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GEOLOGICAL SURVEY

SEDIMENTOLOGY AND STRATIGRAPHY OF THE KANAYUT CONGLOMERATE AND ASSOCIATED UNITS, BROOKS RANGE, ALASKA-- REPORT OF 1979 FIELD SEASON

By

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Sedimentology and stratigraphy of the Kanayut Conglomerate and associated units, Brooks Range, Alaska--Report of 1979 field season

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ABSTRACT

The Endicott Group in the Brooks Range is of Late Devonian Early Mississippian age. It consists of (1) the Hunt Fork Shale, 1,500 m of deep- to shallow-marine, fine- to medium-grained sandstone, siltstone, and phyllitic shale of early Late Devonian age; (2) the Kanayut Conglomerate, as much as 3,000 m of mostly nonmarine conglomerate, sandstone, and shale of late Late Devonian age; (3) the Kekiktuk Conglomerate, 50-100 m of nonmarine conglomerate, sandstone, shale, and coal of Early Mississippian age; (4) the Kayak Shale, 300 m of sandstone, argillaceous limestone, black shale, and red limestone of Early Mississippian age; and (5) the Itkilyariak Formation, 50-300 m of marine shale, calcareous siltstone, quartzite, and limestone that is a lateral equivalent of the Kayak Shale.

The Endicott Group includes two separate sequences, one allochthonous and one autochthonous. The allochthonous sequence consists of a conformable section of the Hunt Fork Shale, Kanayut Conglomerate, and Kayak Shale. This sequence crops out in the central part of the Brooks Range in a series of thrust plates. The autochthonous sequence, consisting of the Kekiktuk Conglomerate and Kayak Shale, rests unconformably on deformed pre-Middle Devonian rocks and granitic plutons of probable Devonian age. This sequence crops out in the northeastern, eastern, and southern Brooks Range around the margins of the allochthonous sequence.

The Kanayut Conglomerate has been subdivided into four regionally persistent members: (a) the basal sandstone member, 560 m of marine medium-grained sandstone and shale with some interbedded nonmarine conglomerate; (b) the lower shale member, 550 m of nonmarine quartzite, conglomerate, and red shale; (c) the middle conglomerate member, 450 m of massive nonmarine pebble and cobble conglomerate and quartzite, and (d) the Stuver Member, 400 m of nonmarine conglomerate, sandstone and shale.

The deep-marine Hunt Fork Shale grades upward into the shallow-marine basal sandstone member of the Kanayut Conglomerate. The lower shale member of the Kanayut was deposited by progradation of meandering stream facies over the basal shallow-marine sandstone member, culminating in braided stream deposits of the middle conglomerate member. The successively overlying Stuver Member and basal sandstone and black shale of the Kayak Shale record a major transgression, from meandering-stream to shallow-marine to deep-marine facies, respectively. The entire sequence records outbuilding of a major fluvial system into a marine basin during Late Devonian time and its subsequent burial by an Early Mississippian marine transgression.

Clast size data from the Kanayut Conglomerate indicate that the largest clasts are generally present in northern or eastern outcrops. Paleocurrent data from the fluvial deposits indicate sediment transport toward the southwest. Conglomerate of the Kanayut depositional system is compositionally very mature, composed primarily of chert with lesser amounts of vein quartz and quartzite. Chert is more abundant in finer conglomerate.

The Kekiktuk Conglomerate was deposited by braided and meandering streams. Paleocurrents indicate sediment transport toward the south and west. The Kekiktuk is also compositionally mature, containing similar clasts as the Kanayut, only with larger amounts of vein quartz. A likely provenance for at least part of the Kekiktuk is pre-Carboniferous chert, quartzite, and granitic rocks that presently crop out in the northeastern Brooks Range and the British Mountains.

INTRODUCTION

Purpose and scope

The Kanayut Conglomerate and associated rocks of the Endicott Group (Tailleur and others, 1967) comprise a depositional complex of Late Devonian and Early Mississippian age in the Brooks Range of northern Alaska (figs. 1 and 2). The Endicott Group contains two potential types of clastic reservoir rocks: (1) regionally extensive Upper Devonian strata in the shallow subsurface of the Brooks Range and Southern Foothills, and (2) Lower Mississippian and possibly Devonian strata in isolated basins in the deep subsurface of the Northern Foothills and Coastal Plain. These potential reservoirs underlie parts of the National Petroleum Reserve in Alaska (NPRA).

This report presents preliminary results of work completed in 1979 in the western Brooks Range between the Kuna and the Killik Rivers and in the eastern Brooks Range between the Yukon border and Galbraith Lake (fig. 3). The report also incorporates stratigraphic information obtained by regional mapping in 1975, 1976, and 1977. Stratigraphic and sedimentologic studies of the Kanayut Conglomerate and related units during the 1978 field season, chiefly in the central and eastern Brooks Range, have been reported in Nilsen and others (1980a). That report also contains a summary of the regional lithostratigraphy and biostratigraphy of the Endicott Group, and the reader is referred to that report for stratigraphic background information. This report emphasizes measured sections and sedimentologic analyses of depositional cycles, paleocurrents, clast size distribution, clast composition, and lithofacies.

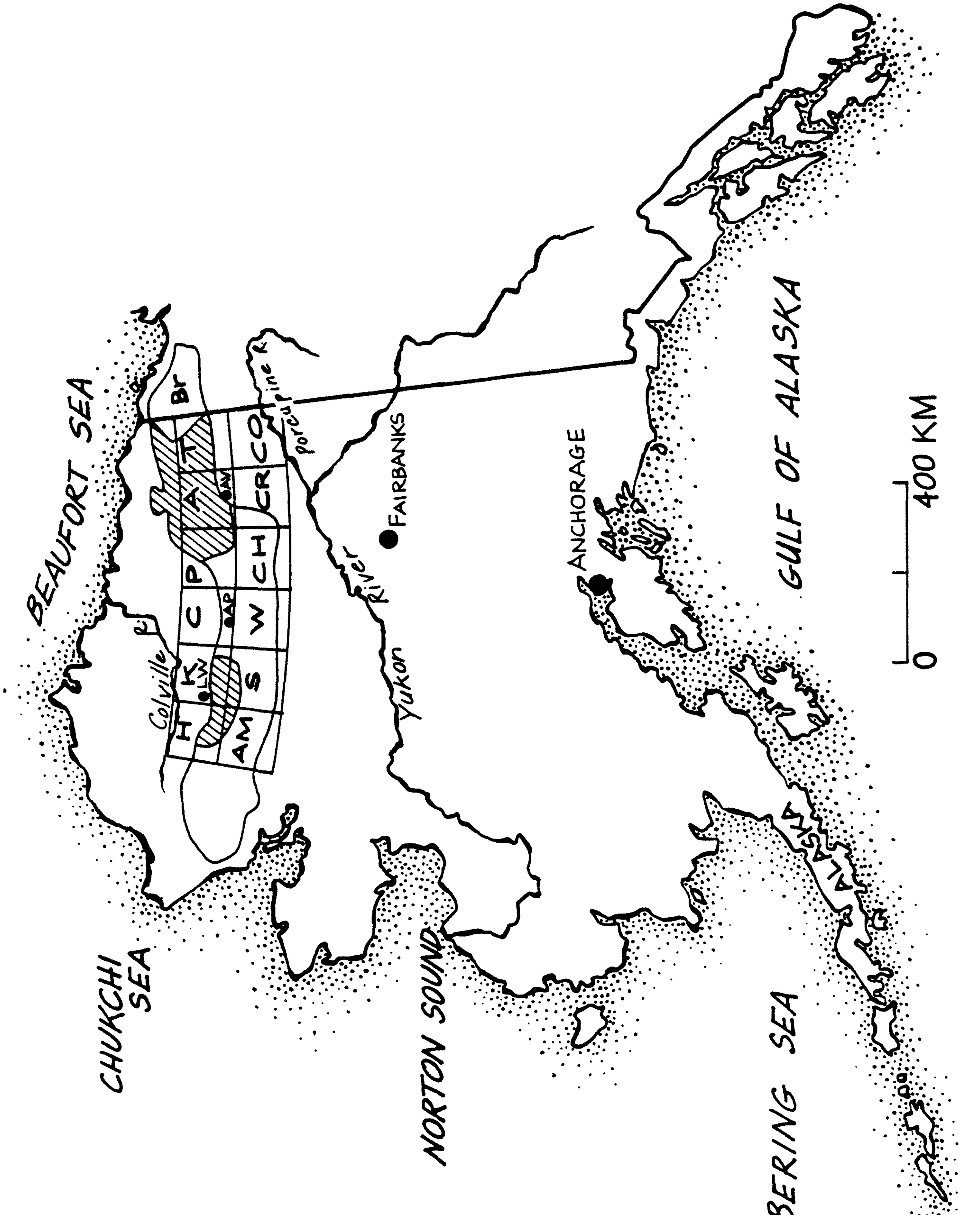


Figure 1.--Index map of Alaska showing location of study area (ruled pattern). British Mountains (Br) and Brooks Range are outlined by heavy lines. Abbreviations: AV, Arctic Village; AP, Anaktuvuk Pass; LW, Lisburne Well Site. Quadrangle names are designated by initial letters: H, Howard Pass; K, Killik River; C, Chandler Lake; P, Philip Smith Mountains; A, Arctic; T, Table Mountain; AM, Ambler River; S, Survey Pass; W, Wiseman; CH, Chandalar; CR, Christian; and CO, Coleen.

