstone matrix. Long axes are oriented parallel to flow and have proven to be useful paleocurrent indicators for the

Shanin Lake Member. Paleosols, levee deposits, shale, and siltstone are rarely present.

Kayak Shale

In its type area, near Shainin Lake, the Kayak Shale is about 300 m thick, rests conformably on nonmarine facies of the Stuver Member, and has been subdivided into 5 members: (1) basal fine-grained sandstone, 40 m thick; (2) lower black shale, 180 m thick; (3) argillaceous limestone, 24 m thick; (4) upper black shale, 40 m thick; and (5) red limestone, 5 m thick. The three lower members, although their thickness varies, can be traced along the entire Brooks Range, despite marked changes in the total thickness of the Kayak from the effects of thrust faulting. However, in the southern and eastern Brooks Range, the Kayak Shale in the allochthonous sequence of the Endicott Group is generally less than 75 m thick and consists mostly of black shale.

The basal sandstone member typically consists of thinly cross-stratified and ripple-marked fine-grained quartzose sandstone with abundant Scolithus burrows, a marine ichnofossil. In its type area and elsewhere, it contains both current- and oscillation-ripple markings, reactivation surfaces, flaser bedding, and herringbone cross laminae and cross strata suggestive of tidal current activity. In most localities within the allochthonous sequence of the Endicott Group, the sandstone rests directly on red or black shale or soils of the topmost fining-upward fluvial cycle of the Stuver Member; however, in contrast to coarse-grained deposits of the Kanayut, it consists wholly of fine-grained sandstone, may contain recumbent and syndepositionally folded cross strata, slump folds, and slurried layers, and may form a thickening- or coarsening-upward megasequence abruptly overlain by black shale of the next member. In a few rare sections, the basal sandstone member forms a very thick cycle of intermixed fine-grained sandstone typical of the basal member and conglomerate of the fluvial Kanayut Conglomerate.

The overlying black shale contains some thin graded beds of fine-grained sandstone that appear to be either turbidites or vertical accumulations of storm-generated sediment overflows. The argillaceous limestone, which appears to form a number of different beds of variable thickness in different areas, contains megafossil debris, including brachiopods, bryozoans, echinoderms, mollusks, and ostracodes. Preliminary examination of these beds suggest a debris-flow origin, because they rest abruptly on and are overlain abruptly by black shale, they are ungraded, have a partly argillaceous matrix, and contain unsorted and chaotic assemblages of calcareous fossil fragments.

The Kayak Shale in general represents a sequence that was deposited in progressively deeper water, except at its top in the central and eastern Brooks Range, where it shoals upward into platform limestone of the Lisburne Group. The basal sandstone represents nearshore deposition, probably in tidal sand flats. Paleocurrent directions from it are highly variable and indicate flow toward the southwest, southeast, and northeast (Nilsen and others, 1980a). The overlying black shale represents deeper marine sedimentation, probably a prodelta slope setting, into which some massive fossiliferous debris flows of argillaceous limestone were resedimented.

MEASURED SECTIONS
Till Creek

The upper part of the Kanayut Conglomerate was measured near the headwaters of Till Creek, approximately 25 km south-southwest of Anaktuvuk Pass (T.36N., R.19W., Wiseman D-3 Quadrangle) in the central Brooks Range (figs. 1, 2, and 4). The section was measured in moderately inclined south-dipping strata in three parts: the lower part on the upper reaches of a northwest-trending ridge about 1 km west of hill 5035 (section 9 and 16), the middle part high on the northern flank of hill 5035 (section 10), and the upper part along the ridge trending southwest from hill 5035 (section 15). The base of the section is bounded by a prominent high-angle fault; the top of the section is conformably overlain by the Kayak Shale and Lisburne Limestone. The section totals 208 m in thickness, with the lower 198 m assigned to the Stuver Member of the Kanayut Conglomerate and the upper 10 m assigned to the Kayak Shale (fig. 5). All of the Ear Peak Member and Shainin Lake Member and an undetermined thickness of the lower part of the Stuver Member are cut out by faults at this location.

The lower 198 m of the section is divisible into twenty fining-upward cycles which range from 4 m to 27 m in thickness and are characteristic of the Stuver Member at its type location (Nilsen and Moore, 1982a). Fourteen cycles consist of a lower sandy and an upper shaley part; the remainder contain only sandstone. The fully developed fining-upward cycles have characteristics similar to cycles deposited by meandering rivers. Cycles which lack shaley upper parts may have had their fine-grained upper parts entirely removed by erosion prior to deposition of the next (overlying) cycle. Alternatively, the latter cycles may represent deposition by meandering rivers transitional in character to braided streams.

The lower sandy intervals of the cycles consist of multiple fining-upward sequences which are separated by erosional surfaces that are commonly marked by oxidized layers and iron-rich concretions. The sandy intervals contain medium- or coarse-grained sandstone at their base which rests erosionally on the underlying cycle. Two cycles are pebbly in their lower parts (at 47 m and 63 m above the base of the section) and contain clasts up to 1 cm in maximum dimension. A third cycle (at 123 m above the base of the section) contains abundant shale rip-up clasts, probably eroded from underlying floodplain deposits. The sandy intervals are mostly trough cross-stratified or parallel-stratified, but are locally massive. Trough cross-strata are medium to large-scale at the base of each cycle, but generally decrease upward in amplitude with grain size, commonly culminating in rippled fine- or very fine-grained sandstone at the top of each sandy interval. The lower sandy parts of the cycles average about 7 m in thickness and are interpreted to be river channel and point bar deposits of meandering rivers.

The upper shaley intervals of the cycles, where best developed, are up to 20 m thick and consist of brown or gray, ripple-marked siltstone which grades upward into fissile, laminated, brown, gray or black shale. Plant fossils are particularly abundant in black shale, but also are present in the other finer grained strata. The shaley intervals locally contain interbedded graded siltstone layers (at 100 m and 175 m above the base of the section) or contain 5-to-50-cm-thick fine- or very fine-grained cross-stratified sandstone (at 50 m and 180 m). The shaley parts of the fining-upward cycles are interpreted to

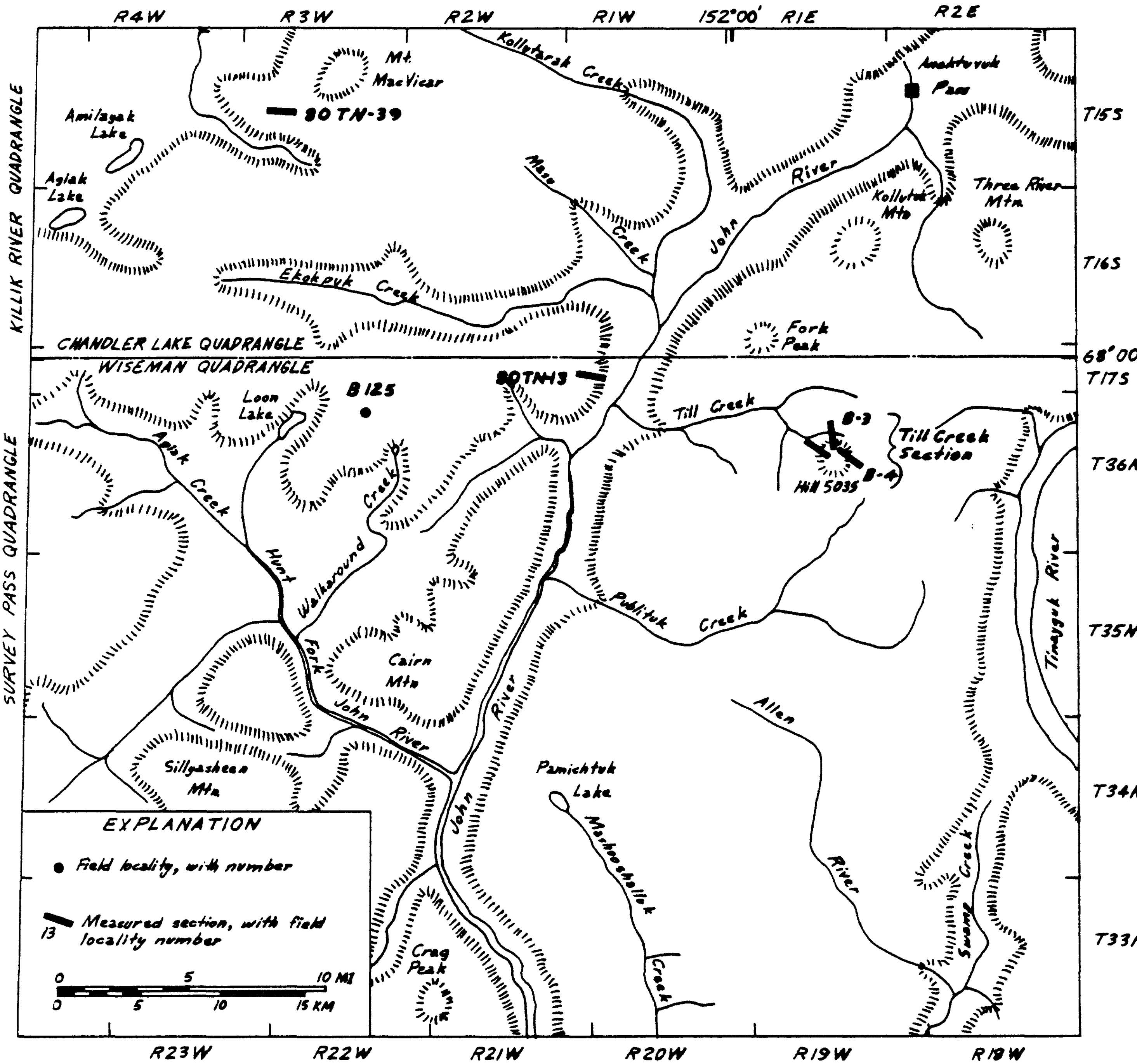
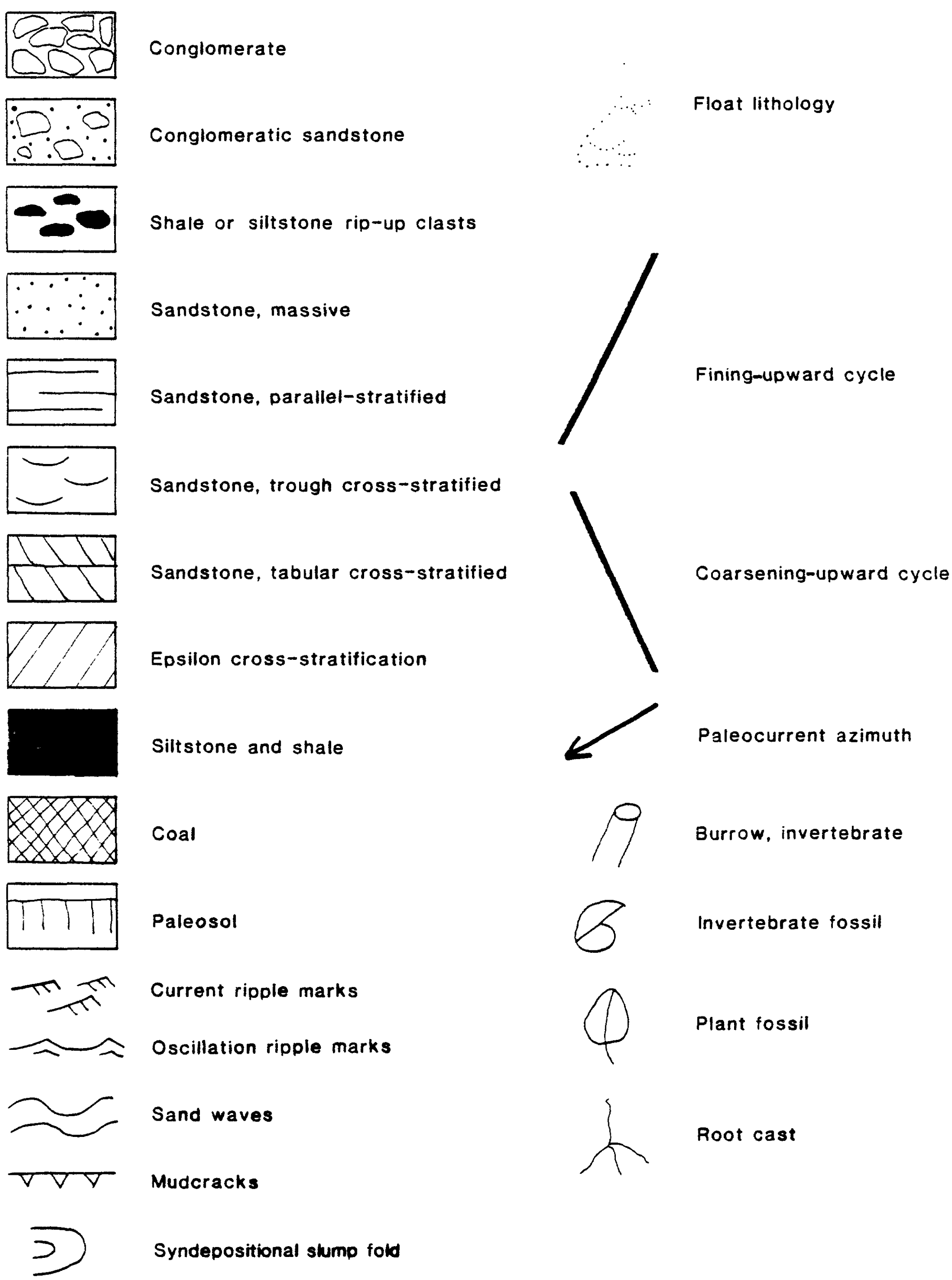


Figure 4.--Index map showing location of measured section of the Kanayut Conglomerate at Till Creek, Central Brooks Range.

SYMBOLS

for figures 5, 7, 8, 10, 11, 12, & 13



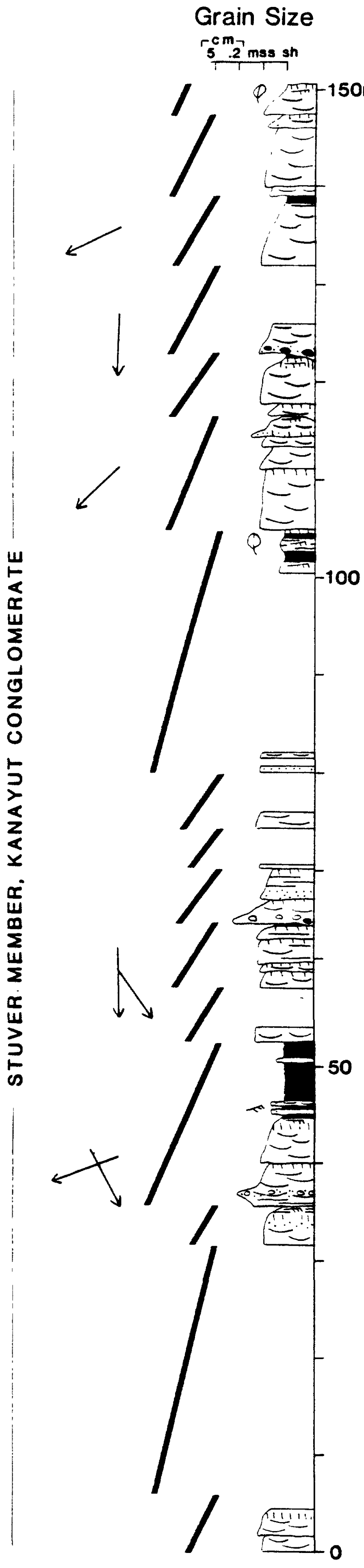
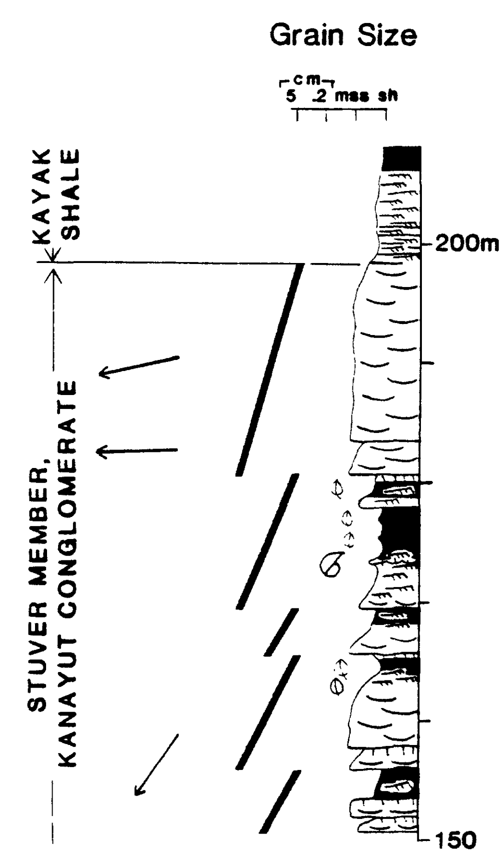


Figure 5.--Measured section of the Stuver Member of the Kanayut Conglomerate at Till Creek, central Brooks Range. See Figures 1 and 4 for location of section.



represent floodplain deposits which have been modified by crevasse-splays and prograding levees. Red oxidized layers present near the top of several cycles are interpreted to represent paleosols developed on the levee-top or floodplain deposits.

The interval from 170 m to 198 m reflects transition from the fluvial Kanayut Conglomerate to the marine Kayak Shale. Because of the dominance of fluvial characteristics, this interval has been assigned to the Stuver Member. Strata between 170 and 180 m comprise a well-developed fining-upward cycle consisting of trough cross-stratified fine- to medium-grained sandstone at its base. This cycle has an erosional base and grades upward into brown and black ripple-marked siltstone. It is overlain by 30 cm of red fine- to very fine-grained sandstone which coarsens up at its base and is marked by oscillation ripple markings which may be indicative of intertidal deposition. The overlying 70 cm of bright red shale (at 174 m) contains abundant, well-preserved brachiopods of latest Famennian age (J. T. Dutro, written commun., 1982) which are also indicative of marine deposition but were probably modified by later development of a paleosol. These fauna, within the upper 30 m of the Kanayut Conglomerate, also indicate that the Kanayut is wholly Devonian in age at this location rather than possibly partly Mississippian as at other locations in the Brooks Range (Nilsen and Moore, 1982a).

The interval between 174 m to 178 m consists of black shale and siltstone with abundant plant fragments. It is overlain by a single 2-m-thick fining-upward sequence containing a basal fine- to medium-grained sandstone that is capped by a paleosol developed in brown and black siltstone. Above this is 14 m of multiple fining-upward sequences of trough cross-stratified medium- to fine-grained sandstone with no intervening shale. This thick sandstone unit contains rare oxidized horizons (paleosols?) and is interpreted to represent fluvial channel and point bar deposits. We believe that the mixed fluvial and marine strata at the top of the Stuver Member reflect interfingering of sediment deposited in interdistributary bays, brackish water swamps, freshwater lakes, fluvial channels, point bars and floodplains.

The thick sandstone unit at the top of the Stuver Member fines upward into 7.5 m of interbedded brown, very fine-grained sandstone and siltstone of the basal sandstone member of the Kayak Shale. The basal sandstone member is thinly bedded, micaceous and contains abundant ripple markings. It is interpreted to have been deposited under nearshore marine and intertidal conditions, and grades upwards into offshore marine black shale and mudstone of the overlying shale member of the Kayak Shale.

Eight paleocurrent measurements obtained from axes of trough cross-strata in the lower part of the measured section indicate that sediment transport was toward the south. Two paleocurrents from trough cross-strata in the thick sandstone unit at the top of the Stuver member, however, indicate that sediment transport had changed toward the west. The azimuthal vector mean of all ten measurements from the Stuver Member is 228° with a standard deviation of 53°.

Kakivilak Creek

Two sections of the upper Kanayut Conglomerate and lower Kayak Shale were measured in the upper reaches of Kakivilak Creek, about 20 km south-southwest of Kurupa Lake and 50 km southeast of the Lisburne Well site (T.32N., R.18E., Killik River quadrangle), west-central Brooks Range (figs. 1, 2, and 6). The first section (section A, fig. 7) is 440 m thick and includes the upper part of the Ear Peak Member, the entire Shainin Lake and Stuver Members and the lower part of the Kayak Shale. It was measured along the ridge flank east of the southwestward-flowing tributary of Kakivilak Creek, in section 7. The second section (section B, fig. 7) is 123 m thick and includes a more detailed, interesting, and better-exposed transitional sequence from the upper Stuver Member into the basal sandstone member of the Kayak Shale. It was measured along a small west-flowing tributary to the southwest-flowing tributary mentioned above, in section 18. Section B contains spectacular examples of channel downcutting, synsedimentary slumping, coal, and interfingering of marine and nonmarine facies.