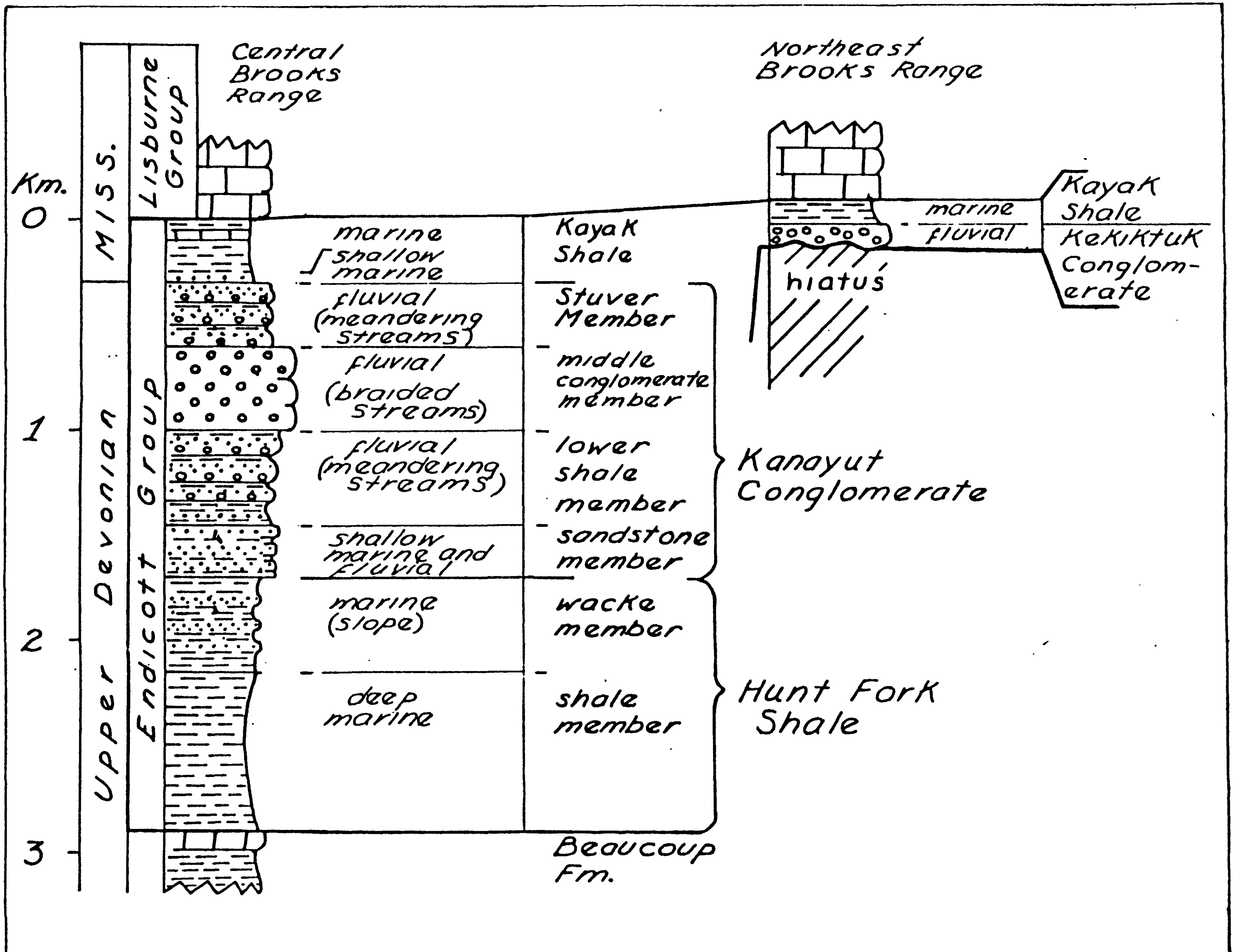


Figure 2. Columnar sections and inferred depositional environments of Endicott Group in the Brooks Range.

Figure 3.--Index map showing distribution of Kanayut Conglomerate and Kekiktuk Conglomerate and major faults in the Brooks Range. Outcrops of the Kanayut Conglomerate are outlined by hachured line, and outcrops of the Kekiktuk Conglomerate are shown by dotted pattern. Outcrops of conglomerate in the eastern Brooks Range that include both Kekiktuk and possible Kanayut are shown by diagonal ruled pattern. Faults that displace the Endicott Group are shown by solid barbed lines. Faults along which younger rocks have been thrust over the Endicott Group at southeast and northwest ends of mapped area are shown by heavy lines with open barbs. Localities mentioned in text are shown by numbers: 1, Arctic Village; 2, Anaktuvuk Pass; 3, Howard Pass; 4, location of Section 78 B46 (measured in 1978); 5, location of Section 78 B111 (measured in 1978); 6, location of Section 78 STU near Shainin Lake (measured in 1978); 7, location of Section 78 CHA near Chandler Lake (measured in 1978); 8, location of Station 78 B208 (measured in 1978); 9, Lake Peters, location of Section 79 B167; 10, location of Section 79 B206; 11, location of Section 79 B136; 12, location of Section 79 B70; 13, location of Section 79 B73. Lisburne 1 indicates location of Lisburne well site. Outlines of outcrops are from: Brosgé and Reiser (1962, 1964, 1965, 1969, and 1971); Brosgé and others (1976 and 1979a); Brosgé and others (1979b); Mayfield and Tailleur (1978); Mayfield and others (1978); Nelson and Grybeck (1980); Reiser and others (1971, 1974), and from unpublished mapping by I. L. Tailleur in the Howard Pass quadrangle and by the authors and H. N. Reiser in the Arctic and Killik River quadrangles.

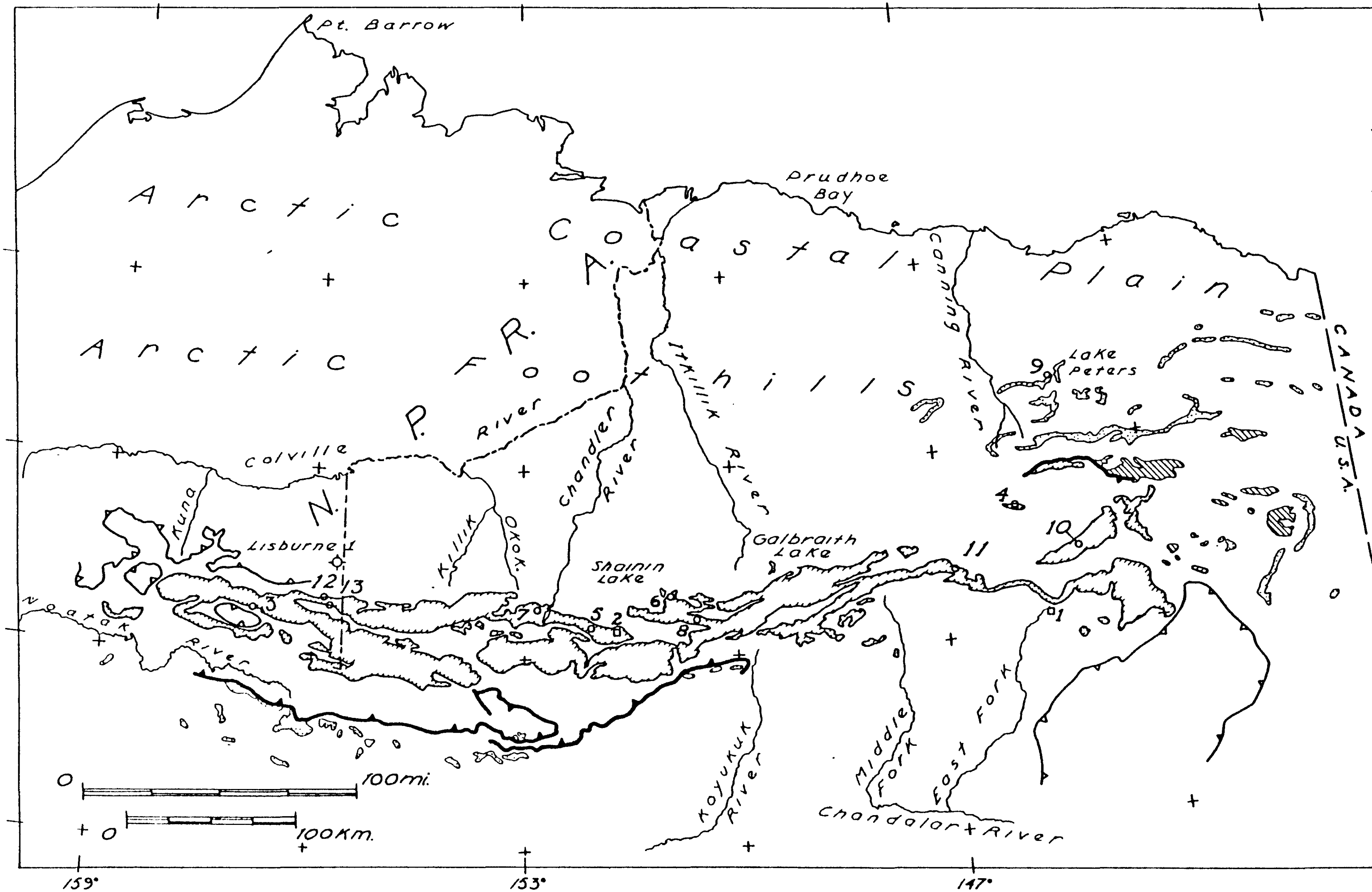


Figure 3.--Index map showing distribution of Kanayut Conglomerate and Kekiktuk Conglomerate and major faults in the Brooks Range.

Stratigraphy

The Upper Devonian and Mississippian strata of the Brooks Range were thought to form a major offlap-onlap megacycle in which the Upper Devonian Kanayut Conglomerate and the Lower Mississippian Kekiktuk Conglomerate are the middle nonmarine part of the cycle (fig. 2). The Devonian Beaucoup Formation (Dutro and others, 1979) and Hunt Fork Shale comprise the lower marine part of the megacycle and the Mississippian Kayak Shale or its local equivalent, the Itkilyariak Formation, comprise the upper marine part.

Prior reconnaissance mapping had outlined the distribution of units of the Endicott Group. However, detailed mapping and division of the Kanayut Conglomerate into informal members were limited to areas near Shainin Lake and Anaktuvuk Pass (Bowsher and Dutro, 1957; Porter, 1966). Members of the Kanayut Conglomerate and of the Hunt Fork Shale have now been mapped in the Philip Smith Mountains quadrangle as a result of fieldwork done in 1975-1976 (Brosgé and others, 1979a) and in most of the Chandler Lake and Killik River quadrangles as a result of fieldwork completed in 1977 and 1978 (Brosgé and others, 1979b).

The Kanayut Conglomerate and Kayak Shale were described by Bowsher and Dutro (1957) in the Shainin Lake area and by Porter (1966) near Anaktuvuk Pass. Bowsher and Dutro described and named the upper three members of the Kanayut, and Porter described the lowest member, which is absent at Shainin Lake. All four members were again described, with revised names, in the Philip Smith Mountains area (Brosgé and others, 1979a). The Hunt Fork Shale was defined by Chapman and others (1964) in its type area just west of the Okokmilaga Valley. The Kekiktuk Conglomerate was named for outcrops west of Lake Peters in the northeastern Brooks Range by Brosgé and others (1962). We remeasured the type section and describe it in this report. The Kekiktuk contains Early Mississippian plant fossils and forms a basal coarse-grained clastic unit coeval with the lower part of the type Kayak Shale. The Itkilyariak Formation, an Early

Mississippian facies-equivalent to that part of the Kayak Shale that crops out in the northeastern Brooks Range, was named by Mull and Mangus (1972) for rocks exposed on Itkilyariak Creek in the Sadlerochit Mountains of the northeastern Brooks Range.

Distribution and structure

Outcrops of the Mississippian Kekiktuk Conglomerate appear to be present in different areas than outcrops of the clastic Upper Devonian rocks, the Beaucoup Formation, Hunt Fork Shale, and Kanayut Conglomerate (fig. 3). The Upper Devonian units crop out in an east-west-trending band adjacent to the 68th parallel and are absent from areas to the north and south where the Kekiktuk Conglomerate in outcrop rests unconformably primarily on deformed pre-Upper Devonian rocks.

Outcrops of the Kekiktuk Conglomerate appear to encircle those of the Beaucoup, Hunt Fork, and Kanayut. This relationship is especially clear at the eastern end of the Brooks Range (fig. 3). Outcrops of the Upper Devonian clastic rocks comprise a series of thrust sheets and are thus allochthonous, whereas outcrops of the Kekiktuk rest primarily on deformed basement and are generally thought to be autochthonous or parautochthonous.

The Mississippian Kayak Shale stratigraphically overlies both the Kanayut Conglomerate and the Kekiktuk Conglomerate and is present throughout most of the Brooks Range. In a small area about 50 to 75 km west-northwest of Arctic Village both the Kanayut and Kekiktuk are absent and the Kayak Shale rests directly on the Hunt Fork Shale.

Most of the Endicott Group in subsurface is only slightly deformed, whereas all outcropping strata are folded and faulted. The thick Devonian rocks of the Endicott Group are broken into large plates that have been thrust northward over each other and over younger rocks. The outcrop trends of the thinner Kekiktuk Conglomerate in both the northeast and southwest Brooks Range reflect the orientation of large anticlinoria in the underlying lower Paleozoic and Precambrian rocks (fig. 3). These dominantly east-west trends bend sharply southward in Canada and converge with those of the southern Brooks Range. As a result, the outcrops of basement rocks and the overlying Kekiktuk Conglomerate surround the eastern outcrop limit of the Upper Devonian clastic rocks.

The Upper Devonian clastic rocks of the Endicott Group form a series of stacked thrust plates in the central Brooks Range. The Kanayut Conglomerate in the central Brooks Range forms three plates that are bounded by south-dipping thrust faults 125 to 450 km long and 15 to 30 km apart, with local displacements of at least 5 to 15 km. Westward the faults obliquely intersect the northern front of the Brooks Range and the thrust plates are folded into west-plunging anticlines that plunge out westward beneath the overlying plate. Eastward most of the faults also die out within the range into overturned anticlines with little or no horizontal displacement. However, the Toyuk thrust of Porter (1966) extends across most, if not all of the Kanayut outcrop belt. Because the plates north of the Toyuk thrust plunge out en echelon to the west, the eastern part of the Toyuk thrust plate forms the south edge of the Kanayut outcrop belt and its western part forms the north edge of the belt of Kanayut at the front of the Range.

A set of north-dipping thrust faults separates the Upper Devonian clastic rocks in the central Brooks Range from the southern belt of Kekiktuk Conglomerate outcrops. If these faults are continuous at depth with the faults that bound the Devonian rocks to the north, the entire outcrop belt of Devonian Endicott Group rocks may be a giant klippe (Mull and others, 1976). However, the connection between these faults appears to be buried beneath subsequent thrust plates on the west and has not yet been found where it should be exposed at the east end of the presumed klippe (fig. 3).

The Kekiktuk, Kayak and Itkilyariak Formations have also been penetrated by drill holes north of the Brooks Range. On the Barrow Arch of the Arctic Coast, the Kekiktuk lies unconformably on Ordovician and Silurian argillite basement (Carter and Laufeld, 1975) and in most places is overlain by the Kayak Shale or the Itkilyariak Formation.

The Upper Devonian part of the Endicott Group is not known for certain to have been reached in the subsurface, but equivalent rocks that have been defined by seismic profiles (Tetra Tech, Inc., 1979) may be present locally in the deeper parts of the Umiat and Meade Basins (fig. 3). The Endicott Group may be as thick as 2,800 m in these deeply buried basins because, although seismic interpretations (Tetra Tech, Inc., 1979) indicate a thickness of less than 1,000 m of strata between the base of the Carboniferous Lisburne Group and argillite basement over most of the area, as much as 4,000 m is present in the Umiat Basin. At the Inigok test well near the edge of the Umiat basin (fig. 3), the Lisburne Group is about 1,200 m thick, the Kayak Shale is 80 m thick, and the Kekiktuk Conglomerate at least 620 m thick (K. J. Bird and I. L. Tailleur, written communications, 1980). Part of the remaining 2,100 m of section in the center of the Umiat Basin may consist of Devonian rocks because it is unlikely that the Kekiktuk attains a thickness of 2,000 m. In Topogoruk Well No. 1 at the northwest edge of the Umiat Basin (fig. 3), steeply dipping conglomerate contains Middle(?) Devonian plants (Collins, 1958).

Acknowledgments

We thank the people of Arctic Village for much kindness and assistance. At the Lisburne Well Site, the Husky Oil Company and its employees provided food, lodging, and assistance of various sorts. Helicopter support by Alaskan Helicopters, Inc., with Lucky Wilson and Bill Woolen, pilots, and Rich Grant, mechanic, is gratefully aknowledged.

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 (fig. 2). The upper part of the Hunt Fork Shale records shoaling marine conditions as it grades upward into the shallow-marine deposits of the basal sandstone member of the Kanayut Conglomerate. The lower shale member of the Kanayut records progradation of fluvial sediments over the basal shallow-marine sandstone, culminating in deposition of the coarser grained fluvial middle conglomerate 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. 2). Thus, the entire sequence records outbuilding of a major fluvial system, most probably a large delta, into a marine basin during Late Devonian time and retreat in Early Mississippian time.

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

A later episode of coarse clastic sedimentation is recorded by the Lower Mississippian Kekiktuk Conglomerate. This episode took place either around the margins of the basin in which the Kanayut was deposited after the major progradational-retrogradational cycle had been completed or in a separate area, probably to the north, of the area of Kanayut sedimentation. Differences in clast composition and facies distribution suggest, in a preliminary fashion, partly different source areas.

Four stratigraphic sections were measured in the Endicott Group during the 1979 field season and four during the 1978 field season (fig. 3; see Nilsen and others, 1980a, for a description of the 1978 sections). No well-exposed sections in the Kanayut Conglomerate have been found west of the Killik River, which has hindered stratigraphic analyses of the offlap-onlap cycle.

Hunt Fork Shale and basal sandstone member of the Kanayut Conglomerate

Shale deposited in low-energy and probable deep-marine (at least below wave base) settings forms most of the lower part of the Hunt Fork Shale. 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 small-scale cross-stratification; however, they are commonly structureless internally, reflecting probable vertical settling from storm-generated overflows or interflows within the water column rather than bottom-flowing turbidity currents.