A shale-rich sequence that includes a single fining-upward cycle that is 32 m thick composes the measured part of the Ear Peak Member (section A, fig. 7, from 0 to 32 m above the base of the section). This very thick cycle contains about 7 m of conglomerate and sandstone at its base and about 25 m of maroon shale with some interstratified ripple-marked siltstone at its top. The lowest conglomerate bed contains a maximum clast size of 3 cm and grades irregularly upward into about 5 m of trough cross-stratified fine- to medium-grained sandstone. The top of the coarse-grained part of the cycle consists of 15 cm of current ripple-marked fine-grained sandstone. Within the overlying shale and siltsone are abundant plant fragments and some red and orange weathered zones that we interpret to be poorly developed paleosols. No paleocurrents were measured in the Ear Peak Member. We interpret the cycle to represent deposition by a meandering stream.

The Shainin Lake Member is about 63 m thick, extending from 42 m to 105 m above the base of section A (fig. 7). It consists almost wholly of interbedded conglomerate and sandstone, with virtually no shale contained within it. Its base and top, however, are marked by thick maroon and black shale intervals, respectively. In addition, some of the covered intervals in the Shainin Lake Member, which total about 6 m or 8-12 percent of the section, may contain some shale partings.

Subdivision of the Shainin Lake Member into fining-upward cycles is possible, but the cycles are not well-defined by shale breaks and the cycles could easily be defined differently by other workers. We subdivide the Shainin Lake member into 5 cycles that average about 13 m in thickness. The Shainin Lake Member appears to be coarsest in its middle part, where clasts as long as 3 cm are present, and finer in its lower and upper parts.

Most of the section is similar to the Shainin Lake Member farther to the east. It consists of repetitive fining-upward couplets of massive to crudely parallel-stratified conglomerate and conglomeratic sandstone overlain by trough cross-stratified fine- to medium-grained sandstone. Individual beds are generally lenticular and abundant small-scale channeling is present. Ripple-marked fine-grained sandstone and siltstone is uncommon. Rip-up clasts of shale are common in some beds of conglomerate and sandstone. Two

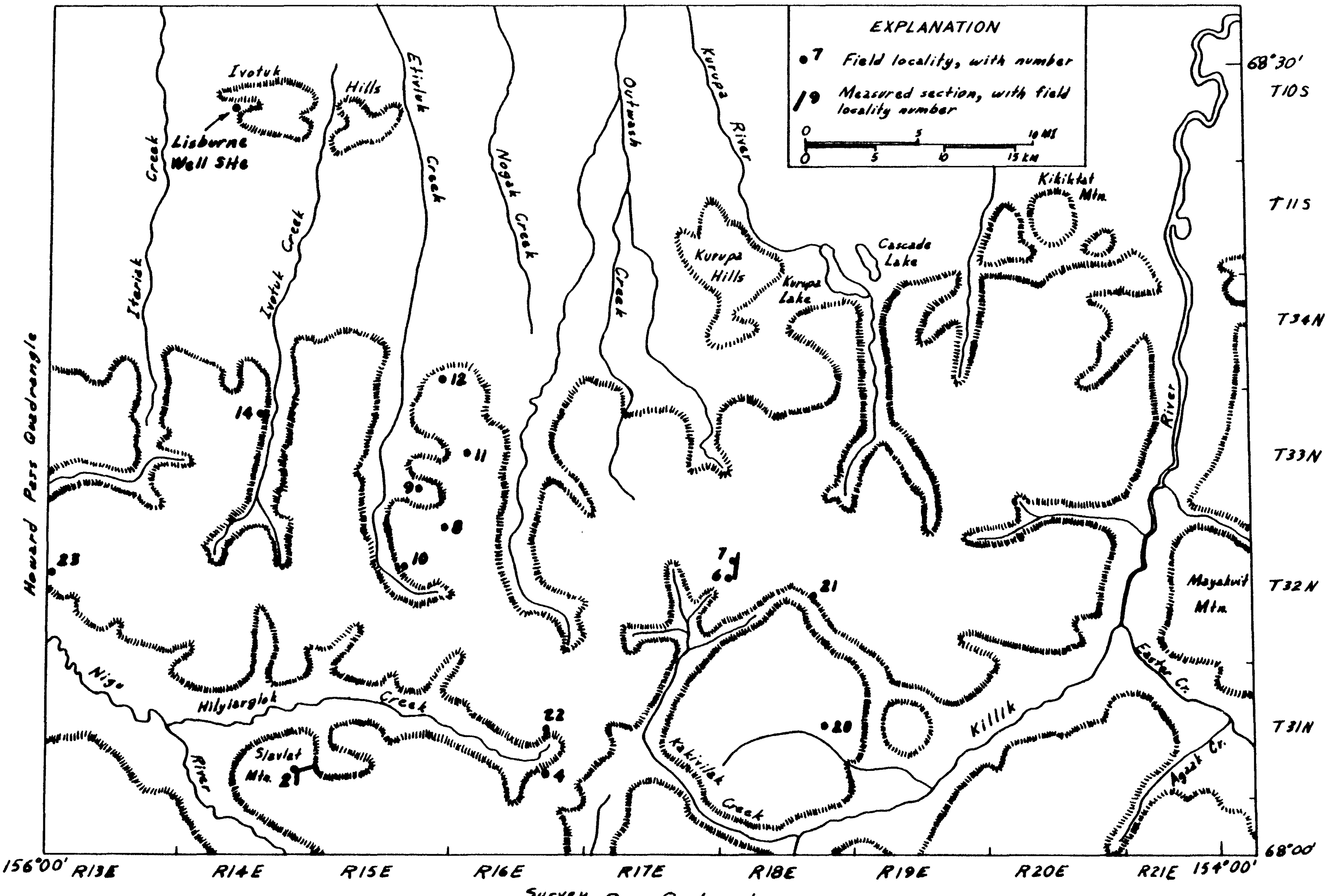


Figure 6.--Index map of west-central Brooks Range showing field localities and measured sections. Map area is in southwest corner of Killik River quadrangle; see Figure 1 for location.

paleocurrent measurements of primary current lineation from the Shainin Lake Member suggest sediment transport to the southwest and south (234° and 173°). We infer that the Shainin Lake Member was deposited by braided streams; however, the streams were transporting finer clast sizes than in areas farther to the east, and the cyclic arrangement of bedding thickness and coarseness suggests a suite of streams with characteristics reflecting the transition from braided to meandering.

The Stuver Member is 323 m thick in section A, extending from 105 m to 428 m above the base of the section. In section B, a partial thickness of 117 m was measured in its upper part from 0 to 117 m above the base of the section. The lower part of the Stuver consists of well-developed fining-upward cycles characteristic of the Stuver in section farther to the east. The upper part, however, is more complex and contains numerous interbeds of marine and intertidal facies more characteristic of the basal sandstone member of the Kayak Shale.

The uppermost well-defined fining-upward fluvial cycle of the Stuver is present between 300 and 350 m above the base of section A and between 0 and 43 m above the base of section B. Based on stratigraphic and geometric relationships in the field, we believe that these fining-upward cycles are correlative and represent the uppermost completely nonmarine part of the Kanayut Conglomerate. The uppermost 78 m of section A (from 350 m to 428 m above the base of the section) and the uppermost 74 m of section B (from 43 m to 117 m above the base of the section) represent the transitional, mixed fluvial and marine sequence, related on a larger scale to interfingering of the upper Stuver Member and basal sandstone member of the Kayak Shale.

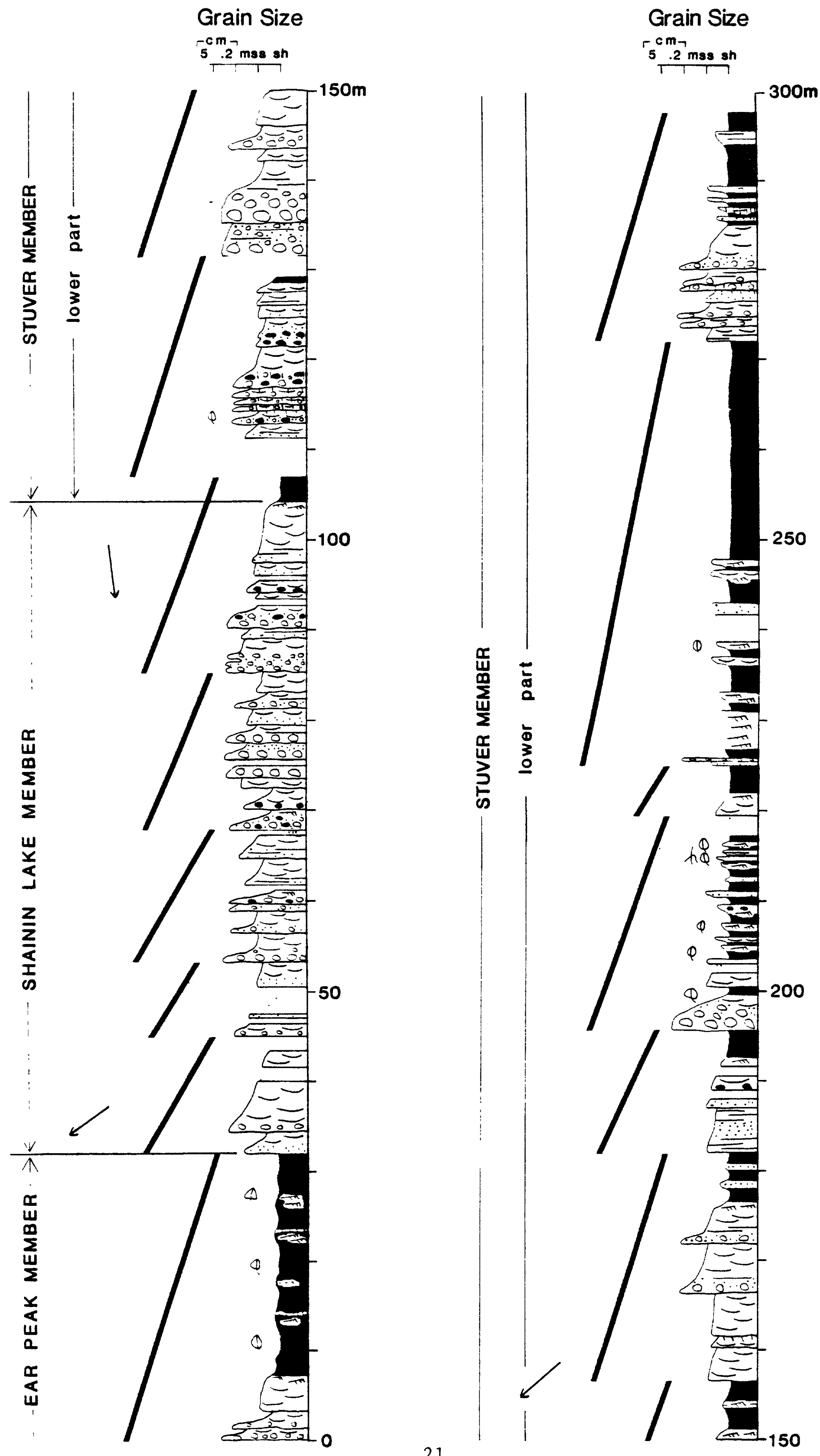
The lower 245 m of the Stuver Member, its wholly fluvial part, can be subdivided into 9 fining-upward cycles that typically have conglomerate at the base and shale at the top. The cycles average about 27 m in thickness, of which about 1/3 of the thickness consists of shale. The cycles generally increase in thickness upsection. The thickness of these cycles is much greater than most cycles in the Stuver Member to the east of Kakivilak Creek, suggesting that rivers were larger in this area and floodplains more extensively developed.

The maximum clast size of the lower Stuver Member is 3 cm, and the clast size generally decreases upsection into the upper transitional part of the Stuver Member. The conglomerate is commonly present at the base of each cycle, but also forms interbeds within the lower parts of cycles. Shale rip-up clasts are present within the cycles, particularly in the lower part of the Stuver.

Most sandstone beds within the Stuver are fine- to medium-grained and have trough cross-strata. The trough cross-strata decrease upward in amplitude, eventually passing into ripple-marked very fine-grained sandstone and siltstone. The ripple-marked sandstone intervals may contain abundant plant fragments and, locally, root impressions. Paleosols are present in some sandstone-rich sequences, such as in the lowest cycle of the Stuver member (between 110 m and 120 m above the base of the section).

The shale intervals of the lower Stuver Member are as thick as 25 m. They are varicolored, including black, gray, maroon, red, brown, orange, and

Figure 7A.--Measured sections at Kakivilak Creek, west-central Brooks Range. A, Shainin Lake and Stuver Members.


Grain Size
cm
5 .2 mss sh
150m
100
50
0
STUVER MEMBER
lower part
SHAININ LAKE MEMBER
EAR PEAK MEMBER
Grain Size
cm
5 .2 mss sh
300m
250
200
150
STUVER MEMBER
lower part

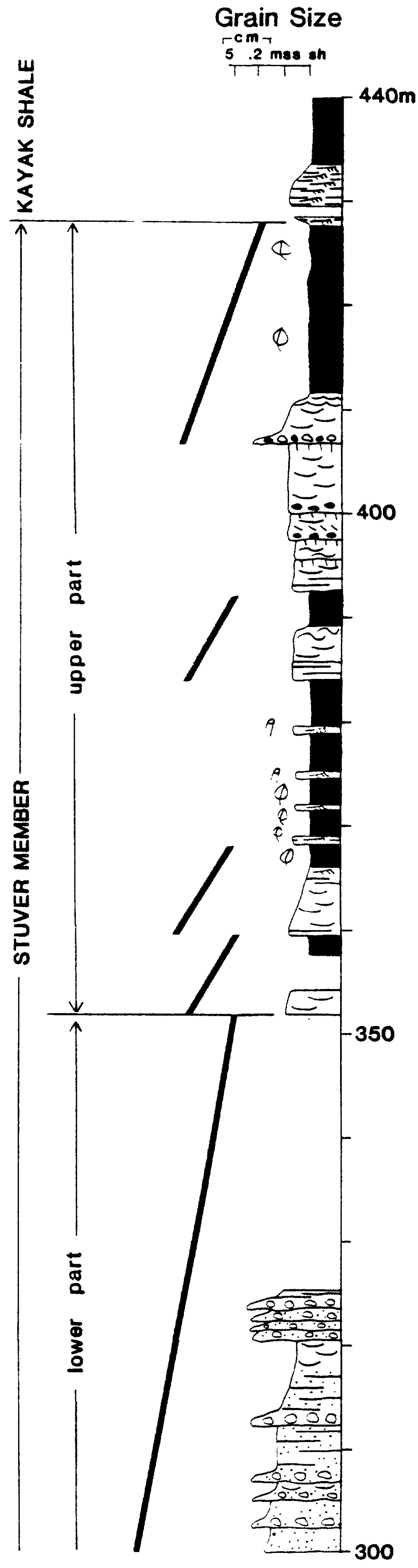


Figure 7A--Continued

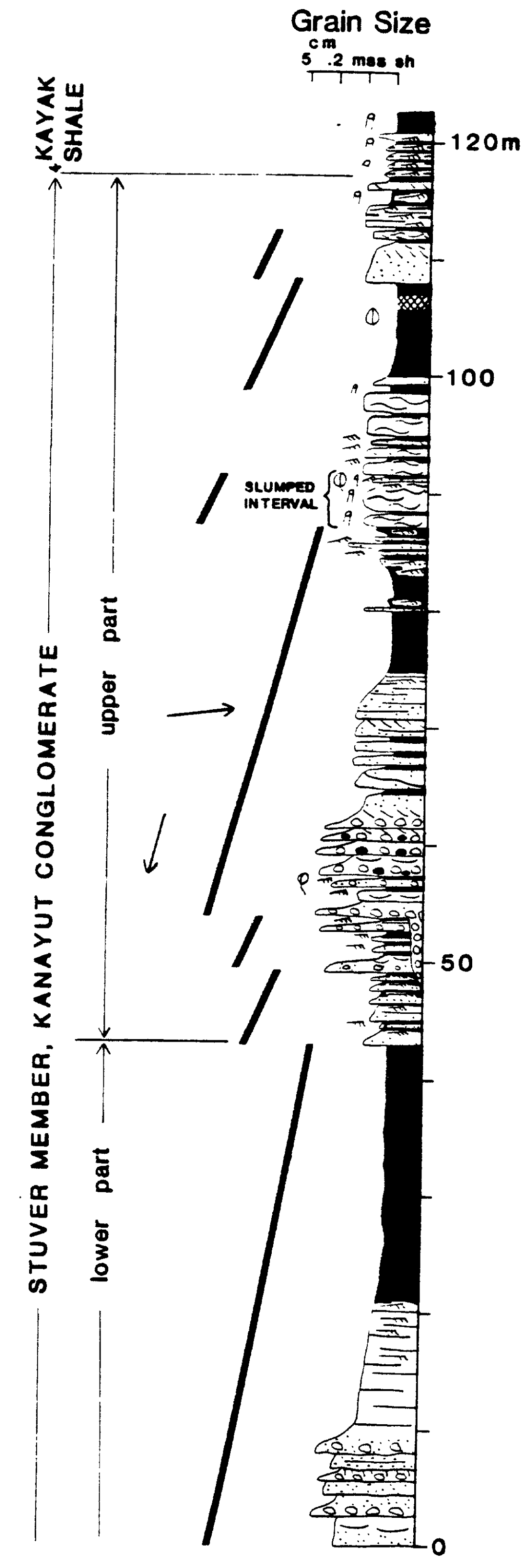


Figure 7B.--Measured sections at Kakivilak Creek, west-central Brooks Range. B, Uppermost part of the Stuver Member and basal part of Kayak Shale. See Figures 1 and 6 for location of section.

yellow. Plant fossils are abundant in some of the shale intervals, especially the black shales. Paleosols are very common in some shale sequences. Thin coarsening-upward cycles that are 1 to 3 m thick and in some places capped by paleosols are common is some shale intervals, particularly between 200 m and 300 m above the base of section A. These thin cycles contain mostly laminated and ripple-marked fine-grained sandstone and siltstone and are interpreted to be formed by levees prograding out over floodplains.

Only one paleocurrent measurement was taken from the lower wholly fluvial part of the Stuver Member. Measured from the trough axis of a trough cross-strata set, it indicates sediment transport to the southwest (229°). We interpret the lower part of the Stuver to have been deposited by meandering streams, with broad floodplain areas.

The upper part of the Stuver Member, approximately 75 m thick, consists of both fluvial and marine rocks. The upper contact with the basal sandstone member of the Kayak Shale is placed by us at the base of the continuous sequence of fine-grained, ripple-marked, bioturbated sandstone that does not contain any interbedded coarser flat-stratified or cross-stratified sandstone, conglomerate, or plant-bearing shale (fig. 7A, B).

In section A, almost 50 percent of the upper Stuver Member consists of black shale with abundant plant debris. The lower part consists of two thin fining-upward cycles (from 352 m to 368 m above the base of the section) that appear to be typical of most fining-upward fluvial cycles in the Stuver Member except that no conglomerate is present and the cycles average only 8 m in thickness. The overlying 16 m consists mostly of black, plant-bearing shale with interbeds of current ripple-marked very fine- to fine-grained sandstone and siltstone. Some of these interbeds have marine burrows, indicating deposition on a floodplain that was partly inundated by marine waters from time to time, possibly in an interdistributary bay at the margins of the Kanayut delta.

Overlying the shaley, possible interdistributary-bay interval is a 9-m-thick fining-upward cycle (from 384 m to 393 m above the base of this section) that contains wavy bedding and herringbone cross-strata in its middle part. This suggests that marine or tidal currents influenced deposition of sands within a probable fluvial channel near the margins of the delta.

The uppermost cycle (from 393 m to 408 m above the base of the section) of the Stuver Member in section A is very complex. The coarser grained part appears in a gross way to coarsen upward and then fine upward at the top. A conglomeratic bed near the top contains pebbles as long as 1 cm. Four paleosols are present within the cycle, indicating subaerial exposure. Rip-up clasts of paleosol material are present in three beds that directly overlie and have erosive contacts with the paleosols. Wavy bedding and oscillation ripple markings suggestive of marine or tidal currents are present in the lower and upper parts of the coarser part of the cycle. Almost 17 m of the black, carbonaceous, plant-bearing shale that does not contain any marine burrows forms the top of the Stuver Member in section A.