Cycles of shallow-marine sandstone characterize the upper part of the Hunt Fork Shale and the basal sandstone member of the Kanayut Conglomerate. These sandstone units are locally fossiliferous and contain assemblages characteristic of shelf, intertidal, lagoonal, and marginal-marine environments. The sandstone strata, deposited as a variety of depositional bodies, most typically form thickening- and coarsening-upward cycles, especially in the sandstone member of the Kanayut Conglomerate. The thickening-upward cycles record progradation of the delta over marine slope and shelf deposits. Although the geometry of these deposits has not been ascertained, the vertical sections resemble those of channel-mouth bars described from many modern deltas.

Other bodies of shallow-marine sandstone, characterized throughout by medium- to large-scale cross-strata that have consistent orientations, may represent offshore bars or spits that formed on the margins of the delta. Variable paleocurrents generally present within the shallow-marine sandstone bodies reflect currents generated by waves, winds, tides, and longshore drift.

Kanayut Conglomerate

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

The cycles characteristically commence at their base with erosional truncation of underlying shale of 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 flood plain 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 if any river channels. In these areas, shale deposited by major floods probably accumulated to substantial thicknesses.

A characterstitic feature of the cycles is long inclined surfaces that cut across the vertical sequence. 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 cyles, and characteristically contain abundant rip-up clasts and fragments of levee and interchannel and floodplain deposits. The bodies may be crevasse-splay deposits formed where levees have been broken through during large floods.

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 accumulated during waning stages of floods and on the protected downstream margins of bars.

The largest conglomerate clasts are found in the middle conglomerate 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 middle conglomerate member. Paleosols, levee deposits, shale, and siltstone are rarely present.

Kekiktuk Conglomerate

The Kekiktuk Conglomerate typically consists of a lower conglomeratic braided stream facies similar to that of the middle conglomerate member of the Kanayut Conglomerate and an upper sandstone-rich meandering stream facies similar to that of the lower shale and Stuver Members of the Kanayut Conglomerate. It represents the basal clastic phase of an onlapping Carboniferous sequence that rests unconformably on deformed older Paleozoic and Precambrian rocks and locally on probable Devonian granitic intrusives (Dillon and others, 1980). In its type section west of Lake Peters in the northeast Brooks Range, the Kekiktuk is 80 m thick and consists of granule to cobble conglomerate and sandstone, with some shale interbeds. The thickness of the Kekiktuk is rather uniform throughout the eastern Brooks Range, generally less than 100 m.

The composition of the Kekiktuk varies considerably from place to place, reflecting a variety of local source areas. Larger clasts are mostly subrounded to rounded chert and quartz, but include at some localities argillite, angular fragments of quartz, and flat slabs of chert from the underlying basement. Quartz-tourmaline cobbles and small grains of cassiterite are common near pre-Mississippian granite in the northeastern Brooks Range (Reed, 1968).

MEASURED SECTIONS

Basal sandstone member of the Kanayut Conglomerate, Iteriak Creek

This section was measured through a conglomeratic sandstone body approximately 50 m thick at the base of the basal sandstone member of the Kanayut Conglomerate (fig. 4). The section is exposed on a ridge crest east of Iteriak Creek in Sec. 30, T. 33 N., R. 13 E., Killik River quadrangle (location 13,

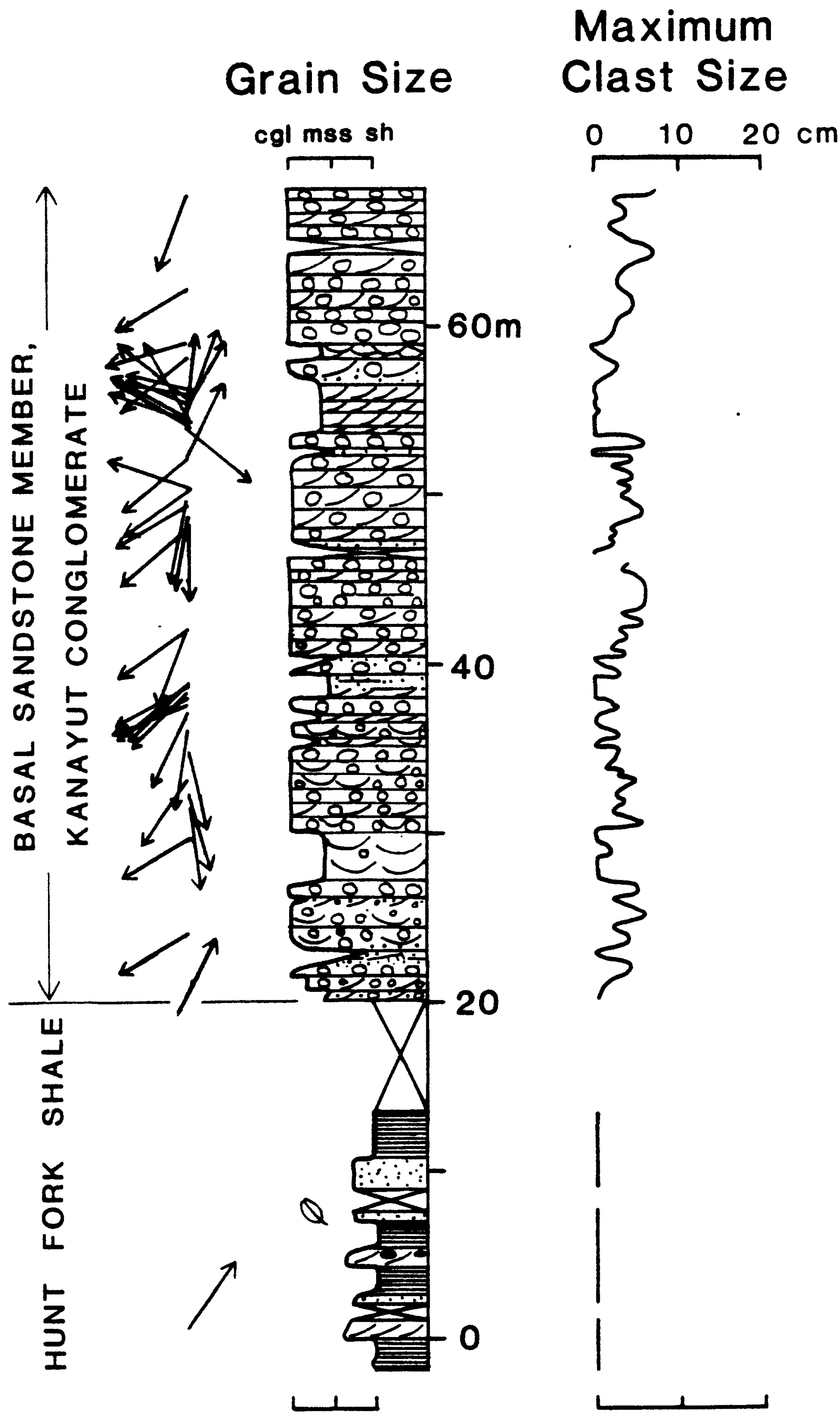


Figure 4.--Measured section of conglomeratic sandstone body in the basal sandstone member of the Kanayut Conglomerate near Iteriak Creek at station 79 B73, western Brooks Range. See Figure 3 for location of section.

fig. 3). The sandstone may form a prominent lens within a thick sequence of more typical brownish-weathering shale. The sandstone body is not laterally continuous and several other lens-shaped bodies of similar pebbly sandstone are present in the basal sandstone member of the Iteriak Creek area. Both underlying and overlying shale, assigned to the upper Hunt Fork Shale, contain sparse marine fossils in thin beds of calcareous sandstone. We interpret the lens to have been deposited as a shallow-marine bar in a delta-front setting.

The sequence generally coarsens upward and consists mostly of pebbly sandstone organized into medium- to large-scale sets of tabular cross-strata. The longest clast observed was 7 cm in length, and the clast composition consisted of about 75 percent chert, 18 percent quartz, 1-2 percent quartzite, and about 5 percent argillite. Cross bed amplitudes average about 40 cm and range from about 5-100 cm. Beds of massive conglomerate, horizontally stratified conglomerate, and trough cross-stratified sandstone are also present within the section. Paleocurrent orientations from cross-strata generally indicate sediment transport to the southwest, although sedimentary transport to the northeast, southeast, and south was determined from some cross-strata, particularly in the lower and upper parts of the section.

We believe that this pebbly sandstone lens was deposited as an offshore marine bar, with variable current directions resulting from offshore, onshore, and longshore transport related to wave-, wind-, storm-, and tide-generated currents. The sequence, although coarser than most, is typical of many marine sandstone bodies in the basal sandstone member of the Kanayut Conglomerate.

Lower shale member of the Kanayut Conglomerate, East Fork of the Chandalar River

A section of the lower shale member of the Kanayut Conglomerate was measured on a ridge east of the East Fork of the Chandalar River north of Arctic

Village, in sec. 2, T. 12 S., R. 30 E. of the Arctic quadrangle (location 10, fig. 3). The lower and upper contacts of the member are not clearly exposed, and as the section was measured, it became clear that some structural deformation was present within the section, primarily as a result of thrust faulting subparallel to bedding. Measurement of the section was terminated when a larger fault was encountered. The upper parts of the section are poorly exposed, preventing proper measurement of the fluvial cycles.