The upper part of the Stuver Member in section B, from 43 m to 117 m above the base of the section, is more complex than that of section A (fig. 7). The lower two thin fining-upward cycles may correlate with the two thin fining-upward cycles in the lower part of the Stuver in section A. These cycles,from 43 m to 54 m above the base of the section, consist mostly of fine-grained or very fine-grained sandstone that is trough cross-stratified laminated and ripple-marked. The cycles average 5.5 m thick and the upper cycle contains an unusual bed of conglomerate near its top.

Both of these thin, lower fluvial cycles are cut into by a major conglomerate-filled channel that forms the base of a very thick and complexly organized fining-upward cycle. This cycle is 33 m thick and extends to 87 m above the base of the section. It contains abundant conglomerate, with clasts as long as 3 cm, and several intervals of rip-up clasts. Trough cross-strata are abundant in the lower part of the cycle and tabular cross-strata in the upper part. No sedimentary features that are clearly marine or tidal were noted in the section, which appears to be mostly, if not completely, fluvial in origin. The upper 12 m of the cycle consists mostly of black shale with thin coarsening-upward cycles of current ripple-marked siltstone and very fine-grained sandstone that we interpret to be prograding levee deposits. It is interesting to note that this thick, coarse-grained, fluvial cycle correlates with the thick, fine-grained, lowest marine or partly marine interval of section A. This marked change in facies over a distance of about 1 km is consistent with the abrupt facies changes noted in most modern delta-front settings.

Above the thick cycle is a thin, generally fining-upward cycle that extends for 87 m to 91 m above the base of the section. The entire 4-m-thick cycle is contorted, folded and deformed by apparent synsedimentary slumping. Wavy bedding in sandstone units, shale drapes, and marine burrows suggest a marine origin for this cycle, which is capped by a thin black shale that contains abundant plant fossils and marine burrows. The disturbed nature of this unit suggests delta-front instability, possibly as a result of sediment loading or seismicity.

The overlying 8 m consists of interbedded fine- to medium-grained sandstone that is characterized by wavy bedding, lens-shaped beds, tabular cross-strata and current ripple markings, and black shale and ripple-marked siltstone. We consider this interval to be of marine or tidal origin.

Overlying this interval is a fining-upward cycle that is dominantly fluvial in origin but contains a marine-influenced basal bed. The cycle, from 99 m to 108 m above the base of the section, is capped by black shale that contains a coal that is several meters thick. At the base of the black shale is a poorly developed paleosol.

The uppermost 9 m of the Stuver Member in section B consists of lens-shaped beds of fine- to medium-grained sandstone that contain wavy bedding, tabular cross-strata, and current ripple markings. Some thin black shale intervals separate the beds of sandstone. Marine burrows are present in one shale interval. Except for possibly the base of the 9 m-thick sequence which consists of a fining-upward massive bed of medium-grained sandstone that is channeled into the underlying black shale, this part of the Stuver appears to be mostly of marine or tidal origin.

Two paleocurrent measurements from the upper Stuver Member indicate sediment transport to the south (195°) and east (83°). Both measurements were from tabular cross-strata within the thick, probably mostly fluvial cycle in section B. The Kayak Shale in both section A and B consists of thinly bedded, very fine- to fine-grained, current ripple-marked, bioturbated sandstone interbedded with bioturbated black shale. The sandstone beds of the basal Kayak are generally less than 5 cm thick and contain almost omnipresent ripple markings.

Siavlat Mountain

A complete section of the Kanayut Conglomerate was measured along the northeast flank of Siavlat Mountain, about 50 km south of the Lisburne Well site in the Killik River quadrangle (S.25, T.31N., R.14E) west-central Brooks Range (figs. 1, 2, and 6). The lower part of the section was measured up a steep ridge forming the northeast flank of Siavlat Mountain and the upper part down a dip slope into a small saddle in which the lower part of the overlying Kayak Shale is preserved. About 79 m of the underlying Noatak Sandstone, 228 m of the Kanayut Conglomerate, and 12 m of the Kayak Shale were measured, a total thickness of 319 m of section (fig. 8).

The upper Noatak Sandstone consists of alternating beds of very fine-, fine-, and fine- to medium-grained sandstone that are not organized into distinct fining- or coarsening-upward cycles. The finer grained beds contain subparallel laminations and ripple-markings, the coarser grained beds trough cross-strata or, locally, wavy bedding and parallel stratification. Tabular cross-strata are common in beds of fine- to medium-grained sandstone in the upper 12 m of the measured section. The ripple markings are mostly current ripple markings, but wave or oscillation ripple markings are also common. The unit is generally flaggy, with bedding thicknesses that range from 1 to 10 cm and average about 3 cm.

One thin interbed of black shale is present at about 52 m above the base of the section. Shale partings are common in many of the sandstone beds, especially as thin drapes over well-preserved wave ripples. Shale rip-up clasts are present in one bed of trough cross-stratified and wavy bedded fine- to medium-grained sandstone at 76 m above the base of the section. Most of the covered intervals, which form 49 m of the total 79 m for the Noatak appear to be underlain by sandstone rather than shale. Thus, the Noatak Sandstone in this area appears to contain fewer shale breaks than the Kanayut Conglomerate.

Marine burrows are abundant throughout the Noatak section but are generally confined to the laminated and rippled finer grained beds of sandstone and shale. No megafossils were found in the section.

Seven paleocurrent measurements were obtained from medium-scale trough cross-strata, tabular cross-strata, primary current lineations, and current ripple markings. They indicate dominant flow toward the west-southwest, with a mean of 252° for six measurements with that orientation; the seventh measurement indicates current flow to the southeast (141°). The azimuthal vector mean and standard deviation of all seven measurements is $234^{\circ} \pm 78^{\circ}$.

The upper Noatak Sandstone in the Siavlat Mountain area appears representative of sedimentation on a marine shelf characterized by flow of currents across the shelf, chiefly toward the west-southwest, the probable offshore direction. Wave ripples suggest water depths were probably less than

30 m and abundant bioturbation indicates the presence of infauna. The lack of prominent depositional cycles suggest shelf deposition in an area distant from channel-mouth bars and progradational cycles associated with the Kanayut delta. We estimated in the field an additional 200 m of Noatak below the base of the measured section, suggesting a total thickness for the Noatak at Siavlat Mountain of about 280 m.

The Kanayut Conglomerate at Siavlat Mountain can be roughly divided into three units that may correlate with its three members as defined at Shainin Lake in the east-central Brooks Range (Bowsher and Dutro, 1957; Nilsen and Moore, 1982a). Mapping by Brosge and others (1982, Plate 1) shows the presence of only the Ear Peak Member and Stuver Member at Siavlat Mountain. However, our measured section consists of the following units in ascending order: (1) 67 m of fining-upward cycles interbedded with fine- to medium-grained sandstone with some very thin shale breaks (from 79 m to 146 m in the section); (2) 122 m of fining-upward cycles of conglomerate, sandstone and shale (from 146 m to 268 m in the section); and (3) 39 m of fining-upward cycles of sandstone with thicker shale breaks (from 268 m to 307 m in the section). These three units do not exactly fit the definitions of the three members of the Kanayut proposed by Nilsen and Moore (1982a); in this preliminary report, they will be informally referred to as units 1, 2 and 3 in ascending stratigraphic order.

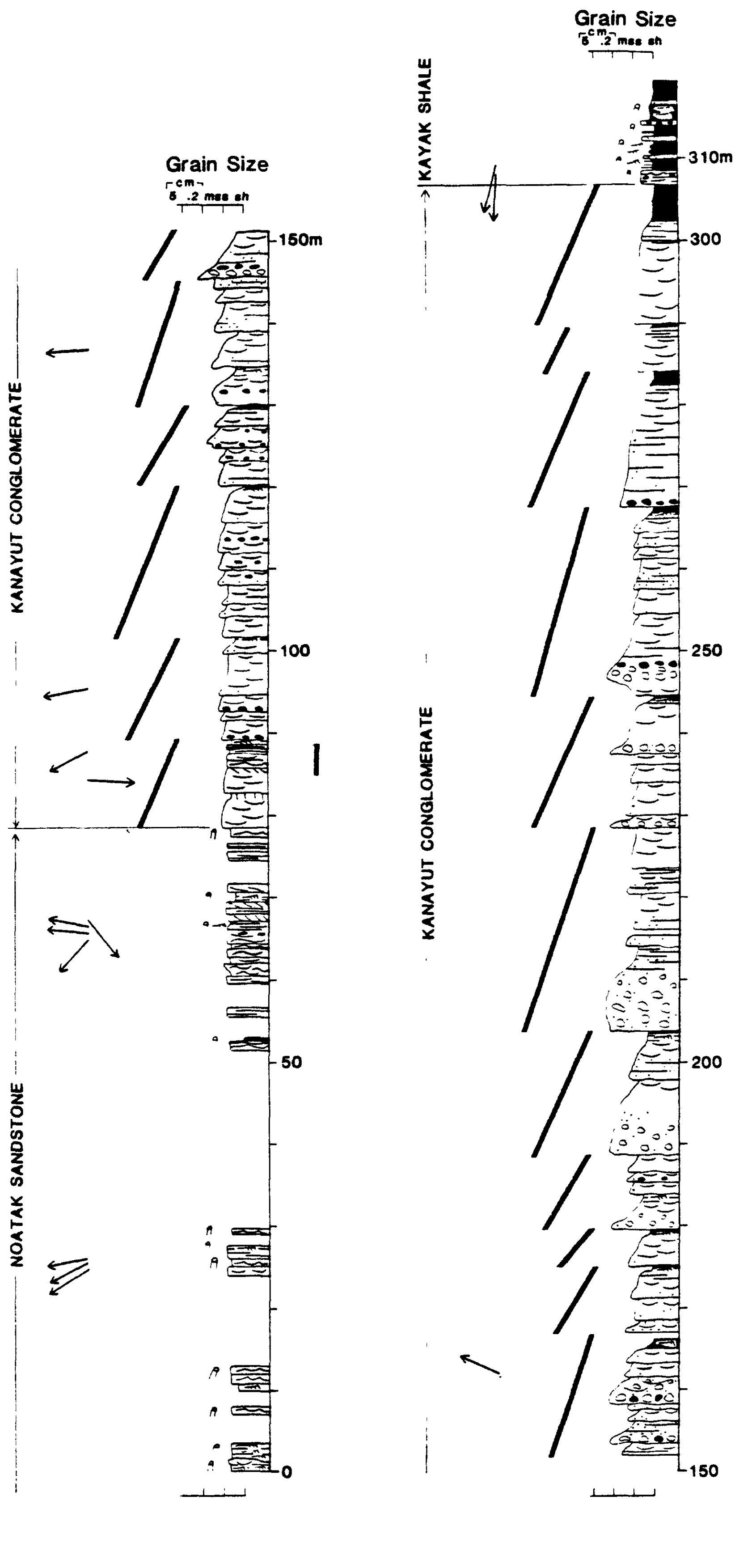
Unit 1 can be subdivided into five fining-upward cycles that average 13.4 m in thickness. Shale is almost totally lacking except as thin partings associated with ripple-marked very fine-grained sandstone at the tops of the cycles. However, rip-up clasts of the shale are abundant throughout unit 1 and suggest that shale was originally deposited on surrounding floodplains but was stripped away by erosion during channel migration. Unit 1 gradually coarsens upward, containing chiefly fine- to medium-grained sandstone in its lower cycles and medium- to coarse-grained sandstone in its upper cycles.

A soil horizon is present about 4 m above the base of the lowest cycle and indicates subaerial weathering. Above the soil horizon is a medium-grained, trough cross-stratified sandstone that is 2.7 m thick. It is in turn overlain by about one meter of marine strata that contains oscillation ripple markings and shale drapes (86-87 m above the base of the section). Thus, the lowest fluvial cycle of the Kanayut at Siavlat Mountain contains one marine interbed in its upper part.

Paleocurrents from primary current lineations in unit 1 suggest sedimentary transport toward the west-southwest, with an azimuthal mean of 255° based on these measurements. A single paleocurrent from the marine interval in the lowest cycle, based on measurement of tabular cross-strata, suggests eastward sediment transport, with an azimuthal direction of 93°. This suggests that marine currents, possibly during a storm interval, washed and transported sand into the mouth of a river channel along the margins of the Kanayut delta.

Unit 2 of the Kanayut Conglomerate can be subdivided into nine fining-upward cycles that average 13.6 m in thickness, approximately the same as those from unit 1. The conglomerate in unit 2 has a maximum clast size of 1.5 cm. Beds of massive conglomerate and conglomeratic sandstone at the base of fining-upward cycles are as thick as 9 m. Most cycles in unit 2 consist, in

Figure 8.--Measured section of the upper part of the Noatak Sandstone, the Kanayut Conglomerate, and the basal part of the Kayak Shale at Siavlat Mountain, west-central Brooks Range. See Figures 1 and 6 for location of section.


Grain Size
cm
5 .2 mss sh
150m
100
50
0
KANAYUT CONGLOMERATE
NOATAK SANDSTONE
Grain Size
cm
5 .2 mss sh
KAYAK SHALE
310m
300
250
200
150
KANAYUT CONGLOMERATE

ascending order, of a basal massive conglomerate or conglomeratic sandstone that may contain rip-up clasts of shale, parallel-stratified coarse-grained sandstone, trough cross-stratified fine- to coarse-grained sandstone, laminated and ripple-marked very fine- to fine-grained sandstone and siltstone, and shale that ranges in color from black to red-brown. Shale is present at the top of only 5 of the 9 cycles of unit 2. The basal massive beds are typically channeled into the shale or thinly interbedded very fine-grained sandstone and siltstone. One paleocurrent measurement of primary current lineation indicates flow toward the west-north-west, 294^{o}.

Unit 3 of the Kanayut Conglomerate consists of 3 fining-upward cycles that average 13 m in thickness. Unit 3 has shale intervals as thick as 5 m and the lowest conglomerate and sandstone to shale ratio in the Kanayut at Siavlat Mountain. In fact, it contains no conglomerate; the lowest cycle starts with very coarse-grained sandstone that contains abundant rip-up clasts of shale and the two overlying cycles start with trough cross-stratified fine-to medium-grained sandstone. The shale at the tops of the cycles is black. Fine to medium-grained, trough cross-stratified sandstone is the dominant bed type in unit 3. No paleocurrents were measured from unit 3. The azimuthal vector mean and standard deviation of 7 paleocurrent measurements from the Kanayut Conglomerate at Siavlat Mountain is $235^{o} \pm 69^{o}$.

The basal sandstone member of the Kayak Shale, of which about 12 m was measured, consists of three interstratified lithologies: (1) fine-grained, cross-stratified sandstone, (2) interlaminated very fine-grained ripple-marked sandstone, siltstone, and shale, and (3) black shale.

The sandstone is quartzitic and has a siliceous cement. Marine burrows are common in the finer grained strata, although no megafossils were found in place. The cross-stratified beds are characterized by tabular cross-strata and are locally lens-shaped. One bed contains imbricated rip-up clasts of mudstone throughout and a second contains herringbone cross-strata suggestive of reversing current flows and tidal influence. The ripple-marked sandstone unit contains mostly current ripple markings with shale drapes, forming flaser bedding. The black shale unit is extensively burrowed and platy in character.

Two paleocurrents measured from medium-scale cross-strata in the lower part of the Kayak indicate southerly current flow with an azimuthal mean of 194^{o}. The general character of the basal sandstone of the Kayak suggests nearshore marine and intertidal sedimentation. Current velocities were generally low, and only fine-grained, texturally and compositionally mature sediment was deposited.

"Husky" Mountains

Three sections of Kanayut Conglomerate, labeled A, B, and C, were measured in the "Husky" Mountains about 65 km north-northeast of the town of Noatak and northwest of the confluence of the Noatak and Kelly Rivers (fig. 9). Section A (field locality 81-TN-36) was measured along a west-trending ridge spur (S.14, T.31N., R.17W., DeLong Mountains quadrangle) across the contact of the Noatak Sandstone and Kanayut Conglomerate (fig. 10). Section B (field locality 81-TN-34) was measured along a north-trending ridge spur (S.9, T.31N., R,17W., DeLong Mountains quadrangle) across the contact of the Kanayut Conglomerate and Kayak Shale (fig. 11). Section C (field locality 81-TN-33) was measured along a southwest-trending ridge crest (S.16, T.31N., R.17W., DeLong Mountains quadrangle) across the contact of the Noatak Sandstone and Kanayut Conglomerate, but consists mostly of Kanayut Conglomerate (fig. 12).

The three sections provide a general framework for understanding the stratigraphy of the Endicott Group and, in particular, the Kanayut Conglomerate in the "Husky" Mountains. The lower contact of the Kanayut is well observed in sections A and C, and the upper part in section B. Unfortunately, we were not able to measure a complete section of the Kanayut Conglomerate. Incomplete thicknesses of about 140 m, 58 m, and 233 m of Kanayut were measured in sections A, B and C, respectively. We believe that the 233 m of Kanayut measured in section C is close to the total thickness of Kanayut in the "Husky" Mountains, which is probably on the order of 250-300 m. The stratigraphy of the region is discussed in ascending stratigraphic order.

The Noatak Sandstone underlies the Kanayut and is probably at least a couple of hundred meters thick. We measured a few meters of it in section A and about 18 m of it in section C. We estimated a thickness of about 100 m of Noatak Sandstone at section C, which is bounded by a fault at its base.

In section A, the uppermost part of the Noatak consists of alternating beds of conglomeratic, coarse-grained sandstone and medium-grained sandstone. The maximum clast size observed was 1 cm. The sandstone is trough cross-stratified and calcareous, with bedding thicknesses of 5 to 15 cm. In section C, the Noatak consists of similar medium- to coarse-grained, trough cross-stratified, calcareous sandstone that contains interstratified intervals of bioturbated, massive, fine- to medium-grained calcareous sandstone. Beneath the measured interval of section C, the Noatak Sandstone contains some conglomerate, with a maximum clast size of 3 cm; and there are some scattered fragments of plant fossils in it. No shale or mudstone was observed in either section of the Noatak.

The Kanayut Conglomerate consists of a series of repetitive fining-upward cycles that are commonly separated by red or black shale intervals. Eleven cycles from the lower Kanayut, averaging about 13 m in thickness, are present in section A, 4 cycles from the upper Kanayut, averaging 14.5 m in thickness, are present in section B, and 27 cycles from the lower, middle, and possibly upper Kanayut, averaging about 8.5 m in thickness, are present in section C. The cycles typically begin with a conglomerate or sandstone that overlies and is channeled into shale.

The lower part of the Kanayut in sections A and C contains interstratified marine rocks in the cycles. These marine rocks, consisting of principally trough cross-stratified sandstone and conglomeratic sandstone, resemble very closely the underlying Noatak Sandstone. The marine rocks have a calcareous cement, locally contain marine burrows, and are present in the middle parts of the otherwise fluvial cycles. Some paleocurrents measured from the marine parts of the cycles indicate flow directions toward the east-southeast rather than west-southwest, as the paleocurrents from the fluvial parts of the cycles indicate. The marine rocks are shown in sections A and C with vertical lines to the right of the sections, under the heading "carbonate cement" (figs. 10 and 12).