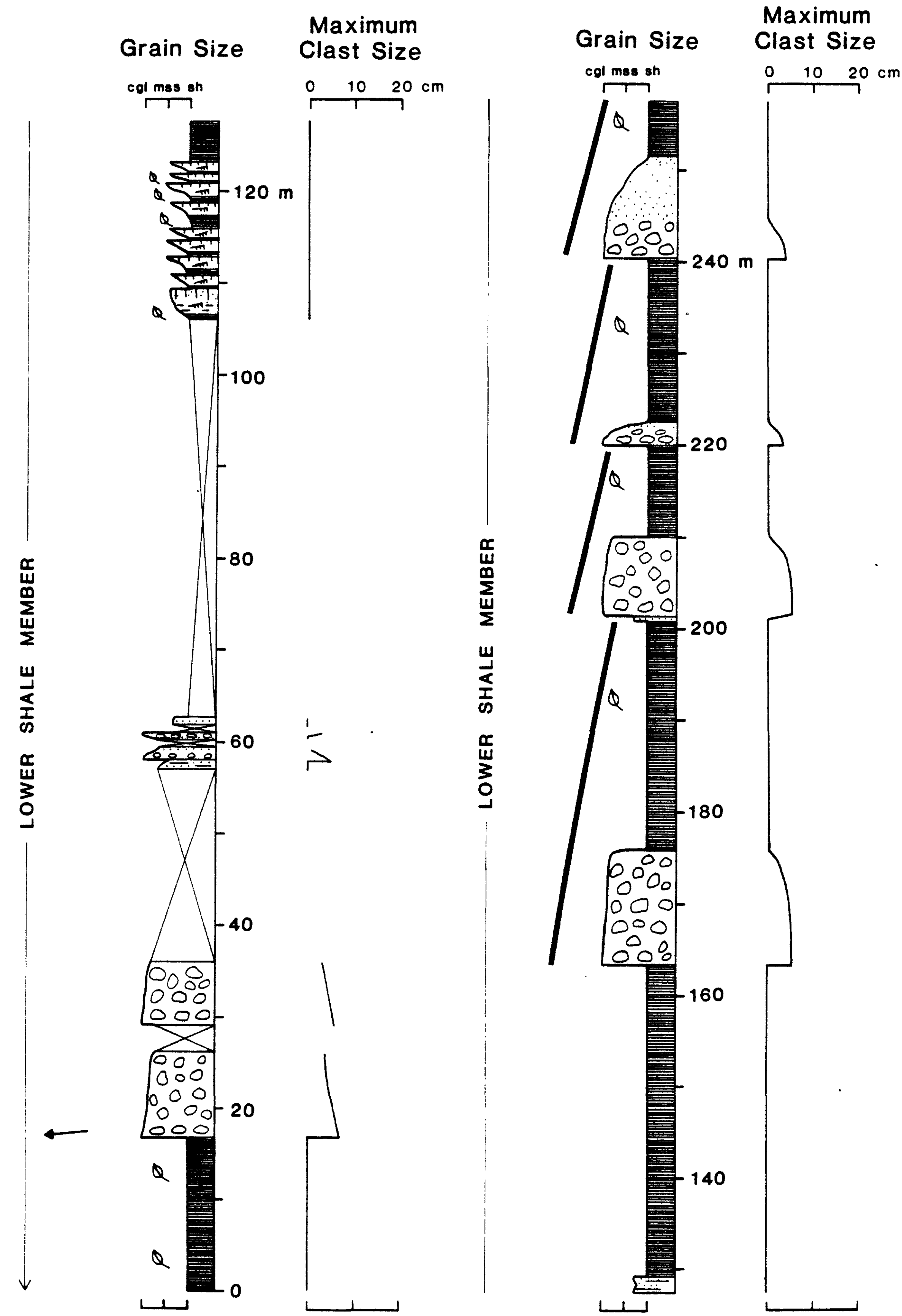
The section consists of repetitive fining-upward cycles typically commencing in the beds of conglomerate or conglomeratic sandstone at the base and extending upward through cross-stratified sandstone to black plant-bearing shale (fig. 5). The maximum pebble size observed within the section was 6 cm. Two paleocurrents indicate sediment transport toward the west near the base of the section and toward the south near the top of the section.

Thirteen fining-upward fluvial cycles were measured, averaging 15 to 20 m in thickness. Abundant and thick black and red shale deposits mark most cycles, with as much as 40 m of shale in one cycle. Cycle 4 interestingly shows a flood-plain sequence of vertical cycles of black plant-bearing shale, thin ripple-marked overbank deposits of fine-grained sandstone, and paleosols. These thin coarsening-upward cycles average a meter or two in thickness and probably record outbuilding of levee deposits into adjacent swampy lowlands or lakes of the flood plain. The depositional setting was probably one characterized by fairly large low-sinuosity meandering streams crossing an extensive flood plain.

Kanayut Conglomerate, Junjik River

An almost complete section of the Kanayut Conglomerate was measured along the south limb of a broad anticline in sec. 35, T. 12 S., R. 22 E. of the Arctic

Figure 5A, 5B.--Measured section of the lower shale member of the Kanayut Conglomerate near the East Fork of Chandalar River at station 79 B206, eastern Brooks Range. See Figure 3 for location of section.



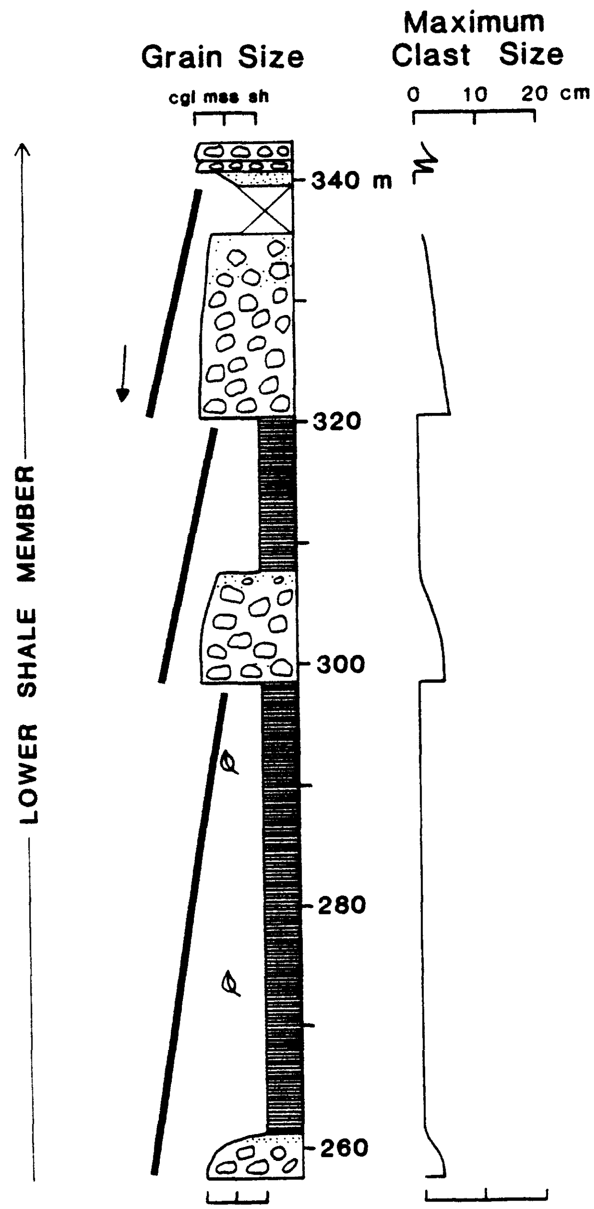


Figure 5A, 5B.--Measured section of the lower shale member of the Kanayut Conglomerate near the East Fork of Chandalar River at station 79 B206, eastern Brooks Range. See Figure 3 for location of section.

quadrangle (location 11, fig. 3). The section is about 730 m thick, with the lower shale member about 280 m thick, and the Stuver Member about 190 m thick (fig. 6). Neither the base nor the top of the Kanayut Conglomerate is clearly exposed, although both are closely approached in the measured section. Paleocurrents are generally directed toward the southwest through the entire section, although some southerly and easterly directions were also recorded.

The lower shale member gradually coarsens and thickens upward toward the base of the middle member. It contains thick sections of shale, both red and black, in its lower part and less shale upward stratigraphically. Plant fossils are generally abundant. Fining-upward cycles more than 20 m thick characterize the basal 200 m and fining-upward cycles less than 10 m thick the upper 80 m of the lower shale member. Conglomerate is present in the member, particularly in the intervals from 170 to 190 m and from 220 to 240 m. However, the conglomerate contains only small pebbles less than 5 cm in length. We interpret most of the lower shale member to have been deposited by meandering streams flowing across an extensive flood plain in which large amounts of overbanked mudstone accumulated. The rivers were smaller and shallower toward the end of the time of deposition of the lower shale member, and locally developed a braided-stream nature characterized by little or no shale deposition during the time of abundant conglomerate deposition about 180 m and 220 m above the base of the unit.

The lower boundary of the middle conglomerate member is placed at the first appearance in the section of coarser conglomerate containing clasts larger than 10 cm and the change in character of the section to one having thick sequences of interbedded conglomerate and sandstone with only minor amounts of shale. The middle conglomerate member is interpreted to have been deposited primarily by braided rivers of various sorts. The amount of shale in the member amounts to about 10 m of the total of 260 m. An extremely thick

Figure 6A, 6B, 6C.--Measured section of the lower shale member, middle conglomerate member, and Stuver Member of the Kanayut Conglomerate near the Junjik River at station 79 B136, eastern Brooks Range. See Figure 3 for location of section.