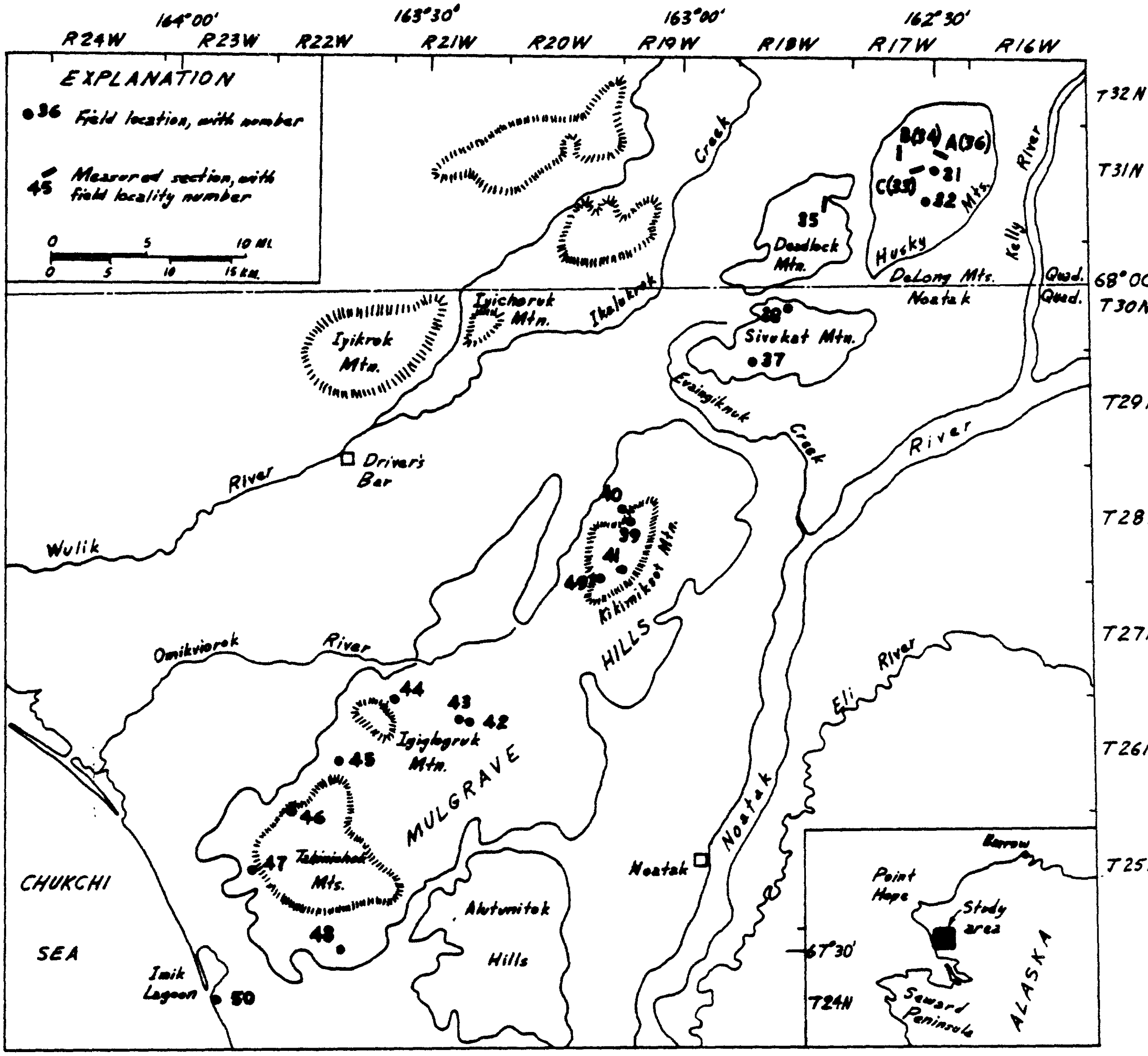


Figure 9.--Index map to the Mulgrave Hills region of the western Brooks Range showing field localities and measured sections.

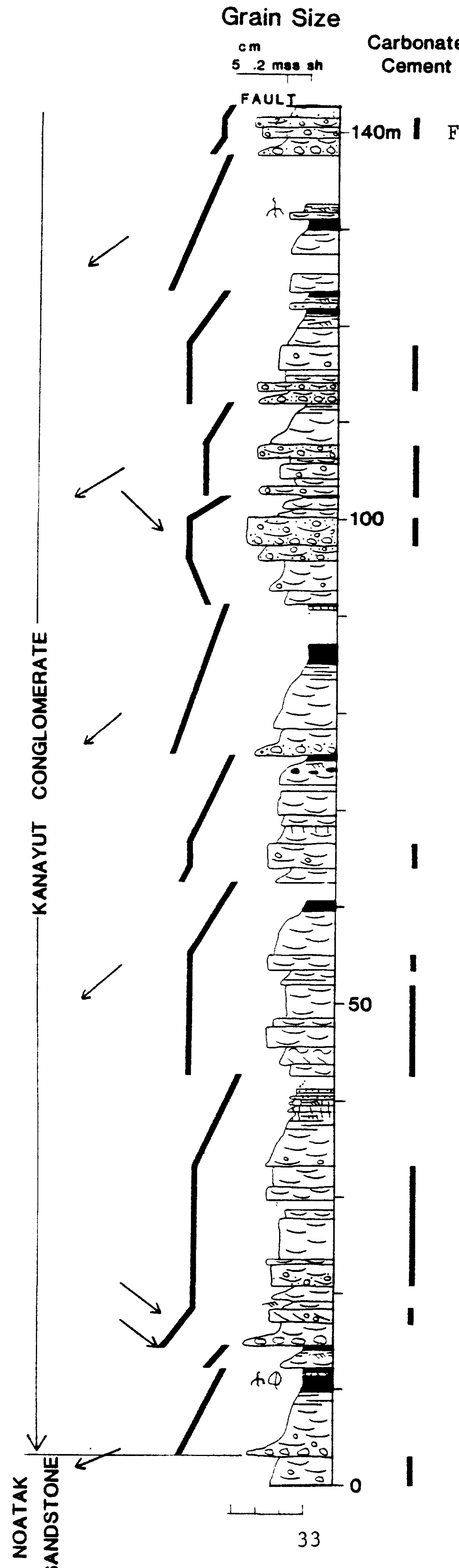
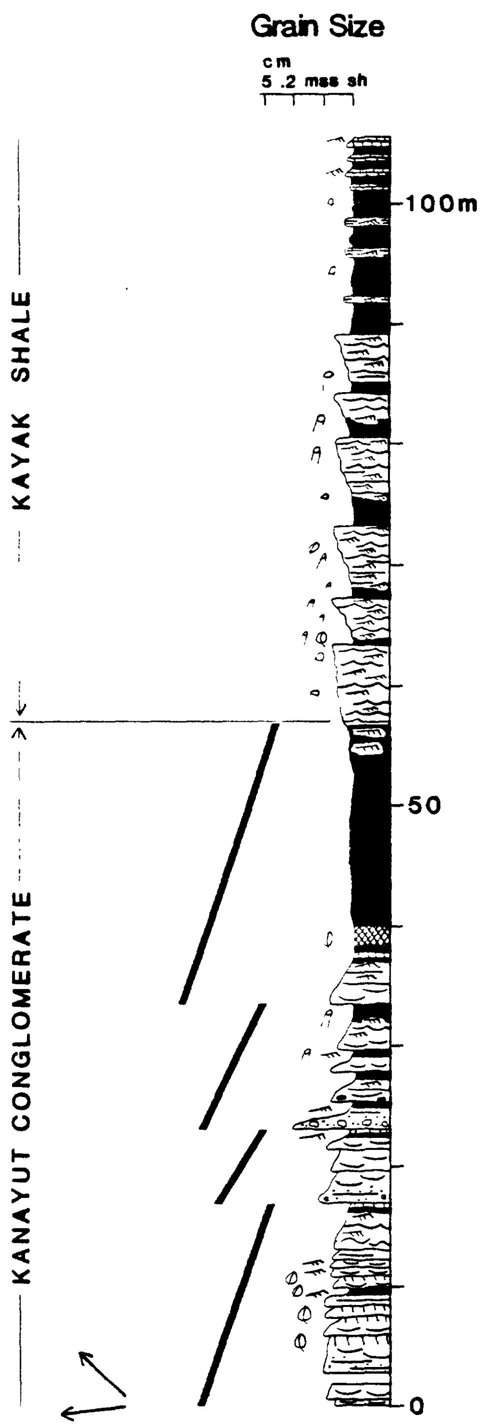


Figure 10.--Measured section A of the Kanayut Conglomerate in the "Husky" Mountains, western Brooks Range. See Figures 1 and 9 for location of section.

Figure 11.--Measured section B of the uppermost Kanayut Conglomerate and basal part of the Kayak Shale in the "Husky" Mountains, western Brooks Range. See Figures 1 and 9 location of section.



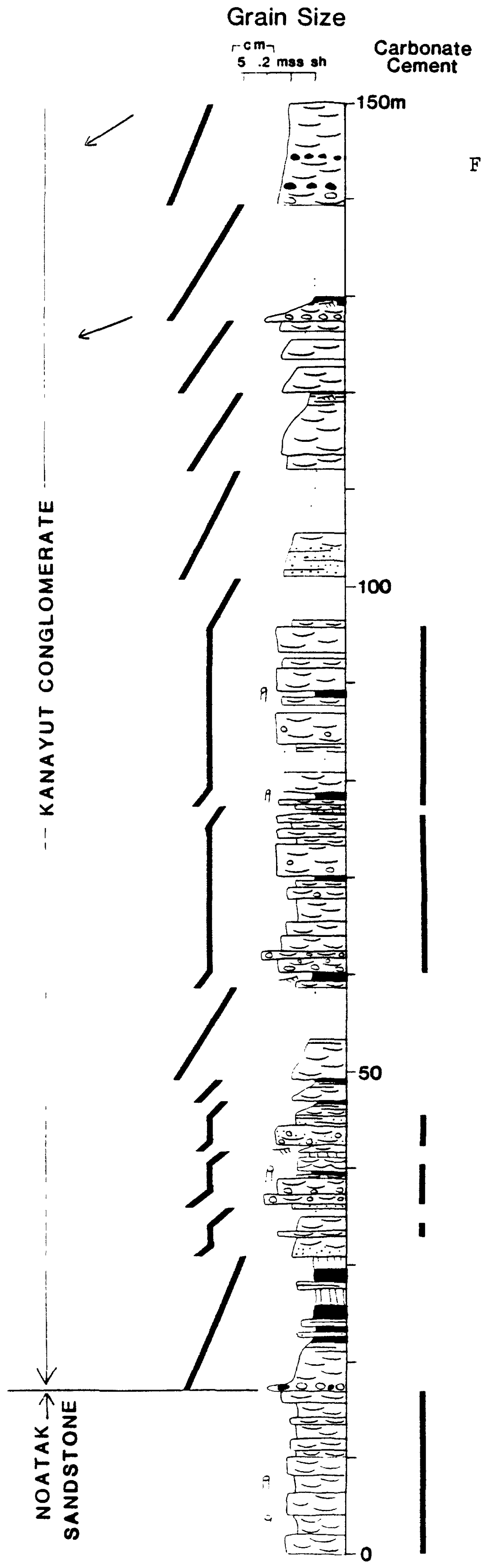
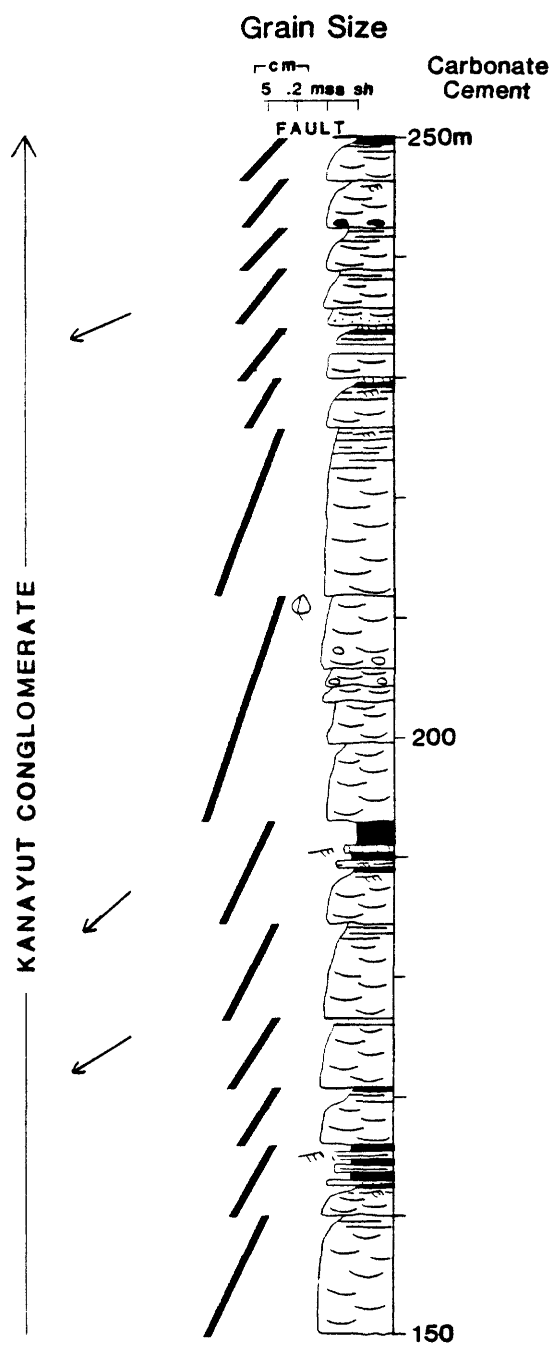


Figure 12.--Measured section C of the uppermost Noatak Sanstone and lower Kanayut Conglomerate in the "Husky" Mountains, western Brooks Range. See Figures 1 and 9 for location of section.



The interstratified marine rocks are present in the Kanayut as high as at least 137 m above the base of the Kanayut in section A and 78 m above the base of the Kanayut in section C. Thus, the intermixed fluvial and marine cycles represent a significant portion of the lower Kanayut Conglomerate in the "Husky" Mountains area.

The mixed marine-fluvial cycles typically begin at their base with channeled conglomerate, conglomeratic sandstone, or medium- and coarse-grained sandstone that resembles fluvial strata at the base of fining-upward cycles in the Kanayut of the central and eastern Brooks Range. The basal beds of the cycles are massive, crudely parallel-stratified, or trough cross-stratified. Downcutting into the underlying shale is generally of less than one meter. The maximum clast size in the conglomerate is 3 cm, although most conglomeratic intervals contain clasts that are less than 1 cm in length. Rip-up clasts of the underlying shale are present in some basal beds.

The cycles that do not contain interstratified marine rocks generally fine upward regularly to red or black shale. Finer grained sandstone with lower amplitude trough cross-strata overlies the basal beds of the cycles. Current ripple-marked and laminated, very fine-grained sandstone and siltstone that grade upward into shale form the upper parts of the cycles. The shale intervals contain plant fragments and locally have paleosols as in the lowest cycle of the Kanayut in sections A and C. Thin coarsening-upward cycles in some of these shaley floodplain deposits are locally capped by paleosols.

The cycles that contain interstratified marine rocks generally have a middle part that does not fine upward regularly. The middle part, formed of the calcareous marine strata, consists of interbedded fine-, medium-, and coarse-grained sandstone that is locally conglomeratic. These beds are mostly trough cross-stratified, but locally contain tabular cross-strata and wavy bedding. The marine beds that form the middle part of the cycles are not organized into fining-upward or coarsening-upward trends. In some cycles, the marine beds form as much as half of the total thickness of the cycle.

These intermixed fluvial and marine cycles in the lower part of the Kanayut Conglomerate in the "Husky" Mountains suggest invasion of fluvial channels by marine waters. Marine conditions, indicated by calcareous cement in the sandstone, northeast-directed paleocurrents, bioturbation, and lack of regular fining-upward cyclicity, apparently extended into the mouths of the distal distributary channels of the Kanayut delta. Because marine conditions extend only into the channels, it is clear that the initial cutting of the channels and their establishment was by typical fluvial processes of river channel formation and migration. Following the partial filling of the channels by marine-influenced, intertidal or estuarine deposits, channel migration or abandonment led to development of nonmarine floodplains that form the tops of each cycle.

The cycles that form the lower Kanayut in sections A and C are roughly correlatable to about 140 m above the base of the Kanayut (figs. 10 and 12). The cycles in section A generally contain more marine units that are present over a thicker stratigraphic interval than those in section C, suggesting a stronger marine influence.

The upper part of the Kanayut Conglomerate, higher than 150 m above the base of the section in section C (fig. 12), consists of repetitive fining-upward cycles generally separated by thin red shale and siltstone intervals. The upper part of the Kanayut contains no interstratified marine beds and is generally finer grained than the lower part of the Kanayut. The maximum clast size of the conglomerate from the upper part of the Kanayut Conglomerate in section C is 0.5 cm. The fining-upward cycles in this part of the Kanayut are generally thinner and the coaser beds consist almost wholly of trough cross-stratified fine- to medium-grained sandstone.

Paleocurrent measurements were made in the Kanayut Conglomerate in sections A and C. Eight measurements from the Kanayut in section A indicate that sediment transport was bimodal with a dominant southwesterly orientation and a subordinate southeasterly orientation (fig. 10). The azimuthal vector mean and standard deviation of the eight measurements is $201^{\circ} \pm 56^{\circ}$. Of these, 5 measurements were taken from calcareous sandstones we interpret to represent marine deposition within the fluvial cycles; these measurements yield a nearly identical mean and standard diviation of $200^{\circ} \pm 60^{\circ}$. Five paleocurrent measurements taken from nonmarine strata in section C, however, indicate very consistent southwesterly sediment transport (fig. 12). They have an azimuthal vector mean and standard deviation of $240^{\circ} \pm 7^{\circ}$.

Stratigraphic subdivision of the Kanayut Conglomerate in the "Husky" Mountains into the Ear Peak, Shainin Lake, and Stuver Members cannot be easily done. We prefer to refer to the Kanayut of this area as undifferentiated, especially because we do not have a complete measured section. The Kanayut can be informally divided into a coarser grained lower part that contains marine interbeds and a finer grained upper part that consists mostly of fluvial deposits.

The upward transition of the Kanayut Conglomerate into the Kayak Shale is shown in section B (fig. 11). The uppermost Kanayut in this section consists of four fining-upward cycles, two of which contain conglomerate with clasts as large as 1 cm at their bases. The conglomerate beds are channeled into gray or maroon siltstone. The lower parts of the cycles consist of massive to crudely parallel-stratified conglomeratic sandstone or sandstone overlain by trough cross-stratified sandstone. Current ripple-marked, very fine-grained sandstone and siltstone overlie the coarser beds and grade upward into shale. Paleosols and coals are present within the shale intervals. Two paleocurrent measurements from nonmarine trough cross-stratified sandstone at the base of section B indicate sediment transport was toward the west (263° and 313°) near the top of the Kanayut.

Within the upper parts of several cycles, burrows, oscillation ripple markings, wavy bedding, and shale drapes over beds of sandstone suggest marine influences on the cyclic sedimentation. In contrast to the marine beds in the lower part of the Kanayut, which are medium- to coarse-grained, have a calcareous cement, and are present in the middle of the cycles, the marine beds in the uppermost part of the Kanayut are very fine- to fine-grained, thin- to medium-bedded, have a siliceous cement, and are present at the tops of the cycles. The beds of very fine- to fine-grained sandstone closely resemble the overlying beds of sandstone in the basal sandstone member of the Kayak Shale.

These transitional cycles of the uppermost Kanayut Conglomerate suggest subsidence below sea level of the floodplain surrounding the fluvial channels. Reworking of levee and floodplain sandstone by wave and current activity yielded well-sorted, thin beds of quartzitic sandstone similar to that of the basal sandstone member of the Kayak Shale. Marine organisms burrowed into the floodplain shales, which probably formed interdistributary bays.

The lower Kayak Shale, of which we measured a thickness of 48 m in section B, has a basal 32 m that is sandstone-rich and is probably the basal sandstone member of the Kayak Shale (fig. 11). The overlying 12 m consists of black siltstone and shale with some interstratified current ripple-marked, very fine-grained quartzitic sandstone. The uppermost 4 m consists of interstratified black shale and thin-bedded, very fine-grained calcareous sandstone characterized by abundant current ripple markings. The calcarenitic sandstones in this uppermost unit appear to be turbidites deposited in deeper marine waters than the sandstones of the basal sandstone member of the Kayak Shale.

The basal sandstone member of the Kayak Shale consists of interbedded black shale and ripple-marked, very fine- to fine-grained quartzitic sandstone (fig. 11). The black shale contains some thin interbeds of ripple-marked siltstone and has abundant plant fragments and marine burrows in it. The bundles of sandstone are organized into coarsening- and thickening-upward cycles that are 3-7 m thick. The cycles are formed of current ripple-marked, very fine-grained sandstone and siltstone above black shale at the base. The middle parts of the cycles consist of oscillation and current ripple-marked, very fine- to fine-grained sandstone. The upper parts of the cycles consist of wavy bedded, locally trough cross-stratified, fine-grained sandstone. Bed thicknesses for the sandstone change upward in the cycles from 1 to 15 cm.

The cycles within the basal sandstone member are suggestive of increasingly higher energy conditions in the depositional site, which was probably a shelf setting in which tidal activity and wave activity was prominent. The coarsening-upward cycles may reflect progradation of small offshore bars adjacent to a transgressing shoreline.

Deadlock Mountain

An incomplete section of the upper part of the Noatak Sandstone and lower part of the Kanayut Conglomerate was measured along the north side of Deadlock Mountain, about 55 km north-northeast of the town of Noatak in the DeLong Mountains quadrangle (S.26, T.31N., R.18W.), western Brooks Range (figs. 1, 2 and 9). The section was measured uphill from an elevation of 2,560 feet (790 m) to an elevation of 2,700 feet (822 m), traveling southward in a direction of 175°. The section is present on the upper limb of a major overturned, north-closing anticline of which the Noatak Sandstone forms the core. From an elevation of 1,600 feet (490 m) to 2,120 feet (648 m) on the ridge, fluvial cycles of the Kanayut Conglomerate are exposed in the overturned lower limb of the anticline. From 2,120 feet (648 m) to 2,560 feet (790 m), the Noatak Sandstone is exposed, overturned toward the north in its lower part, vertically dipping in its central part, and southward dipping and not overturned in its structurally and stratigraphically highest part. We measured the Noatak between 2,560 feet (790 m) and 2,620 feet (805 m) and the overlying Kanayut between 2,620 feet (805 m) and 2,700 feet (822 m). The whole sequence of Endicott Group rocks rests with fault contact upon probable Mesozoic cherts exposed on the lower part of the ridge.

The section measured is about 75 m thick and includes about 20 m of Noatak Sandstone and 55 m of Kanayut Conglomerate (fig. 13). We estimate an additional thickness of at least 50 m of Noatak Sandstone below the point at which the measured section was started.

The upper 20 m of the Noatak Sandstone here consists almost wholly of interbedded medium-grained sandstone having large-scale trough cross-strata and fine- to medium-grained sandstone having small-scale trough cross-strata. Each interbed is about 3 m in thickness. The upper Noatak is a quartzose sandstone but has a calcareous cement and thus fizzes upon application of dilute HCI to either fresh or weathered rock surfaces. The bed thicknesses of the medium-grained sandstone average about 8 cm and the amplitude of the cross-strata averages about 30 cm. For the fine- to medium-grained sandstone, the bed thicknesses average about 3 cm in thickness and the amplitude of the cross strata averages about 15 cm. A single paleocurrent measurement from the axis of a set of trough cross-strata indicates a west-southwesterly flow of 248°.

The 50 m of Noatak Sandstone below the measured section consists generally of alternating intervals of gray-weathering, conglomeratic, medium- to coarse-grained, trough cross-stratified calcareous sandstone and brown-weathering, massive, bioturbated, silty, fine- to medium-grained calcareous sandstone. The two bedding types appear to alternate through the section without forming distinct fining-upward or coarsening-upward cycles. The coarser intervals generally range in thickness from 5 to 40 m, contain scattered pebbles that are 1-2 cm long, and are very well sorted. They contain prominent red- and orange-weathering calcareous concretions. The finer intervals generally range in thickness from 2 to 10 m, contain no pebbles, and are poorly sorted, with abundant mica and some plant fragments. The alternating intervals clearly represent alternating high- and low-energy depositional settings, probably on the inner part of a marine shelf. Paleocurrents from the high-energy, coarser intervals generally suggest southward transport of sediments, possibly a longshore or offshore direction.

The lower Kanayut Conglomerate can be divided into seven fining-upward cycles that averge about 8 m in thickness. The basal part consists of three prominent cycles which are successivly thicker upward and marked by channeled conglomerate at their bases. The two lowest cycles consist mostly of conglomerate and sandstone with little shale. The third cycle contains about 11 m of red shale that contains plant fossils, root imprints, and some thin interbeds of current ripple-marked very fine-grained sandstone and shale.

The next three cycles, from 47 m to 65 m above the base of the section, average 6 m in thickness and contain relatively little conglomerate and sandstone, being formed mostly of red shale and siltstone with abundant plant fossils. The maximum clast size in the conglomerates is 1 cm. A paleosol is prominently developed near the top of the coarser grained lower part of the sixth cycle.

The six fining-upward cycles in the lower Kanayut are similar to cycles measured in the Ear Peak Member farther east in the Brooks Range (Nilsen and others, 1980b, 1981b, 1982). They resemble fluvial cycles deposited by meandering streams, and the plant-bearing red shale, root impressions, and paleosols suggest subaerial deposition.

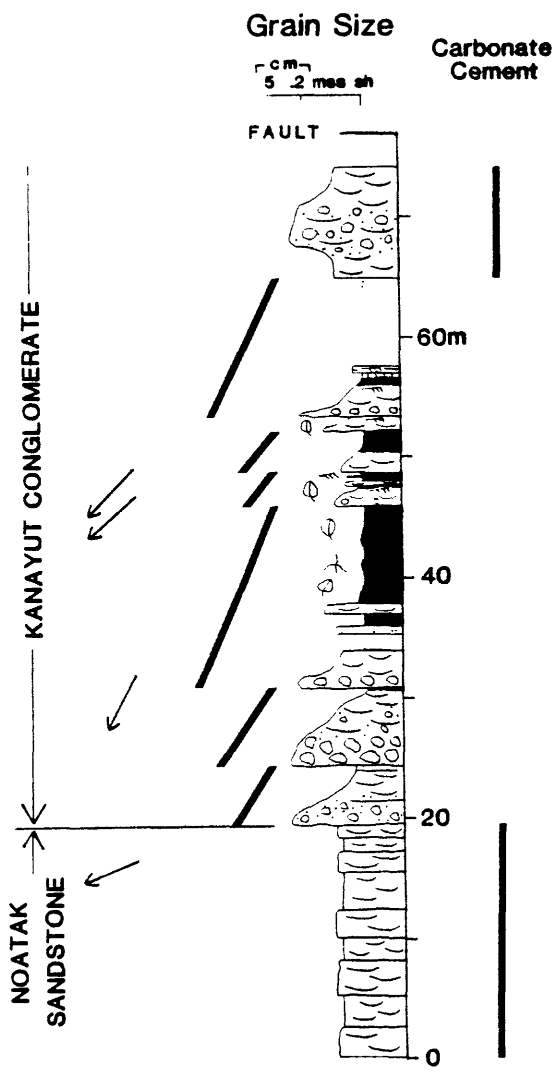


Figure 13,--Measured section of uppermost Noatak Sandstone and lower Kanayut Conglomerate at Deadlock Mountain, western Brooks Range. See Figures 1 and 9 for location of section.

The basal conglomerate of each cycle is typically massive and contains mostly chert pebbles with some quartz and quartzite pebbles. The overlying fine- to medium-grained sandstone is trough cross-stratified and in turn overlain by current ripple-marked and laminated very fine-grained sandstone and siltstone. The conglomerate and sandstone have siliceous cements, do not fizz with application of dilute HCl, and do not have red-weathering calcareous concretions, in contrast to units of the Noatak Sandstone. Three paleocurrents, measured from the axes of trough cross-strata, indicate flow toward the southwest, with a mean azimuthal direction of 220°.

The uppermost unit of the measured section, from 65 to 75 m above the base of the section, consists of interbedded trough cross-stratified, medium-grained sandstone and trough cross-stratified, conglomeratic coarse-grained sandstone. It contains no shale, has a maximum clast size of 2 cm, has a calcareous cement, forms an irregular or noncyclic pattern, and resembles the underlying Noatak Sandstone. We consider it to be a tongue of marine sandstone and conglomerate within the lower Kanayut. It is indicative of the interfingering nature of the contact between the Kanayut Conglomerate and Noatak Sandstone (see descriptions of "Husky" Mountains sections). The top of this unit is truncated by a fault, and we terminated the measured section at the fault.

CONGLOMERATE CLAST COMPOSITION

In order to determine the conglomerate distribution and provenance for the Kanayut Conglomerate and associated units, Nilsen and others (1980b, 1981b, 1982) determined the clast composition of 94 beds of conglomerate at 67 locations scattered throughout the central and eastern Brooks Range. We have made one additional pebble count of conglomerate in the Kanayut in the western Brooks Range during the 1981 field season (Table 1). The new pebble count was made at Deadlock Mountain in the De Long Mountains quadrangle and provides a check on possible variation of the clast composition of the Kanayut Conglomerate in the western Brooks Range.

We also present here a revised compilation of all pebble count data that we have collected to date in the Brooks Range (Table 2). This table replaces those reported in Nilsen and others (1980b, 1981b, 1982) because we have since reassigned several pebble counts to different units and corrected typographical errors. Our earlier descriptions and conclusions of the data remain essentially unchanged; only the new data from the Kanayut Conglomerate in the western Brooks Range will be discussed here. With only one exception (Nilsen and others, 1982), all pebble counts were made by counting one hundred randomly selected clasts larger then 1 cm in the field, noting the lithic type of each pebble and longest clast from each count.

Conglomerate of the Kanayut Conglomerate in the central and eastern Brooks Range is generally characterized by a high chert content and lesser amounts of vein quartz and quartzite and is compositionally mature. Quartzose clasts (chert + vein quartz + quartzite) range from 83% to 100% and average greater than 99% in all central and eastern Brooks Range Kanayut pebble counts (Table 2). Other clasts, including argillite and carbonate, are only locally present.

Table 1.--Maximum clast size and percentage of each clast type from pebble count of the Kanayut Conglomerate from Deadlock Mountain, western Brooks Range. See Figure 9 for location of pebble count.

Field Station	Maximum Clast Size	White Chert	Gray Chert	Black Chert	Red Chert	Vein Quartz	Quartzite	Argillite
81-TN-35	3 cm	9	31	32	1	25	2	0

Table 2. Compilation of maximum clast size and percentage of each clast type from pebble counts made during the 1978, 1979, 1980, and 1981 field seasons from the Kanayut Conglomerate and associated units.

Field Station	Maximum clast size (cm)	Percent of clast lithology											
		White Chert	Gray Chert	Black Chert	Red Chert	Green Chert	Vein Quartz	Quartzite	Quartzite Conglomerate	Argillite-phyllite	Carbonate	Greenstone	Unknown
Kekiktuk Conglomerate													
78 ABe 10	3	26	16	37	0	0	21	0	0	0	0	0	0
78 ABe 42	3	8	31	44	0	0	13	2	0	2	0	0	0
78 ABe 47	4	7	6	8	0	0	77	1	0	1	0	0	0
78 ABe 46	5	22	46	18	0	0	11	4	0	0	0	0	0
78 ABe 46	20	6	29	19	0	0	23	21	0	2	0	0	0
78 ABe 48	3	8	10	30	0	0	50	0	0	2	0	0	0
78 ABe 58	4	26	21	25	0	0	27	1	0	0	0	0	0
79 ABe 95	4	4	0	0	0	41	46	1	0	8	0	0	0
79 ABe 95	5	23	0	0	0	23	36	0	0	18	0	0	0
79 ABe 99	8	32	3	5	0	0	51	0	0	9	0	0	0
79 ABe 167	18	2	22	12	0	0	40	6	0	15	0	0	3
79 ABe 167	13	1	18	20	0	0	40	16	0	3	0	0	2
79 ABe 167	2	3	7	2	0	0	87	0	0	1	0	0	0
79 ABe 172	5	0	0	0	0	0	10	76	0	0	0	14	0
79 ABe 172	5	8	27	10	0	0	37	18	0	0	0	0	0
79 ABe 175	5	7	11	6	0	0	65	7	0	4	0	0	0
79 ABe 177	3	25	56	17	0	0	2	0	0	0	0	0	0
79 ABe 185	4	19	36	29	0	0	5	6	0	5	0	0	0
79 ABe 185	4	25	22	3	0	0	44	4	0	2	0	0	0
79 ABe 185	4	7	25	21	0	0	41	5	0	1	0	0	0
79 ABe 186	8	11	61	25	0	0	2	1	0	0	0	0	0
Undifferentiated Kekiktuk Conglomerate and Kanayut Conglomerate													
78 ABe 44	6	14	23	47	0	0	13	2	0	1	0	0	0
79 ABe 158	8	26	27	23	0	0	23	1	0	0	0	0	0
79 ABe 159	5	13	26	21	0	0	37	0	0	3	0	0	0
79 ABe 181	8	1	29	21	0	0	33	14	0	1	0	0	0
79 ABe 184	4	0	35	22	0	0	40	3	0	0	0	0	0
Basal Sandstone Member, Kayak Shale													
80 TN-43	3	15	36	32	0	0	15	2	0	0	0	0	0
80 TN-43	5	31	40	12	0	0	17	0	0	0	0	0	0
Stuver Member, Kanayut Conglomerate													
78 STU	6	31	35	20	0	0	12	2	0	0	0	0	0
78 STU	4	49	32	9	0	0	8	2	0	0	0	0	0
78 STU	5	46	29	12	0	0	12	1	0	0	0	0	0
78 ABe 11D	3	73	23	4	0	0	0	0	0	0	0	0	0
78 ABe 11H	6	74	22	4	0	0	0	0	0	0	0	0	0
79 ABe 22	5	20	35	30	0	0	11	4	0	0	0	0	0
79 ABe 30	1	21	16	2	0	0	61	0	0	0	0	0	0
79 ABe 31	3	16	49	22	0	0	9	4	0	0	0	0	0
79 ABe 106	2	18	21	16	0	0	43	0	0	2	0	0	0
80 TN-43	2.5	16	38	28	0	0	17	1	0	0	0	0	0

Field Station	Maximum clast size (cm)	Percent of clast lithology											
		White Chert	Gray Chert	Black Chert	Red Chert	Green Chert	Vein Quartz	Quartzite	Quartzite Conglomerate	Argillite-phyllite	Carbonate	Greenstone	Unknown
Shainin Lake Member, Kanayut Conglomerate													
78 CHA	5	37	31	18	0	0	11	3	0	0	0	0	0
78 CHA	4	16	55	20	0	0	7	2	0	0	0	0	0
78 ABe 31	4	33	44	17	0	0	5	1	0	0	0	0	0
78 ABe 34A	9	10	51	22	0	0	12	5	0	0	0	0	0
78 ABe 35	6	19	44	22	0	0	10	5	0	0	0	0	0
78 ABe 45	6	50	30	7	0	0	10	3	0	0	0	0	0
78 ABe 111	3	35	22	27	0	0	10	3	0	3	0	0	0
78 ABe 111	6	15	42	27	1	0	14	1	0	0	0	0	0
78 ABe 202	5	15	49	24	0	0	11	1	0	0	0	0	0
78 ABe 202	5	26	30	34	0	0	10	0	0	0	0	0	0
78 ABe 203	8	29	31	22	0	0	9	7	1	0	1	0	0
78 ABe 205	16	18	55	10	0	0	4	10	3	0	0	0	0
78 ABe 208	14	13	28	30	1	0	16	6	4	2	0	0	0
78 ABe 211	6	12	45	31	0	0	5	5	2	0	0	0	0
78 ABe 216	2.5	36	45	14	0	0	4	1	0	0	0	0	0
79 ABe 114	2	9	19	38	0	0	17	0	0	17	0	0	0
79 ABe 136	5	14	44	22	0	0	19	1	0	0	0	0	0
79 ABe 136	5	1	49	37	0	0	12	0	0	1	0	0	0
79 ABe 136	4	3	35	40	0	0	16	1	0	3	0	0	2
79 ABe 166	3	10	26	11	0	0	43	5	0	5	0	0	0
79 ABe 171	5	13	18	3	0	0	58	8	0	0	0	0	0
79 ABe 196	5	3	41	40	0	0	11	4	0	1	0	0	0
79 ABe 198	4	13	42	27	0	0	14	4	0	0	0	0	0
79 ABe 199	5	7	59	22	0	0	11	1	0	0	0	0	0
79 ABe 201	5	4	35	19	27	0	13	2	0	0	0	0	0
79 ABe 203	5	11	50	23	0	0	13	2	0	0	1	0	0
80 TN-44	4	20	14	14	39	0	13	0	0	0	0	0	0
80 TN-44	4	12	20	12	45	0	10	1	0	0	0	0	0
80 TN-47	12	16	30	26	0	0	22	5	1	0	0	0	0
80 TN-47	8	35	23	17	0	0	17	7	1	0	0	0	0
80 TN-47	9	37	24	14	0	0	20	5	0	0	0	0	0
80 TN-47	6	40	23	8	0	0	22	6	1	0	0	0	0
80 TN-47*	14*	0	11	7	0	0	15	24	43	0	0	0	0

Table 2 (continued)

Field Station	Maximum clast size (cm)	Percent of clast lithology: White Chert	Gray Chert	Black Chert	Red Chert	Green Chert	Vein Quartz	Quartzite	Quartzite Conglomerate	Argillite-phyllite	Carbonate	Greenstone	Unknown
Ear Peak Member, Kanayut Conglomerate													
78 ABe 33	4.5	8	57	34	0	0	1	0	0	0	0	0	0
78 ABe 34A	8	12	72	10	0	0	4	2	0	0	0	0	0
78 ABe 36	4	17	37	40	0	0	6	0	0	0	0	0	0
78 ABe 207	3	18	44	31	0	0	6	1	0	0	0	0	0
79 ABe 43	5	28	33	22	0	0	17	0	0	0	0	0	0
79 ABe 206	5	10	45	33	4	0	7	1	0	0	0	0	0
80 TN-12	3	28	41	18	0	0	11	2	0	0	0	0	0
80 TN-12	4	42	26	14	0	0	13	4	0	1	0	0	0
80 TN-12	5	30	35	14	0	0	15	6	0	0	0	0	0
80 TN-46	3	14	40	26	2	0	18	0	0	0	0	0	0
80 TN-46	2	22	31	32	2	0	13	0	0	0	0	0	0
Kanayut Conglomerate, undifferentiated													
78 ARR-14	10	39	13	17	0	0	20	11	0	0	0	0	0
81 TN-35	3	9	31	32	1	0	25	2	0	0	0	0	0
Noatak Sandstone													
79 ABe 73	3	12	37	23	0	0	18	2	0	8	0	0	0
79 ABe 73	3	4	50	23	0	0	18	1	0	4	0	0	0
79 ABe 73	5	20	25	31	0	0	19	1	0	4	0	0	0
Hunt Fork Shale													
79 ABe 52	6	3	21	42	0	0	27	3	0	4	0	0	0
79 ABe 133	3	4	31	55	0	0	0	1	0	9	0	0	0
Beaucoup Formation													
78 ARR-16	10	16	54	29	0	0	1	0	0	0	0	0	0
78 ABe 7	4	22	48	20	0	0	0	0	0	10	0	0	0
78 ABe 8	8	55	17	8	0	0	9	4	0	6	1	0	0
78 ABe 8B	8	41	28	8	0	0	0	0	0	0	23	0	0
78 ABe 18	13	20	20	1	49	8	0	0	0	2	0	0	0
79 ABe 161	6	31	30	14	0	0	10	0	0	15	0	0	0

* Only clasts larger than 7 cm were included in this count.

The single pebble count from the Kanayut in the western Brooks Range is similar to those of the central and eastern Brooks Range. The western Brooks Range conglomerate consists of 100 percent quartzose clasts, and includes 73% chert clasts (Table 1). Chert includes white, gray and black varieties as in the central and eastern Brooks Range, but also includes red chert which is restricted to a few locations near Shainin and Galbraith Lakes in the central Brooks Range. The significance of the localized presence of red chert in the Kanayut is not presently known. Argillite clasts are also present in the western Brooks Range, but do not appear in the count because they are present in percentages of less than 1 percent.

Figure 14A shows the composition of the single pebble count from the Kanayut Conglomerate in the western Brooks Range on a ternary diagram with quartzose clasts, carbonate clasts, and nonquartzose clasts as poles, and the range and average of the central and eastern Brooks Range data for comparison. The plot shows that the data from the western Brooks and central and eastern Brooks Range are essentially identical and that there is no significant difference in compositional maturity between the two areas.

Figure 14B is a ternary diagram that has chert, vein quartz, and quartzite clasts as poles. It shows the composition of the pebble count from the western Brooks Range and the range and average of the Kanayut Conglomerate data from the central and eastern Brooks Range for comparison. Pebble counts from the Kanayut Conglomerate in the central and eastern Brooks Range are displaced toward the chert pole and away from the quartzite pole. In these counts, chert clasts range from 34 to 100 percent and average 82 percent, vein quartz averages 15 percent but ranges up to 61 percent, and quartzite clasts are minor but persistent constituent (average 3 percent) that locally comprises as much as 21 percent of the clasts. By comparison, the western Brooks Range pebble count is somewhat more enriched in vein quartz than the average of the Kanayut Conglomerate data from the cental and eastern Brooks Range, but is well within the range of composition of the central and eastern Brooks Range conglomerates.