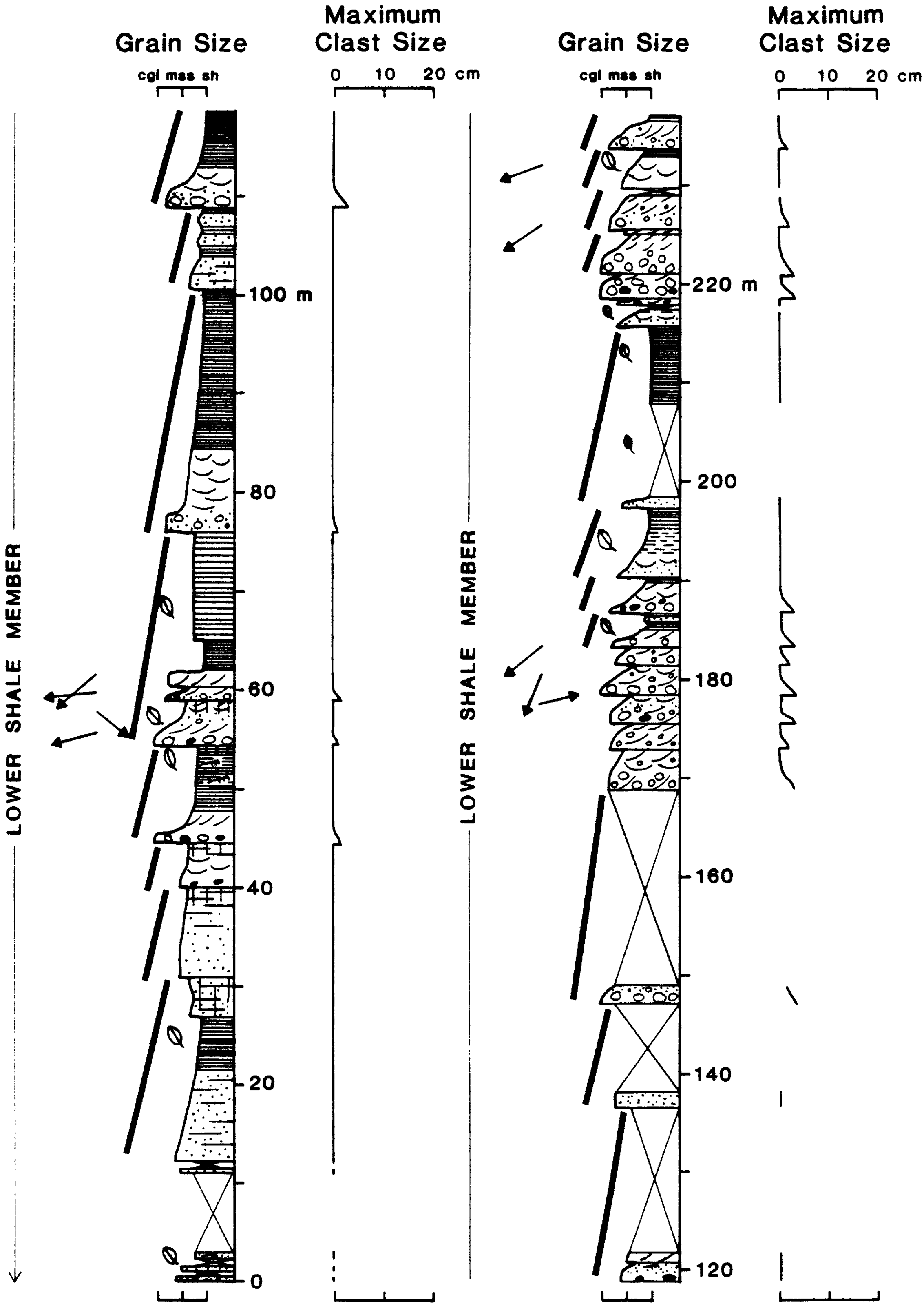


Figure 6A, 6B, 6C.--Measured section of the lower shale member, middle conglomerate member, and Stuver Member of the Kanayut Conglomerate near the Junjik River at station 79 B136, eastern Brooks Range. See Figure 3 for location of section.

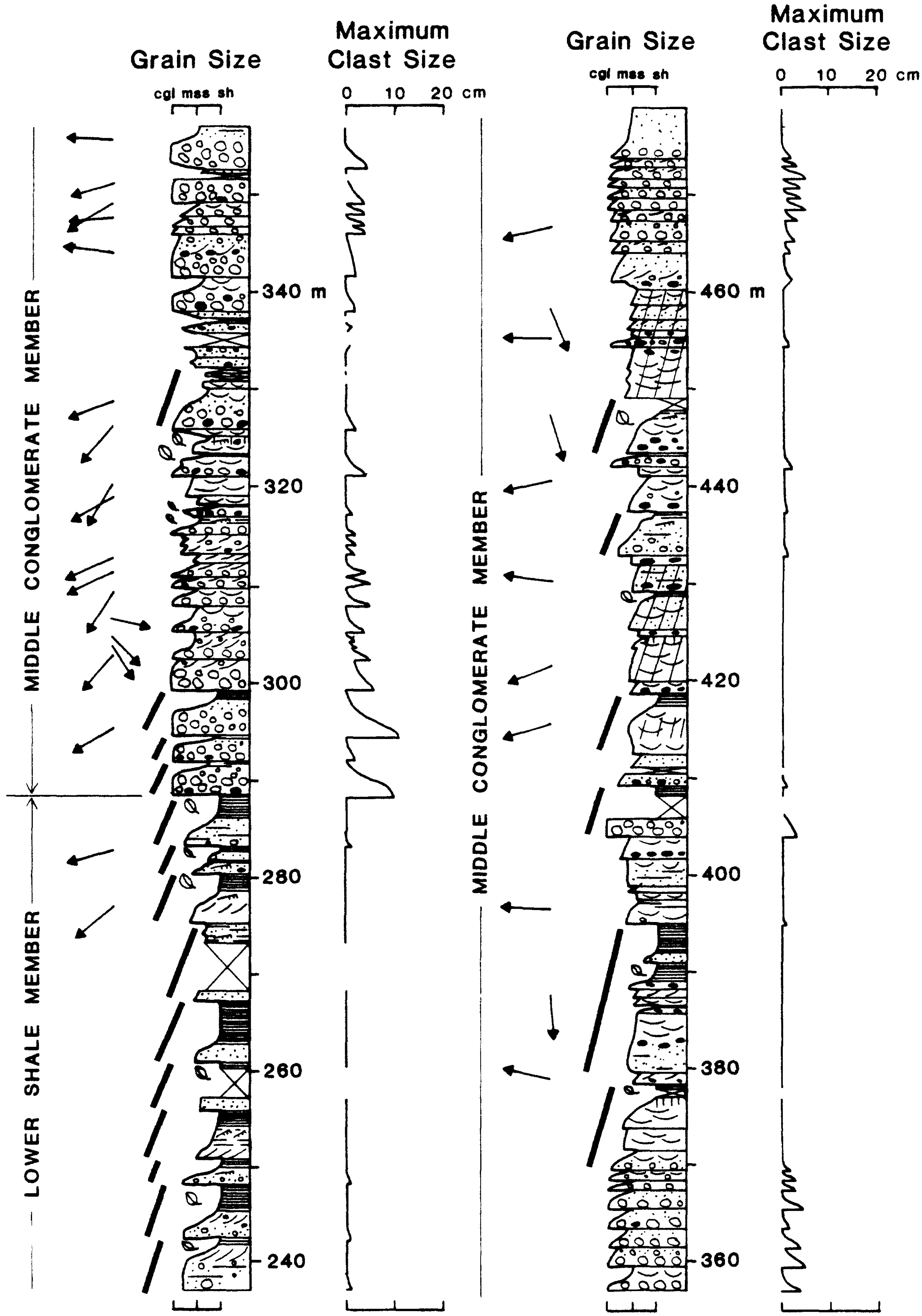
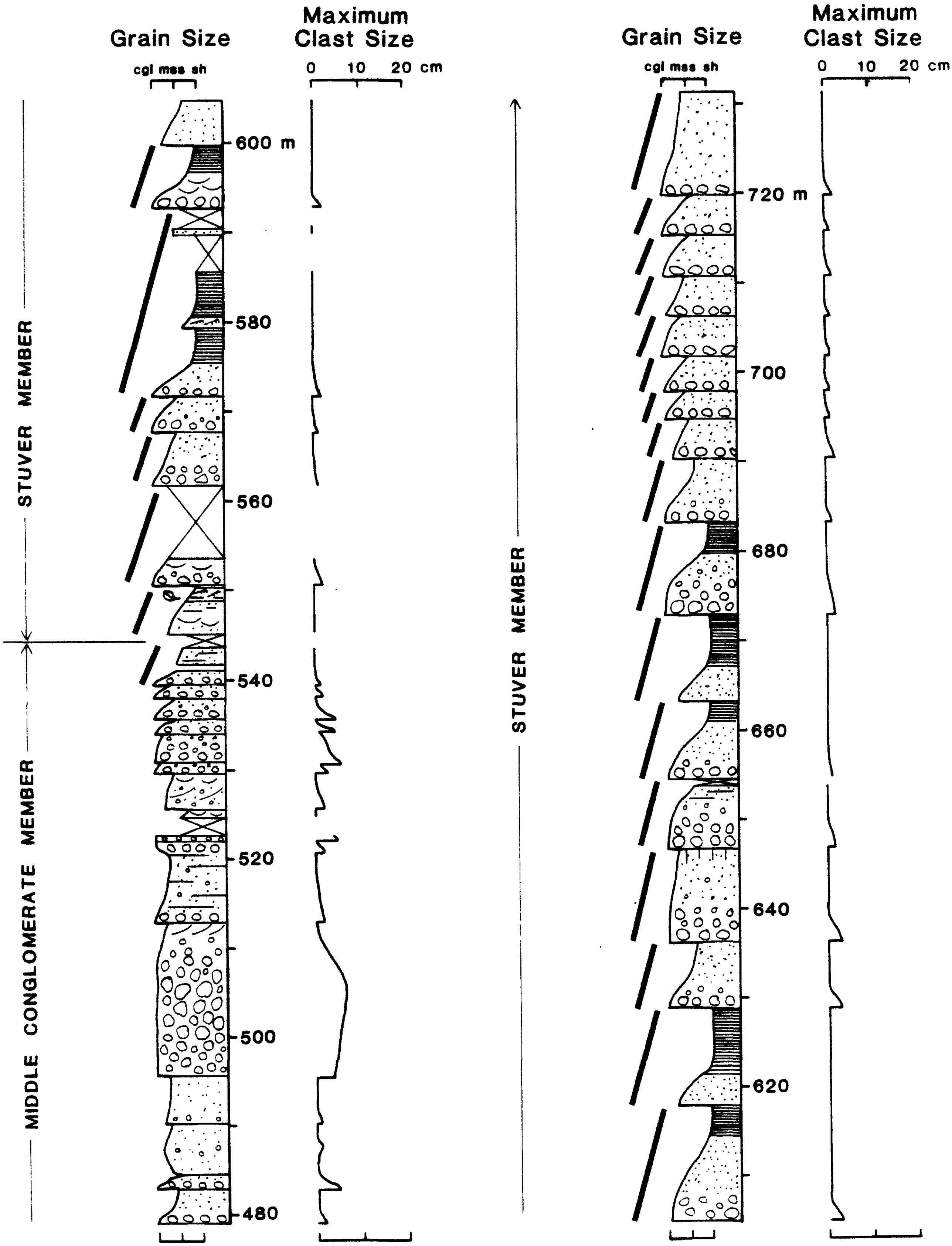