The 1981 pebble count data from exposures of Kanayut Conglomerate in the western Brooks Range plot within the fields for the Kanayut Conglomerate in the central and eastern Brooks Range and are comparable to the earlier data in every respect. We suggest that this generally consistent conglomerate composition throughout the very extensive Kanayut depositional system indicates that the Kanayut detritus was probably derived from a single major source terrane that was largely sedimentary or metasedimentary in composition. However, it is also probable that the mature composition of the Kanayut may have resulted from extensive chemical weathering prior to erosion or during transport and that its composition may not be fully indicative of its provenance.

CONGLOMERATE CLAST SIZE DATA

The maximum dimension of the largest conglomerate clast was measured at each station where conglomerate was observed, in order to determine overall changes in the size of material transported by the Endicott Group depositional system. In our previous reports, we presented maximum clast size data collected during the 1978, 1979, and 1980 field seasons at 163 locations in the Kanayut Conglomerate and 28 locations in the Kekiktuk Conglomerate (Nilsen and others, 1980b, 1981b, 1982). In this report, we present data collected

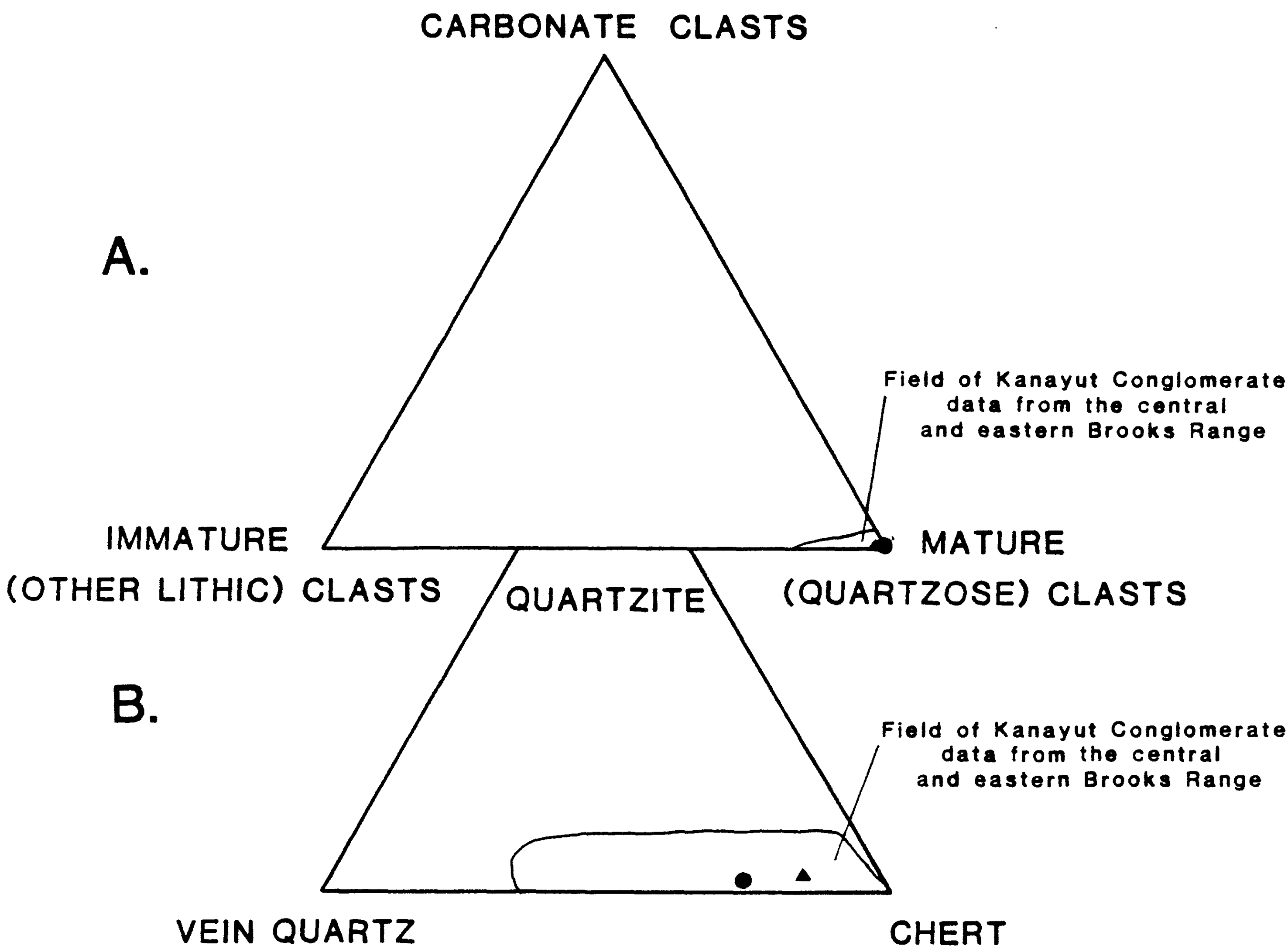


Figure 14.--Ternary diagrams from pebble counts of the Kanayut Conglomerate made during the 1978, 1979, 1980, and 1981 field seasons. A, Carbonate clast - immature - clast diagram. Solid lines indicate the extent of the field of all data from the Kanayut Conglomerate collected in the central and eastern Brooks Range. The solid triangle represents the average of all data from the Kanayut Conglomerate collected in the central and eastern Brooks Range; the solid circle is the single pebble count from the western Brooks Range (Table 1).

from the Kanayut Conglomerate at 55 additional locations during the 1981 field season.

Because our earlier data were not well dispersed geographically, we attempted during the 1980 and 1981 field seasons to collect measurements in areas from which we previously had no data. In addition, our previous data were commonly taken from only a limited portion of the entire stratigraphic thickness of a member or formation so that many data points were representative of only a limited stratigraphic thickness of the unit. During the 1980 and 1981 field seasons, we collected data primarily from bouldery rubble in modern alluvial fans of streams draining restricted areas. Care was taken to choose streams draining only exposures of Kanayut Conglomerate and to measure clasts in boulders obviously derived from the Kanayut by fluvial processes. By this method, we were able to more easily sample a large thickness of stratigraphic section for the largest clast contained in their conglomeratic strata. However, the map distribution of maximum clast sizes must still be interpreted cautiously with regard to paleogeography because of the presence of significant amounts of structural shortening, including at least three major thrust faults within the outcrop belt. Nevertheless, several major conclusions can be drawn from the available data.

We have compiled a map of maximum clast size data from the Kanayut Conglomerate collected during the 1978, 1979, 1980 and the 1981 field seasons (fig. 15). All of the 1981 data was collected in the central and western Brooks Range. Most of the central Brooks Range data was obtained from areas along the southern edge of the outcrop belt of the Kanayut Conglomerate and Noatak Sandstone south of Anaktuvuk Pass, and in the southwestern and southeastern parts of the Killik River and Howard Pass quadrangles, respectively. The western Brooks Range data was collected in the Mulgrave Hills and "Husky" Mountains (fig. 9). The Shainin Lake Member generally contains the largest clasts and we collected most data from it.

The pattern of sediment dispersal is apparent from a contour map of clast sizes (fig. 16). This map is drawn from the information presented in figure 15. Thrust plates are not palinspastically restored. Nevertheless, the map shows the well-defined maxima of clast sizes in the Shainin Lake area and in the easternmost outcrops. The geometry of the contour lines around these clast size maxima indicates that sediment transport in both systems was primarily toward the southwest or south.

The largest clasts we observed in the Kanayut Conglomerate are 23 cm in length and are located near Shainin Lake. To the west and south of Shainin Lake, the clast size decreases regularly and dramatically. Conglomerate is rare in the Kanayut north of the Noatak River, demonstrating a marked westward decrease in clast size away from Shainin Lake. Clast size also decreases southeast of Shainin Lake, as far east as Arctic Village, at approximately 146^{o} longitude, where the largest clasts are 5 cm in size. The distribution of decreasing clast sizes around the Shainin Lake region suggests that it may mark an entry site of a major trunk system into the Kanayut depositional basin that dominated sediment dispersal patterns from the present position of Arctic Village westward to near the Nimiuktuk River.

A second major trunk system may be indicated by the clast size data in the northern and eastern outcrops of the Kanayut. Clast sizes in the region

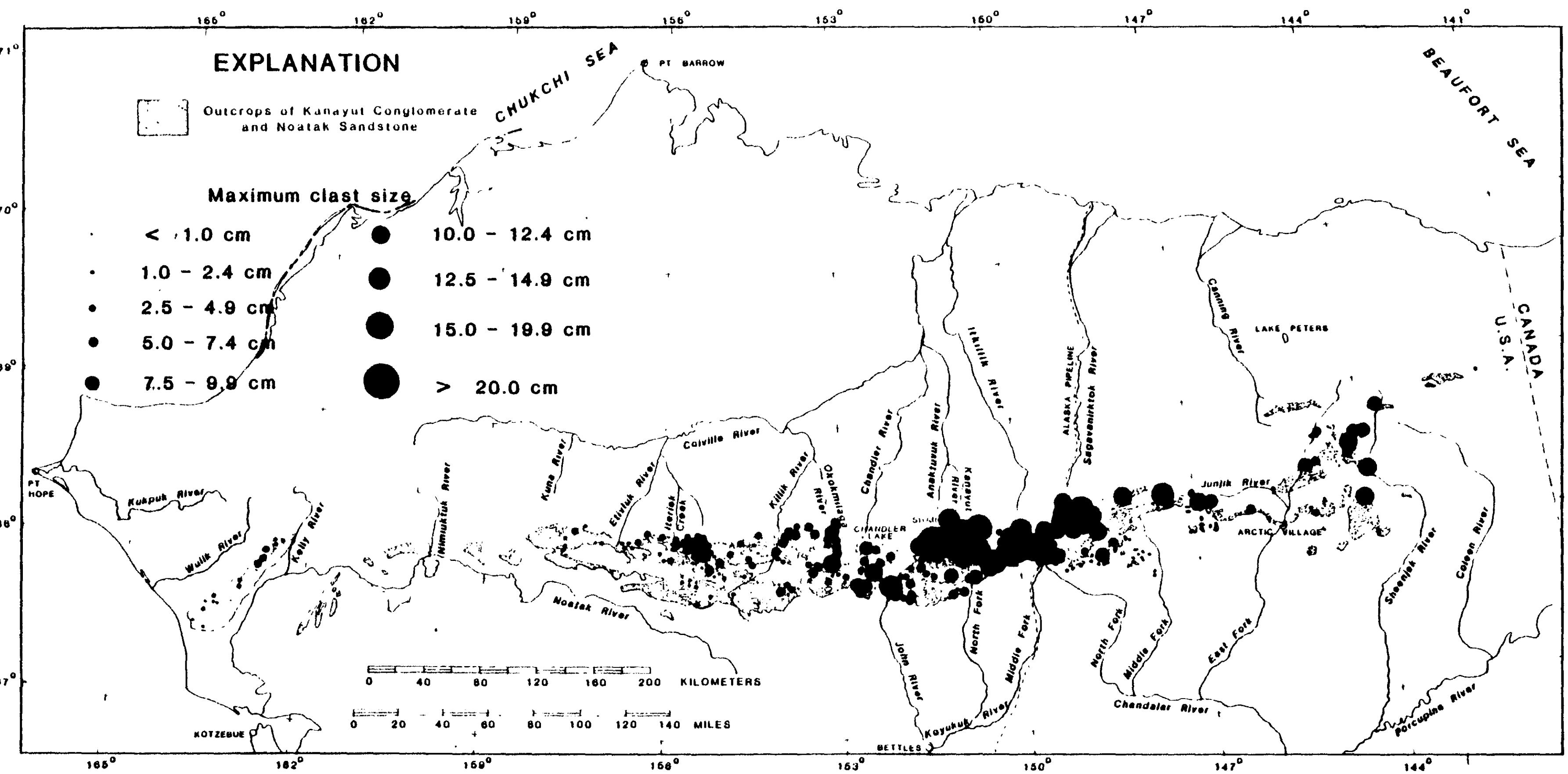


Figure 15.--Map showing distribution of maximum clast sizes, Kanayut conglomerate.

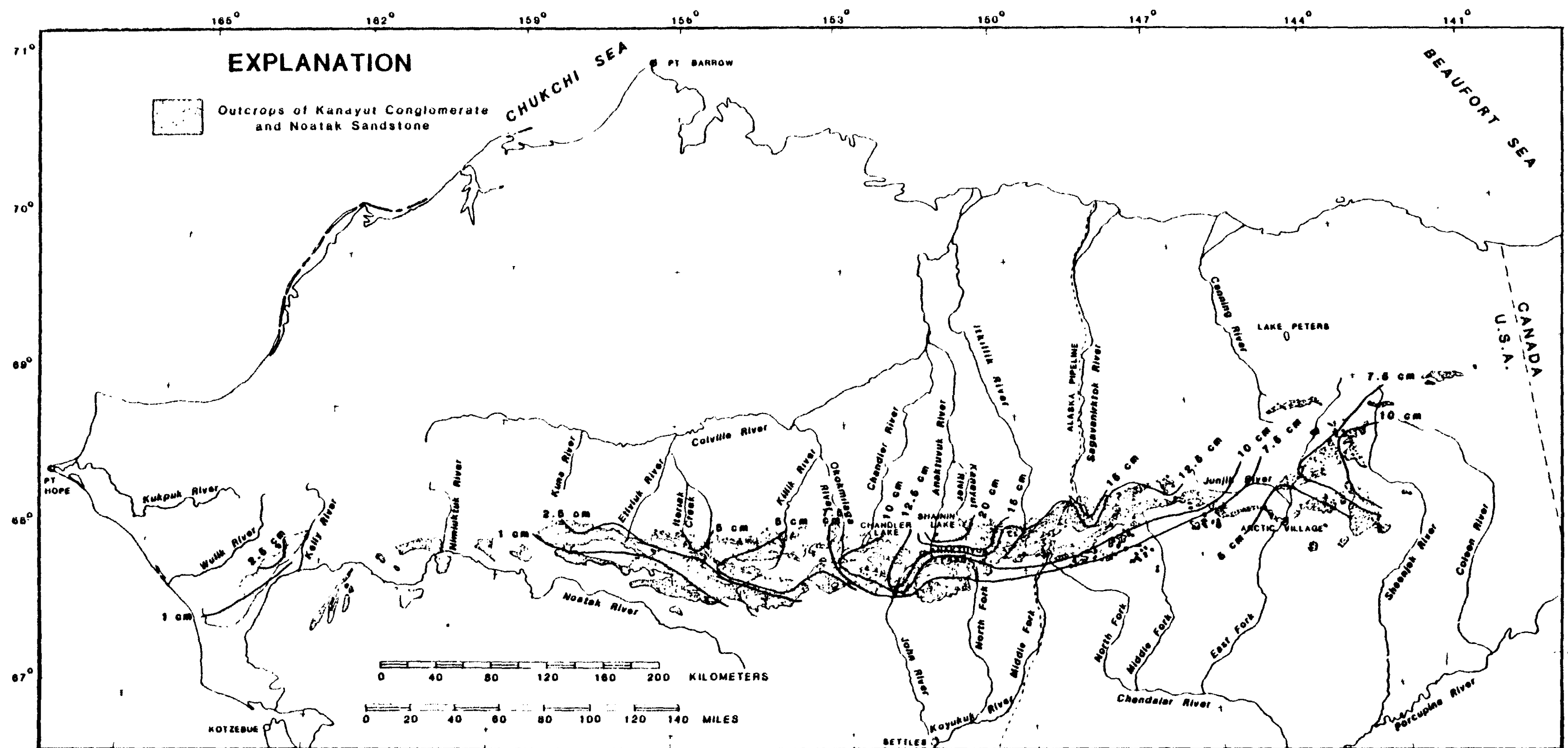


Figure 16.--Contour map showing distribution of maximum clast sizes, Kanayut Conglomerate. Contour interval is variable.

decrease from a maximum of 10 cm in the eastern outcrops to less than 5 cm in the Arctic Village area. This distribution of clast sizes suggests that sediment dispersal in the eastern part of the Kanayut was from east or northeast to southwest or west.

In the western Brooks Range, clast sizes appear to decline radially outward from a maximum of 3 cm along the northwestern edge of the outcrop belt. The smallest clasts are present in the southernmost outcrops of the Mulgrave Hills, suggesting sediment dispersal toward the south, southwest and possibly southeast.

In addition to the three major clast size maxima which help define large-scale sediment dispersal patterns in the eastern, central, and western Brooks Range, several other maxima are present along the northern edge of the belt of Kanayut exposures. These are found west of the headwaters of the Junjik River, near the Sagavanirktok River, east of Iteriak Creek, and south of the Kuna River (fig. 16). Minimal bowing of the contour lines south of these clast-size maxima along the southern edge of the belt of exposure indicates that these systems were probably overwhelmed in their southern extremes by detritus transported by the major distributary system emanating from the Shainin Lake region. These second-order size maxima may mark the entry sites of smaller river systems into the Kanayut basin. All four of the smaller systems appear to suggest southerly transport of sediment from a northern source.

The distribution of discrete clast size maxima along the eastern and northern edges of the belt of exposure of the Kanayut indicates that the highlands from which the Kanayut detritus was derived were located along the northern and eastern margins of the basin. Maximum clast sizes in other ancient and modern river systems suggest that the coarse clasts in the Shainin Lake area may have been deposited close to the margin of the Kanayut basin. The edge of the basin in that area, however, has either been removed by faulting or is not exposed. The clast size data strongly argue against a southern highland that contributed sediment to the Kanayut basin, and suggest that the Kanayut was originally deposited along a south-facing margin of a mountainous belt.

PALEOCURRENTS

Introduction

Nilsen and others (1980b) plotted 166 paleocurrent measurements made in 1978 from the Kanayut Conglomerate, Kekiktuk Conglomerate, and Kayak Shale. During the 1979 field season, an additional 292 paleocurrent measurements were collected from these units and the Hunt Fork Shale and Beaucoup Formation at 63 separate locations (Nilsen and others, 1981b). Data from both years were compiled and presented in map form (Nilsen and others, 1980a). An additional 316 measurements were collected during the 1980 field season from the Hunt Fork Shale, Kanayut Conglomerate, and Kayak Shale (Nilsen and others, 1982). During the 1981 field season, we collected another 72 paleocurrent measurements from those same units and the Noatak Sandstone, bringing the total to 846 determinations for all three seasons.

Sedimentary features measured during the 1981 field season include trough cross-strata (48 measurements), tabular cross-strata (11 measurements), primary current lineations (10 measurements), ripple markings (2 measurements), and flute casts (1 measurement). Restorations of paleocurrent directions to the horizontal were done manually on a stereonet. Computer-calculated vector means and standard deviations were determined for 5 locations at which more than four paleocurrent measurements were made and also for the total number of paleocurrent measurements from each of the various stratigraphic units. Bidirectional features such as primary current lineation were assigned a westerly or southerly sense because of the preponderance of unidirectional indictors with that orientation.

We discuss below our paleocurrent measurements from the Hunt Fork Shale, Noatak Sandstone (formerly the basal sandstone member of the Kanayut Conglomerate), the Kanayut Conglomerate, and the Kayak Shale. For a discussion of data from the Kekiktuk Conglomerate and Beaucoup Formation, the reader is referred to Nilsen and others (1981b).

Hunt Fork Shale

A total of 31 paleocurrent determinations were obtained from the Hunt Fork Shale at 12 separate locations during the 1979 and 1980 field seasons (Nilsen and others, 1980b, 1981b). An additional 3 measurements were collected from 3 different locations during the 1981 field season but 3 of the measurements which were collected at a single location in 1979 were reassigned to the Noatak Sandstone, causing the total number of measurements from the Hunt Fork Shale to remain at 31. Sedimentary features measured include 15 trough cross-strata, 8 primary current lineations, 4 tabular cross-strata, 3 oscillation ripple markings, and 2 flute marks.

Figure 17 is a map compilation of all paleocurrent data collected from the Hunt Fork Shale, with outcrops of the Noatak Sandstone and Kanayut Conglomerate plotted for reference. The data show that sediment transport in the Hunt Fork Shale was everywhere generally toward the southwest. The azimuthal vector mean and standard deviation of all measurements from the Hunt Fork Shale are $215^{o} \pm 56^{o}$, reflecting the overall southwesterly sediment transport direction (fig. 17). The relative consistency of these data probably indicates that sediment was chiefly transported offshore. A few measurements which show significant deviation from the mean may result from storm-generated currents affecting sediments deposited in shallower water.

Noatak Sandstone

Sixty-eight paleocurrent measurements, taken from 13 separate locations in the former marine basal sandstone member of the Kanayut Conglomerate, were reported in map form and by summary rose diagram by Nilsen and others (1980a, sheet 2). Nilsen and Moore (1982a) later correlated the basal sandstone member of the Kanayut Conglomerate with the Noatak Sandstone of the western Brooks Range. The nomenclature of Nilsen and Moore (1982a) is herein used; all of the paleocurrent data are therefore now assigned to the Noatak Sandstone. During the 1981 field season, we collected a total of 18 new paleocurrent measurements from the Noatak Sandstone, including 7 from the Mulgrave Hills in the western Brooks Range. We present here a compilation of the data collected from the previously named basal sandstone member of the Kanayut Conglomerate and the data collected during 1981. We also include here several paleocurrent measurements collected during 1980 which have been reassigned from the Hunt Fork Shale to the Noatak Sandstone.

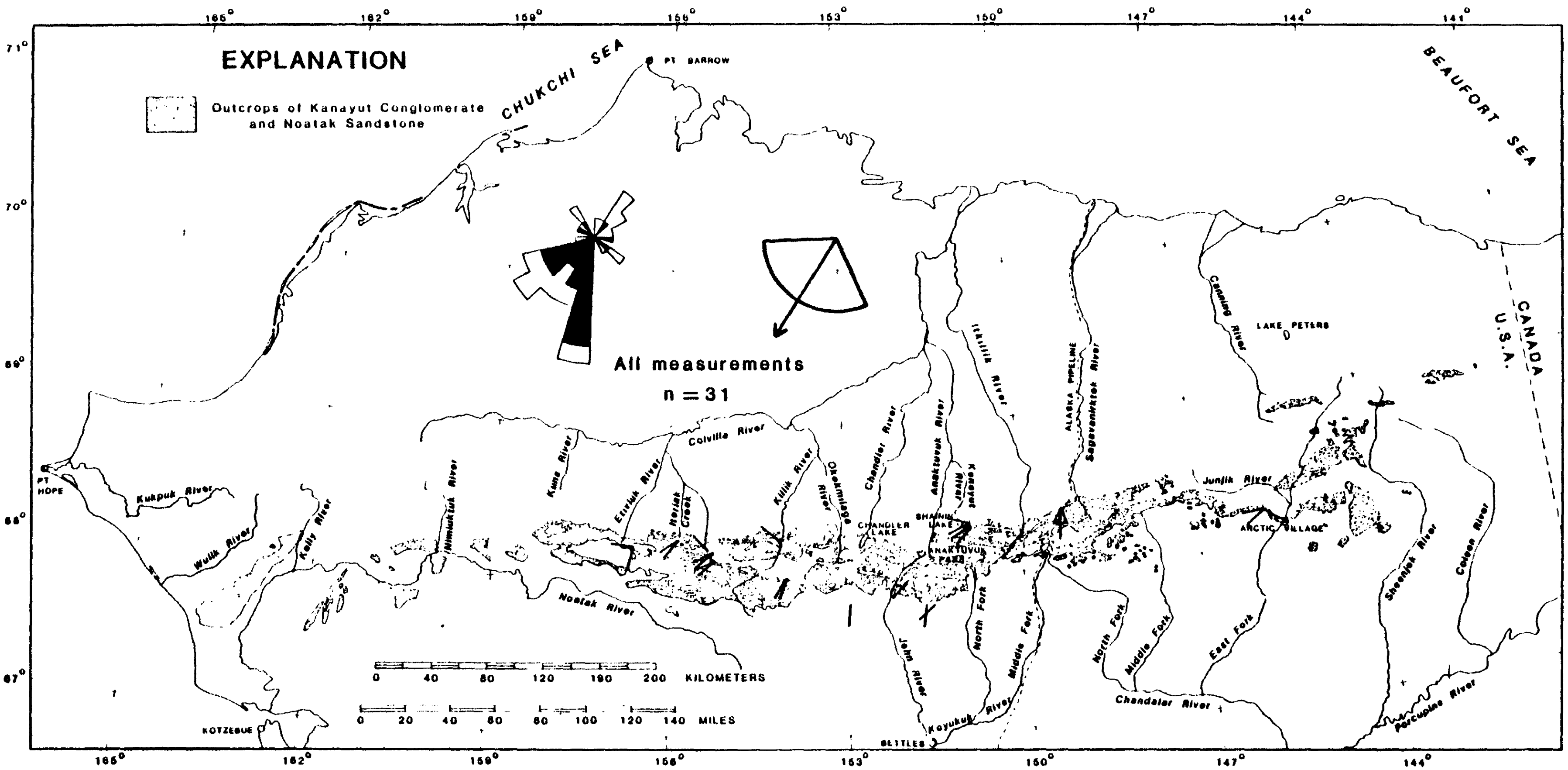
A total of 87 paleocurrent measurements collected from the Noatak Sandstone are presented in map form in Figure 18. Sedimentary features measured include tabular cross-strata (43 measurements), trough cross-strata (27 measurements), primary current lineations (14 measurements), ripple markings (2 measurements) and pebble trains (1 measurement). The paleocurrent data broadly suggest westerly or southwesterly sediment transport, but are very variable in orientation. The azimuthal vector mean and standard deviation of all measurements from the Noatak Sandstone are $247^{\circ}\pm69^{\circ}$, reflecting overall southwesterly sediment transport. Seven paleocurrent measurements taken from the Noatak Sandstone in the Mulgrave Hills in the western Brooks Range yield an azimuthal vector mean and standard deviation of $201^{\circ}\pm37^{\circ}$ whereas the azimuthal vector mean and standard deviation of 80 paleocurrent measurements taken in the central and eastern Brooks Range is $242^{\circ}\pm70^{\circ}$. These data may suggest that sediment transport is more southerly in orientation in the western Brooks Ranges than in the central and eastern Brooks Range. This difference is not considered to be statistically significant, but may result from counter-clockwise oroclinal rotation of the western Brooks Range during the Mesozoic as suggested by regional structural trends. Alternatively, the difference in orientation may result from irregularities in the configuration of the Kanayut-Noatak depositional basin.

We believe that the Noatak Sandstone was deposited chiefly as marine bars. The general consistency of the paleocurrent data from the Noatak Sandstone suggests that sediment transport was primarily offshore. Paleocurrent measurements which deviate significantly from the mean may have resulted from local onshore and longshore sediment transport related to wind-, wave-, storm-, and tide-generated currents.

Kanayut Conglomerate

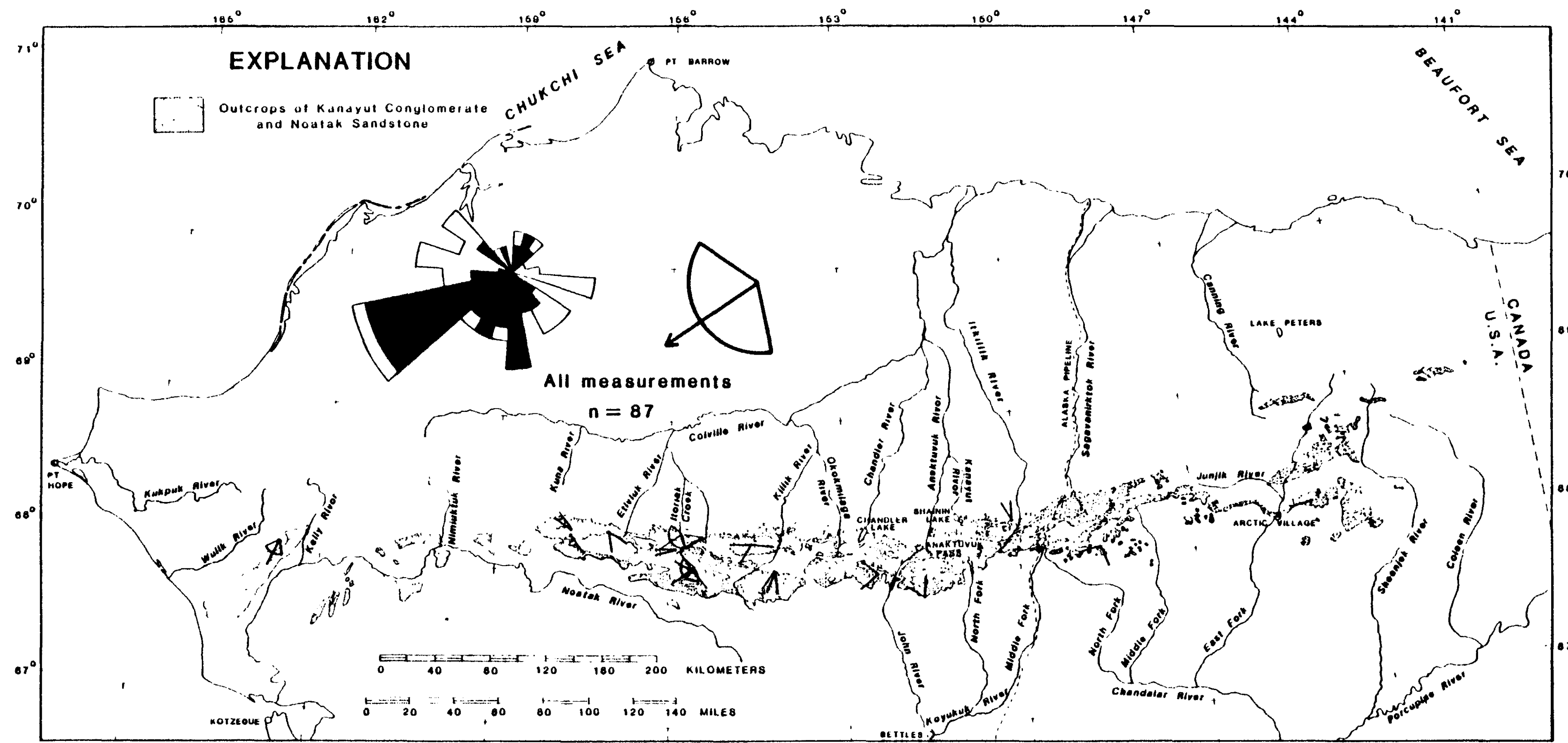
In our report of the 1978 field season, we plotted 158 paleocurrent measurements from the fluvial Ear Peak (formerly the lower shale member), Shainin Lake (formerly the middle conglomerate member), and Stuver Members of the Kanayut Conglomerate (Nilsen and others, 1980a). During the 1979 field season, we measured an additional 156 paleocurrent directions at 35 separate locations. The orientation of the measurements was compiled and plotted in map form and by summary rose diagram (Nilsen and others, 1981a, sheet 1). Another 291 determinations were later collected during the 1980 field season and reported by Nilsen and others (1982b). We report here an additional 49 paleocurrent measurements collected during the 1981 field season, including 20 collected from the Mulgrave Hills in the western Brooks Range (fig. 9), a region in which we previously had no data. These data, together with the reassignment of several paleocurrents to other units, brings the total number of paleocurrent measurements from the Kanayut Conglomerate to 626. Sedimentary features measured during all four field seasons include 283 trough cross-strata, 157 clast imbrication and long-axis orientations, 82 tabular cross-strata, 66 primary current lineations, 16 current ripple markings, 8 flute marks, 4 pebble trains, 4 erosional scours, 2 surfaces with aligned plant fragments, 1 channel-margin orientation, and 1 fluid-escape fold.

The paleocurrent data are presented in map form on Figure 19 using a summary rose diagram and azimuthal vector mean and standard deviation. The



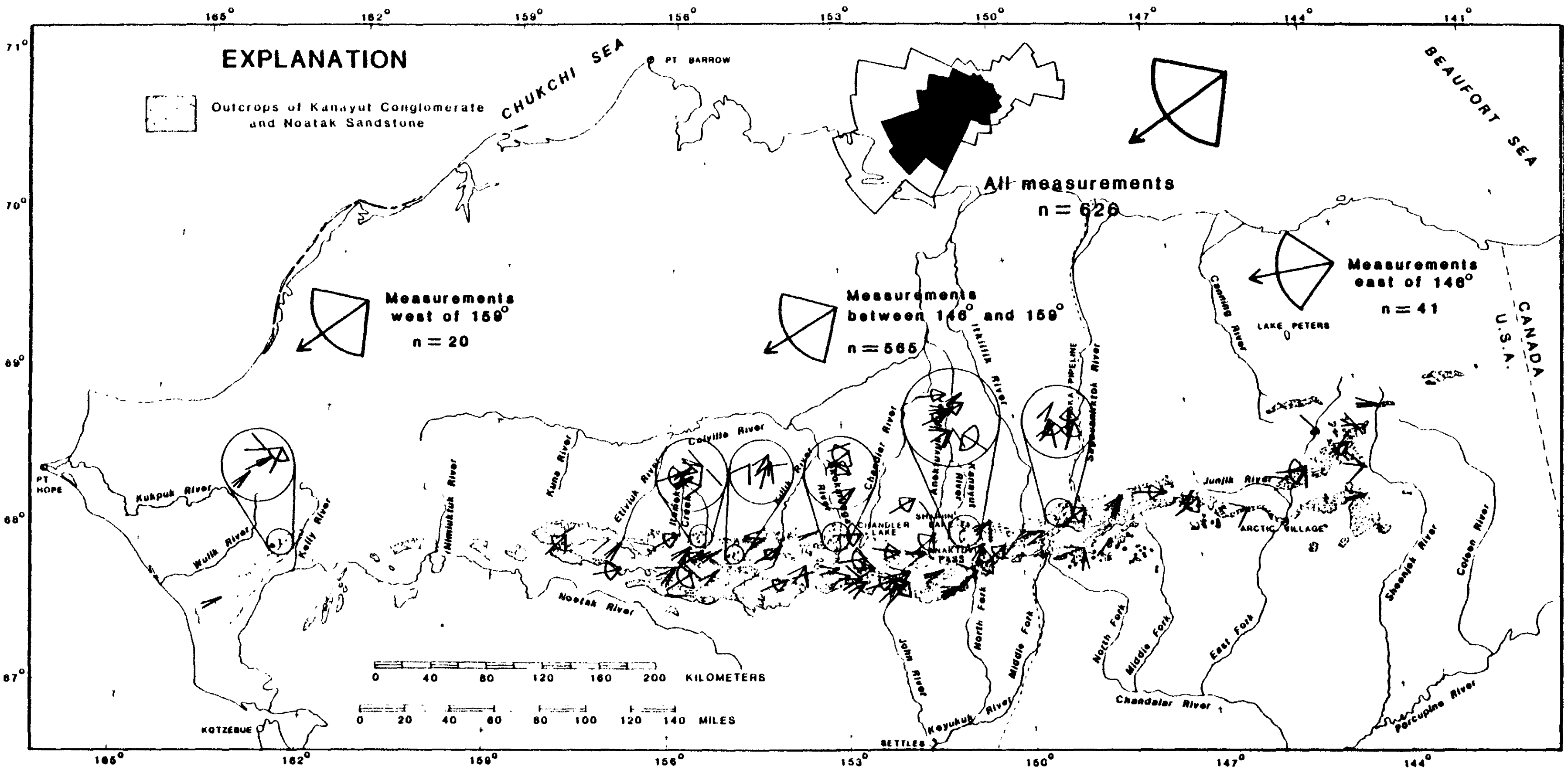
HUNT FORK SHALE PALEOCURRENTS

Figure 17.--Palecurrent map for the Hunt Fort Shale.



NOATAK SANDSTONE PALEOCURRENTS

Figure 18.--Palecurrent map for the Noatak Sandstone.



KANAYUT CONGLOMERATE PALEOCURRENTS

Rigure 19.--Paleocurrent map for the Kanayut Conglomerate.

map shows that the paleocurrent data consistently shows westerly or southwesterly sediment transport throughout the belt of exposure. Significant numbers of southerly-directed paleocurrent measurements are present along the Alaska pipeline in the Atigun River area (see inset, fig. 19) and in a limited area about 30 km west of the Killik River (see inset, fig. 19). Unidirectional indicators, shown by the darkened area in the rose diagram (fig. 19) indicate predominantly southwesterly sediment transport. Bidirectional indicators (those giving direction, but not sense of transport), shown by the clear area in the rose diagram, also suggest west-southwest (or east-northeast) sediment transport. The azimuthal vector mean and standard deviation of all measurements from the Kanayut Conglomerate is $242^{\circ} \pm 47^{\circ}$, but range from $172^{\circ} \pm 28^{\circ}$ to $304^{\circ} \pm 30^{\circ}$ for individual locations having more than 4 measurements (fig. 19).

Because maximum clast data size from the Kanayut indicates that there were at least two and perhaps three major trunk systems feeding sediment into the Kanayut depositional basin (see Maximum Clast Size Data, page 41), we have determined the azimuthal vector mean and standard deviation of paleocurrent data separately from three depositional regions -- called here for convenience the western, central and eastern Brooks Range regions. These three regions, subdivided at 146° and 159° longitude, approximate the areas of influence of the three major trunk systems delineated by the maximum clast size data.

Forty-one paleocurrents from the Kanayut Conglomerate measured in the region east of 146° longitude (approximately the location of Arctic Village) yield an azimuthal vector mean and standard deviation of $269^{\circ} \pm 44^{\circ}$. These data suggest that sediment transport was predmoninantly toward the west at the eastern end of the Kanayut basin.

Paleocurrent data in the central Brooks Range, from which most of our data comes, may have been influenced largely by the trunk system which entered the basin in the Shainin Lake area (see Maximum Clast Size Data). Five hundred and sixty-five paleocurrent measurements taken between 146° and 159° longitude yield an azimuthal vector mean and standard deviation of $240^{\circ} \pm 46^{\circ}$, indicating that sediment transport was generally toward the southwest in the central Brooks Range.

In the western Brooks Range, 20 paleocurrent measurements taken west of 159° longitude yield an azimuthal vector mean and standard deviation of $229^{\circ} \pm 46^{\circ}$. These data suggest that sediment transport was somewhat more southerly directed in the western Brooks Range. This more southerly orientation may have resulted from counter-clockwise oroclinal rotation during Mesozoic thrusting, as suggested by regional structural trends or, alternatively, from irregularities in the configuration of the Kanayut depositional basin.

We also calculated the azimuthal vector mean and standard deviation of paleocurrent data from the three members of the Kanayut Conglomerate in order to quantify any possible shift of sediment transport through time in the Kanayut depositional basin. Two hundred fourteen paleocurrent measurements taken from the Ear Peak Member yield an azimuthal vector mean and standard deviation of $242^{\circ} \pm 47^{\circ}$; 237 measurements from the Shainin Lake Member yield $246^{\circ} \pm 41^{\circ}$; 131 measurements from the Stuver Member yield $232^{\circ} \pm 56^{\circ}$ and 41 measurements from undifferentiated areas of exposure of the Kanayut

Conglomerate, mainly in the southern and western Brooks Range, yield $242^{\circ} \pm 47^{\circ}$. These data are generally consistent between members but may suggest that sediment transport was slightly more southerly-directed during deposition of the Stuver Member. This difference, however, is probably statistically insignificant. We believe, therefore, that the fluvial sediment transport direction was predominantly toward the southwest throughout the entire time of deposition of the Kanayut Conglomerate. Donovan and Tailleur (1975) previously determined southerly directions of sediment transport for the Kanayut Conglomerate.

Kayak Shale

Nineteen paleocurrent measurements from the shallow-marine or intertidal basal sandstone member of the Kayak Shale were previously reported by Nilsen and others (1982b). During the 1981 field season we collected 2 additional paleocurrent measurements and have reassigned 2 additional measurements from the Kanayut Conglomerate. The total number of paleocurrent measurements collected to date from the Kayak Shale is 23, including 8 current ripple markings, 5 oscillation ripple markings, 6 tabular cross-strata, 2 trough cross-strata, 1 clast long-axis orientation and 1 ball and pillow structure.