Figure 6A, 6B, 6C.--Measured section of the lower shale member, middle conglomerate member, and Stuver Member of the Kanayut Conglomerate near the Junjik River at station 79 B136, eastern Brooks Range. See Figure 3 for location of section.



and massive conglomeratic unit at about 500 m above the base of the Kanayut records the culmination of middle conglomerate member deposition. Most of the middle member consists of fining-upward couplets of conglomerate and trough-cross-stratified or tabular cross-stratified conglomeratic sandstone or sandstone.

The Stuver Member consists of fining-upward cycles of conglomerate, sandstone and shale. The maximum clast size of the conglomerate decreases to less than 5 cm in length. The cycle thicknesses average between 10 and 15 m, with shale as thick as 10 m in the lower part of the member. Paleosols are present in the Stuver about 655 m above the base of the section, and plant fossils are locally abundant in overbank levee deposits and flood plain shales. The Stuver Member contains almost no shale in its upper 45 m, where cycles consist of repetitive fining-upward couplets of conglomerate and sandstone that average about 7 m in thickness. The presence of this shale-deficient uppermost part of the measured Stuver section suggests that the section is incomplete, because the Stuver typically contains abundant shale in its upper part throughout the Brooks Range (see fig. 7 for example).

Kanayut Conglomerate, Iteriak Creek

A partial section of the Kanayut Conglomerate was measured on the west side of the valley of Iteriak Creek in sec. 33, T. 34 N., R. 13 E. of the Killik River quadrangle (location 12, fig. 3). About 190 m of section was measured, with about 70 m covered (fig. 7). Neither the base nor top of the Kanayut is exposed in the section, which is overturned to the east.

The section generally coarsens upward to its middle part and then fines upward to the top. We believe that the three fluvial members of the Kanayut are exposed in this section: 60 m of the lower shale member, about 90 m of the middle conglomerate member, and about 40 m of the Stuver Member. Although the

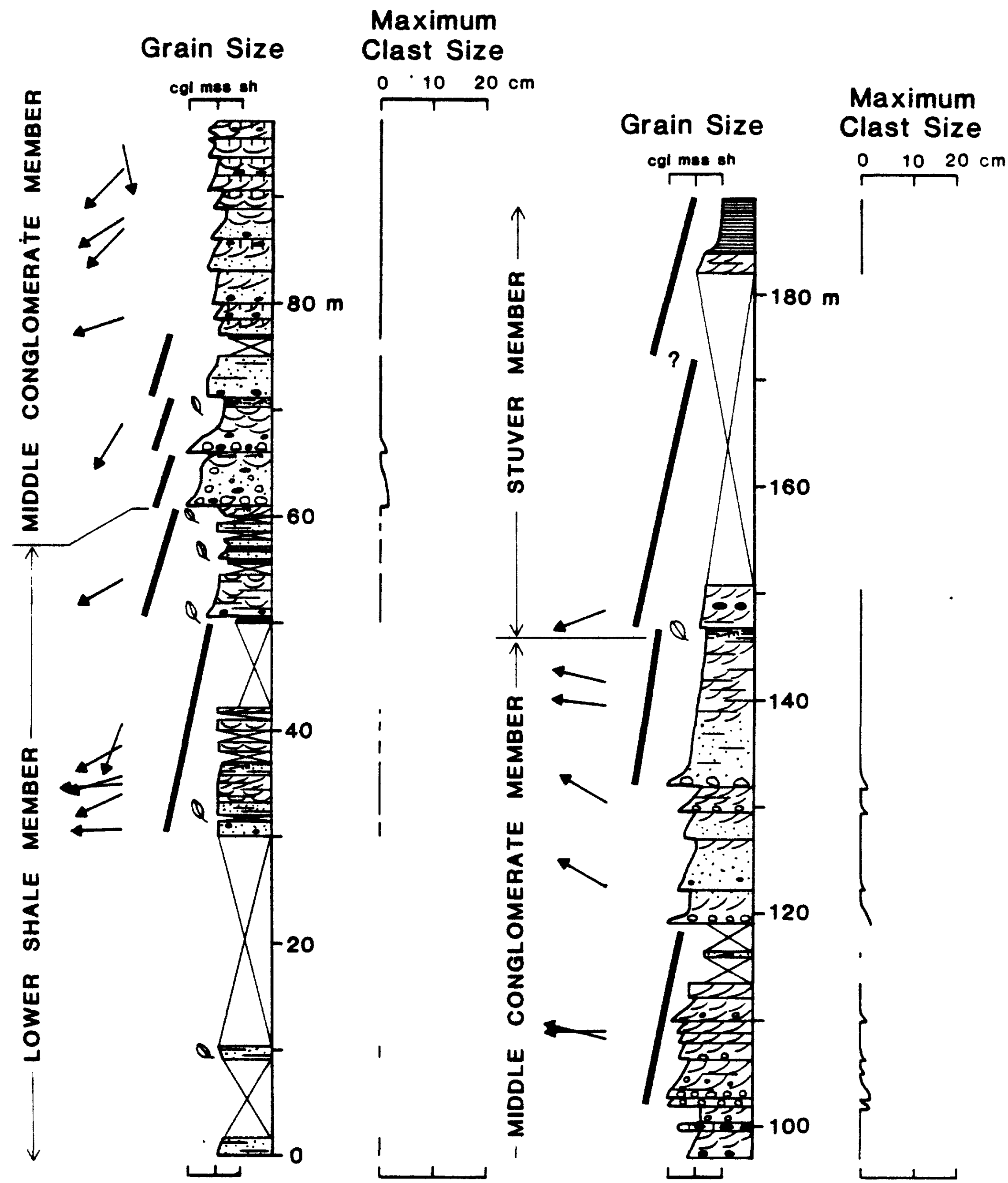


Figure 7.--Measured section of the Kanayut Conglomerate near Iteriak Creek at station 79 B70, western Brooks Range. See Figure 3 for location of section.

total thickness of the Kanayut is not exposed, regional relations and the minimal thickness of the middle conglomerate member suggest that the Kanayut Conglomerate is very thin in the Iteriak Creek area. The maximum conglomerate clast size is about 3 cm. Paleocurrents generally indicate sediment transport to the west throughout the section. Plant fragments are common in very thin-bedded sandstone and shale at the tops of some fining-upward cycles.

The lower shale member and Stuver Member contain fining-upward cycles from 5 to 15 m thick, although the lower and upper parts of the section are poorly exposed and may consist largely of shale and fine-grained sandstone deposited in floodplain environments. The middle conglomerate member consists mostly of alternating conglomerate and cross-stratified sandstone. Fining-upward cycles are present in parts of it, but no shale is exposed. Paleosols are common in the middle part of the section, developed on trough-cross-stratified sandstone.

Kekiktuk Conglomerate, Lake Peters

The type section of the Kekiktuk Conglomerate in the Lake Peters area of the northeastern Brooks Range (location 9, fig. 3) was remeasured to more carefully describe the sedimentary facies. The section was originally measured and described by Brosgé and others (1962).