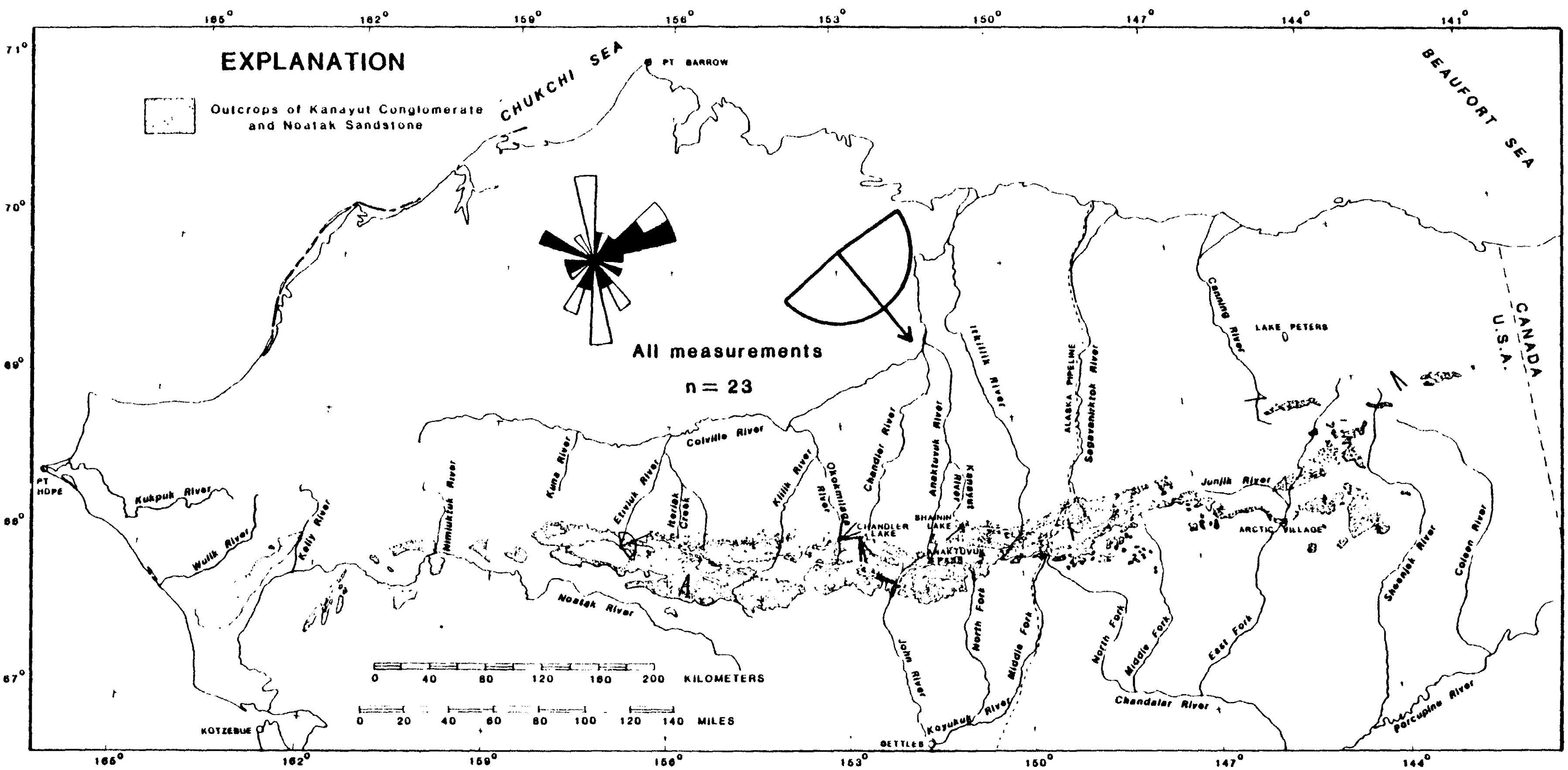
Although the sediment transport direction given by the measurements is relatively consistent at each location, there is considerable variability in data between locations (fig. 20). Because of this geographic variation, the significance of the vector mean and standard deviation ($142^{\circ} \pm 85^{\circ}$) is relatively minor. We attribute the variability of paleocurrent mesurements in the Kayak Shale to alternating offshore, onshore, and longshore sediment transport related to wave-, wind-, storm-, and tide-generated currents.

SUMMARY

This report summarizes stratigraphic and sedimentologic data collected during the 1981 field season in the central and western Brooks Range. The Kanayut Conglomerate consists of three fluvial members, in ascending order, the Ear Peak, Shainin Lake, and Stuver Members. The Ear Peak Member in the areas covered by this report overlies calcareous sandstone and conglomerate of the Noatak Sandstone that was deposited in shallow-marine environments. The Ear Peak Member is inferred to have been deposited by meandering streams, the Shainin Lake by braided streams, and the Stuver by meandering streams. The Stuver Member is overlain by shallow-marine and intertidal fine-grained sandstone at the base of the Kayak Shale.

The three members of the Kanayut can be recognized in the central Brooks Range (figs. 5, 7 and 8), but are not differentiable in the western Brooks Range (figs. 10, 11, 12, 13). The coarse-grained Shainin Lake Member, which permits separation of the members in the central and eastern Brooks Range, apparently pinches out between Siavlat Mountain and the Mulgrave Hills region to the west. The Kanayut Conglomerate in the western Brooks Range consists of as much as 300 m of meandering-stream deposits that contain abundant interbeds of marine strata in the upper and lower parts.

The maximum clast size of conglomerate decreases westward, southward, and eastward from the Shainin Lake area in the central Brooks Range, suggesting that a major trunk stream originally entered the depositional basin in this



KAYAK SHALE PALEOCURRENTS

Rigure 20.--Palocurrent map for the Kayak Shale.

area. A second major trunk stream probably entered the depositional basin at its northeastern end, and possibly a third influenced deposition in the western Brooks Range.

The composition of the Kanayut Conglomerate clasts varies little from place to place or member to member. In most of the conglomerates examined, about 80-95 percent of the pebbles are chert, about 5-15 percent quartz, and 1-5 percent quartzite. Pebbles or argillite and other rock fragments are rare.

The orientations of cross-strata, primary current lineations, current ripple marks, and imbrication and long axes of pebbles in the three fluvial members of the Kanayut consistently show sediment transport toward the southwest across most of the central and western Brooks Range.

The facies sequence in the Hunt Fork Shale and Kanayut Conglomerate suggests that the Kanayut comprises the fluvial part of a prograding delta system (fig. 21). The consistent southwestward direction of paleocurrents in the fluvial deposits, together with the southwestward decrease of grain size, suggests an eastern, northern, or northeastern source, although the allochthonous nature of the outcrop belt precludes identification of the source at present. Judging from the abundance of chert, quartz, and quartzite clasts in the Kanayut, the source terrane was probably composed mostly of slightly metamorphosed sedimentary rocks or underwent extensive chemical weathering.

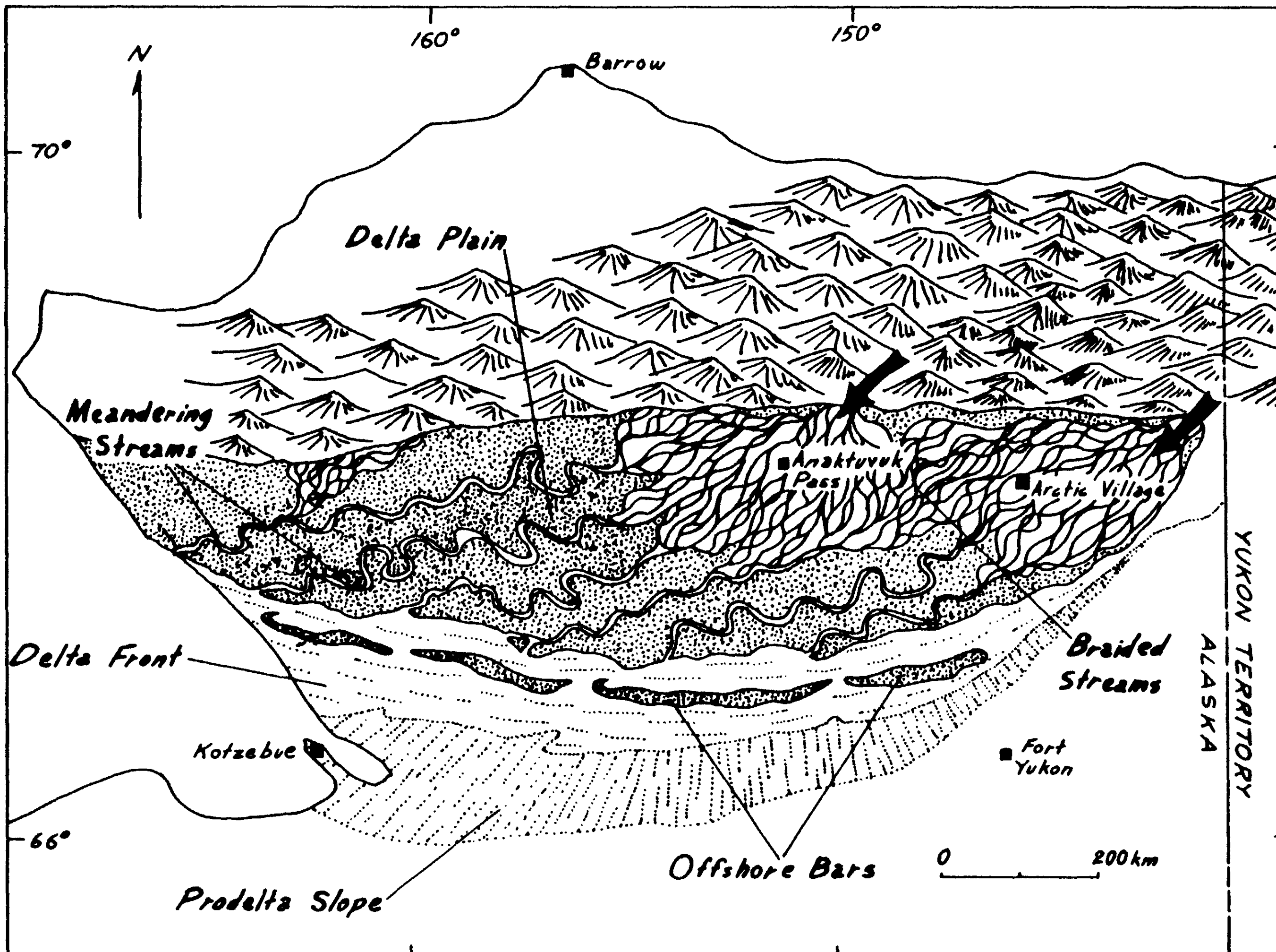


Figure 21.--Paleogeographic map showing approximate extent of the Kanayut delta. Arrows indicate chief areas of sedimentary input. The delta is shown in its present location, without required palinspastic reconstruction.

REFERENCES CITED

Bowsher, A. L., and Dutro, J. T., Jr., 1957, The Paleozoic section in the Shainin Lake area, central Brooks Range, Alaska: U.S. Geological Survey Professional Paper 303-A, p. 1-39.

Brosge, W. P., Dutro, J. T., Jr., Mangus, M. D., and Reiser, H. N., 1962, Paleozoic sequence in eastern Brooks Range, Alaska: American Association of Petroleum Geologists Bulletin, v. 46, no. 12, p. 2174-2198.

Brosge, W. P., Nilsen, T. H., Moore, T. E., and Dutro, J. T., Jr., 1982, Geology of the Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate, Brooks Range, Alaska: U.S. Geological Survey Professional Paper on the National Petroleum Reserve, Alaska, in preparation.

Brosge, W. P., and Reiser, H. N., 1962, Preliminary geologic map of Christian quadrangle, Alaska: U.S. Geological Survey Open-File Map OF-62-15, scale 1:250,000

----- 1964, Geologic Map and section of the Chandalar quadrangle, Alaska: U.S. Geological Survey Open-File Map I-375, scale 1:250,000.

_____ 1965 Preliminary geologic map of the Arctic quadrangle, Alaska: U.S. Geological Survey Open-File Report OF-65-22, scale 1:250,000.

_____ 1969, Preliminary geologic map of Coleen quadrangle, Alaska: U.S. Geological Survey Open-File Report OF-69-25, scale 1:250,000.

_____ 1971, Preliminary bedrock geologic map, Wiseman and eastern Survey Pass quadrangles, Alaska: U.S. Geological Survey Open-File Report O -71-56, 2 sheets, scale 1:250,000.

Brosge, W. P., Reiser, H. N., Dutro, J. T., Jr., and Detterman, R. L., 1976, Reconnaissance geologic map of the Table Mountain quadrangle, Alaska: U.S. Geological Survey Open-File Map 76-546, 2 sheets, scale 1:200,000.

_____ 1979a, Bedrock geologic map of the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-879B, 2 sheets, scale 1:250,000.

Brosge, W. P., Reiser, H. N., Dutro, J. T., Jr, and Nilsen, T. H., 1979b, Geologic map of Devonian rocks in parts of the Chandler Lake and Killik River quadrangles, Alaska: U.S. Geological Survey Open-File Map OF-79-1224, scale 1:200,000.

Carter, C., and Laufeld, S., 1975, Ordovician and Silurian fossils in well cores from North Slope of Alaska: American Association of Petroleum Geologists Bulletin, v. 59, no. 3, p. 457-464.

Chapman, R. M., Detterman, R. L., and Mangus, M. D., 1964, Geology of the Killik-Etivluk Rivers region, Alaska: U.S. Geological Survey Professional Paper 303-F, p. 325-407.

Collins, F. R., 1958, Test wells, Topogoruk area, Alaska: U.S. Geological Survey Professional Paper 305-D, p. 265-316.

Dillon, J. T., Pessel, G. H., Chen, J. H., and Veach, N. C., 1980, Middle Paleozoic magmatism and orogenesis in the Brooks Range, Alaska: Geology, v. 8, p. 338-343.

Donovan, T. J., and Tailleur, I. L., 1975, Map showing paleocurrent and clast-size data from the Devonian-Mississippian Endicott Group, northern Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-692, scale 1:7,500,000.

Dutro, J. T., Jr., 1952, Stratigraphy and paleontology of the Noatak and associated formations, Brooks Range, Alaska: U.S. Geological Survey, Geological Investigations, Naval Petroleum Reserve No. 4, Alaska, Special Report No. 33, 154 p.

----- 1953a, Stratigraphy and paleontology of the Noatak and associated formations, Brooks Range, Alaska (abs.): Geological Society of America Bulletin, v. 64, no. 12, pt. 2, p. 1415.

----- 1953b, Stratigraphy and paleontology of the Noatak and associated formations, Brooks Range, Alaska: Ph.D. thesis, Yale University, New Haven, Connecticut, 154 p.

Dutro, J. T., Jr., Brosge, W. P., Detterman, R. L., and Reiser H. N., 1979, Beaucoup Formation, a new Upper Devonian stratigraphic unit in the Central Brooks Range, northern Alaska, in Sohl, N. F., and Wright, W. B., eds., Changes in stratigraphic nomenclature by the U.S. Geological Survey, 1978: U.S. Geological Survey Bulletin 1482-A, p. A63-A69.

Ellersick, I., Mayfield, C. F., Tailleur, I. L., and Curtis, S. M., 1979, Thrust sequences in the Misheguk Mountain quadrangle, Brooks Range, Alaska, in Johnson, K. M., and Williams, J. R., eds, The United States Geological Survey in Alaska: Accomplishments during 1978: U. S. Geological Survey Circular 804-B, p B9-B10.

Martin, A. J., 1970, Structure and tectonic history of the western Brooks Range, De Long Mountains and Lisburne Hills, northern Alaska: Geological Society of America Bulletin, v. 81, p. 3605-3622.

Mayfield, C. F., and Tailleur, I. L., 1978, Bedrock geology map of the Ambler River quadrangle, Alaska: U.S. Geological Survey Open-File Map 78-120A, scale 1:250,000.

Mayfield, C. F., Tailleur, I. L., Mull, C. G., and Sable, E. G., 1978, Bedrock geologic map of the south half of National Petroleum Reserve in Alaska: U.S. Geological Survey Open-File Map OF-78-70B, 2 sheets, scale 1:500,000.

Mull, C. G., and Mangus, M. D., 1972, Itkilyariak Formation: New Mississippian formation of Endicott Group, Arctic slope of Alaska: American Association of Petroleum Geologists Bulletin, v. 56, no. 8, p. 1364-1369.

Mull, C. G., and Tailleur, I. L., 1977, Sadlerochit?? Group in the Schwatka Mountains, south-central Brooks Range: U.S. Geological Survey Circular 751-B, p. 1327-1329.

Mull, C. G., Tailleur, I. L., Mayfield, C. F., and Pessel, G. H., 1976, New structural and stratigraphic interpretations, central and western Brooks Range and Arctic slope: U.S. Geological Survey Circular 773, p. 24-26.

Nelson, S. W., and Grybeck, Donald, 1980, Geologic map of the Survey Pass quadrangle, Alaska: U. S. Geological Survey Miscellaneous Field Studies Map MF-1176-A, scale 1:250,000.

Nilsen, T. H., 1981, Upper Devonian and Lower Mississippian redbeds, Brooks Range, Alaska, in Miall, A. D., ed., Sedimentation and tectonics in alluvial basins: Geological Association of Canada Special Paper 23, p. 187-219.

Nilsen, T. H., Brosge, W. P., Dutro, J. T., Jr., and Moore, T. E., 1981a, Depositional model for the fluvial Upper Devonian Kanayut Conglomerate, Brooks Range, Alaska, in Albert, N. R. D., and Hudson T., eds., The United States Geological Survey in Alaska: Accomplishments during 1979: U.S. Geological Survey Circular 823-B, p. B20-B21.

Nilsen, T. H., and Moore, T. E., 1982a, Stratigraphic nomenclature for the Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate, Brooks Range, Alaska: U.S. Geological Survey Bulletin, in press.

----- 1982b, Kanayut Conglomerate in the westernmost Brooks Range, Alaska, in Coonrad, W., ed., The United States Geological Survey in Alaska: Accomplishments during 1981: U.S. Geological Survey Circular, in press.

Nilsen, T. H., Moore, T. E., Balin, D. F., and Johnson, S. Y., 1982, Sedimentology and stratigraphy of the Kanayut Conglomerate, central Brooks Range, Alaska--Report of 1980 field season: U.S. Geological Survey Open-File Report 82-199, 81 p.

Nilsen, T. H., Moore, T. E., and Brosge, W. P., 1980a, Paleocurrent maps for the Upper Devonian and Lower Mississippian Endicott Group, Brooks Range, Alaska: U.S. Geological Survey Open-File Report 80-1066, scale 1:1,000,000.

Nilsen, T. H., Moore, T. E., Brosge, W. P., and Dutro, J. T., 1981b, Sedimentology and stratigraphy of the Kanayut Conglomerate and associated units, Brooks Range, Alaska--Report of 1979 field season: U.S. Geological Survey Open-file Report 81-506, 37 p.

Nilsen, T. H., Moore, T. E., Dutro, J. T., Jr., Brosge, W. P., and Orchard, D. M., 1980b, Sedimentology and stratigraphy of the Kanayut Conglomerate and associated units, central and eastern Brooks Range, Alaska--Report of the 1978 field season: U.S. Geological Survey Open-File Report 80-888, 40 p.

Porter, S. C., 1966, Stratigraphy and deformation of Paleozoic section at Anaktuvuk Pass, central Brooks Range, Alaska: American Association of Petroleum Geologists Bulletin, v. 50, no. 5, p. 952-980.

Reed, B. L., 1968, Geology of the Lake Peters area, northeastern Brooks Range, Alaska: U.S. Geological Survey Bulletin 1236, 132 p.

Reiser, H. N., Brosge, W. P., Dutro, J. T., Jr., and Detterman, R. L., 1971, Preliminary geologic map, Mt. Michelson quadrangle, Alaska: U.S. Geological Survey Open-File Report OF-71-237, scale 1:200,000.

_____ 1974, Preliminary geologic map of the Demarcation Point quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-610, scale 1:250,000.

Roeder, D. and Mull, G. C., 1978, Tectonics of Brooks Range ophiolites, Alaska: American Association of Petroleum Geologists Bulletin, v. 62, p. 1696-1702.

Tailleur, I. L., Brosge, W. P., and Reiser, H. N., 1967, Palinspastic analysis of Devonian rocks in northwestern Alaska, in Oswald, D. H., ed., International Symposium on the Devonian System: Alberta Society of Petroleum Geologists, v. 2, p. 1345-1361.

Tetra Tech, Inc., 1979, Seismic survey data, National Petroleum Reserve in Alaska, revised May 1978: National Oceanographic and Atmospheric Administration, Environmental Data and Information Service, 10 maps.