The section is about 80 m thick (originally measured to 60 m) and forms an overall gradually fining-upward section (fig. 8). It can be divided informally into three members; a thin basal conglomerate-breccia a few meters thick containing weathered clasts of basement rock, a middle member that is about 60 m thick, and an upper member about 20 m thick. Each member is interpreted to have been deposited by fluvial processes, the lower and middle by braided streams and the upper chiefly by meandering streams. Paleocurrents consistently indicate southeasterly transport of sediments.

The base of the section is marked by an angular unconformity between the Kekiktuk Conglomerate and deformed underlying phyllite, slate, and quartzite

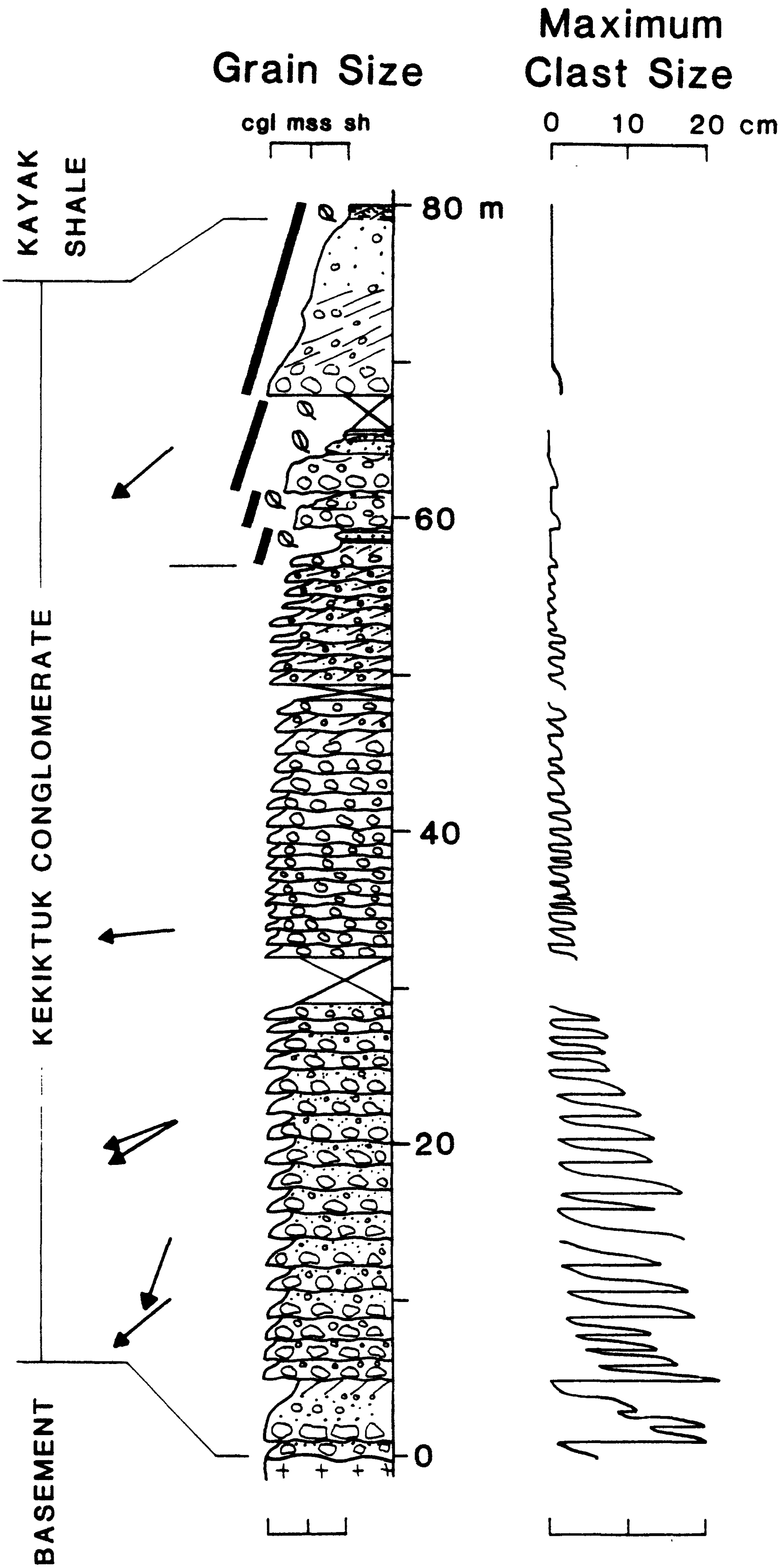


Figure 8.--Measured type section of the Kekiktuk Conglomerate west of Lake Peters at station 79 B167, northeastern Brooks Range. See Figure 3 for location of section.

of the pre-Upper Devonian basement. The lowermost 30 cm consists of residual basal breccia-conglomerate containing angular to subrounded clasts of basement rock as large as 6 cm, about one-half very fine-grained quartzite; this basal unit has an open framework with clasts floating in a sandy to silty matrix.

Above the overlying 70 cm of quartzitic sandstone is a 120-cm-thick conglomerate bed that contains cobbles as large as 20 cm that are weathered out of a soft matrix that has some features characteristic of paleosols. Above this unit, the middle member consists of very resistant quartzitic sandstone and conglomerate typical of the main part of the Kekiktuk Conglomerate throughout the eastern Brooks Range.

The middle member consists almost completely of fining-upward couplets of conglomerate and sandstone. The base of each conglomerate is channeled into the underlying sandstone and each couplet forms a fining-upward unit, as shown by the grain size plots on figure 8. The conglomerates are clast-supported, typically massive to crudely parallel-stratified, and have well-defined fabrics characterized by upstream dip of imbricated clasts and orientation of long axes parallel to flow. Matrix consists of sandstone and finer conglomeratic sandstone. Pebbly mudstone or pebbly siltstone indicative of debris-flow sedimentation was not recognized above the basal two meters. The sandstones are either massive, crudely parallel stratified, or trough cross-stratified. They are typically medium- to very coarse-grained, and typically pebbly. They appear in outcrop as thin, wide lenses truncated above by beds of conglomerate.

The upper member contains five fining- and thinning-upward cycles that increase upward in thickness from about 3 m to 11 m in thickness. The tops of these cycles consist of shaly intervals or are represented by covered intervals in which shale marks most of the float. The cycles indicate a different type of fluvial sedimentation, more closely resembling cycles of meandering streams. The cycles consist most typically of a basal conglomeratic interval that contains pebbles less than 2 cm in length, massive medium- to coarse-grained, quartzitic sandstone, trough cross-stratified fine- to medium-grained quartzitic sandstone, ripple-marked fine- to very fine-grained sandstone interbedded with red shale, and red or black shale. Plant fragments are abundant in the fine-grained parts of the cycles, typically as transported fragments.

The top of the section is marked by an abrupt upward transition from black shale at the top of the uppermost 11-m-thick fluvial cycle of the upper member of the Kekiktuk Conglomerate to ripple-marked fine-grained quartzitic sandstone of the basal sandstone of the Kayak Shale. The transition appears conformable and we interpret it to represent an upward change in depositional setting from floodplain deposits of a meandering stream facies to a tidal sand body facies.

CONGLOMERATE CLAST SIZE DATA

Introduction

The maximum dimension of the ten largest conglomerate clasts was measured at each station where conglomerate was observed in order to determine overall changes in clast size. In our report on the 1978 field season, we presented the mean size of the ten largest clasts from 28 stations in the Kanayut Conglomerate and Kekiktuk Conglomerate (Nilsen and others, 1980a, fig. 8). In this report we have compiled and present maximum clast size from 43 stations measured in 1978 and 67 stations measured in 1979.

The data are not geographically well dispersed, being concentrated around the Lisburne No. 1 well site and the villages of Arctic Village and Anaktuvuk Pass, so that east-west and north-south changes are difficult to ascertain. At many stations only a portion of the entire stratigraphic thickness of a member or of the formation was examined, so that many plots represent the mean only for a limited stratigraphic thickness of the unit. In addition, the map distribution of maximum clast sizes must be cautiously interpreted with regard to paleogeography because of the presence of at least three major thrust faults within the outcrop belt and the lack of well-defined marker beds for regional correlation. Nevertheless, several useful conclusions can be derived from the limited data.

Kanayut Conglomerate

Maximum clast size data was collected at a total of 81 locations in the Kanayut Conglomerate in 1978 and 1979 (fig. 9). The middle conglomerate member generally contains the largest clasts, and we collected more data from it than from other members.

The Kanayut Conglomerate generally contains larger clasts in northern and eastern outcrops. North to south decreases in clast size are readily visible in the Lisburne well site and Anaktuvuk Pass areas. In the area of Arctic Village, the largest maximum clast for the middle conglomerate member was also observed in northernmost outcrops. East to west decreases in clast size are apparent between Arctic Village and Anaktuvuk Pass and between Anaktuvuk Pass and the Lisburne well site. West of the Lisburne No. 1 well site, conglomerate is rare in the Kanayut, strongly indicating a westward decrease in clast size.

These data suggest that sediment transport of the Kanayut Conglomerate was from the north and east and toward the south and west. The sharp increase in clast size in the Anaktuvuk Pass area may signal the presence of a second major input to the Kanayut Conglomerate in that area. Also, the largest clast size in the lower shale member of the Kanayut Conglomerate was noted in the southeasternmost observed outcrop, suggesting possible derivation of clasts from the east-southeast.

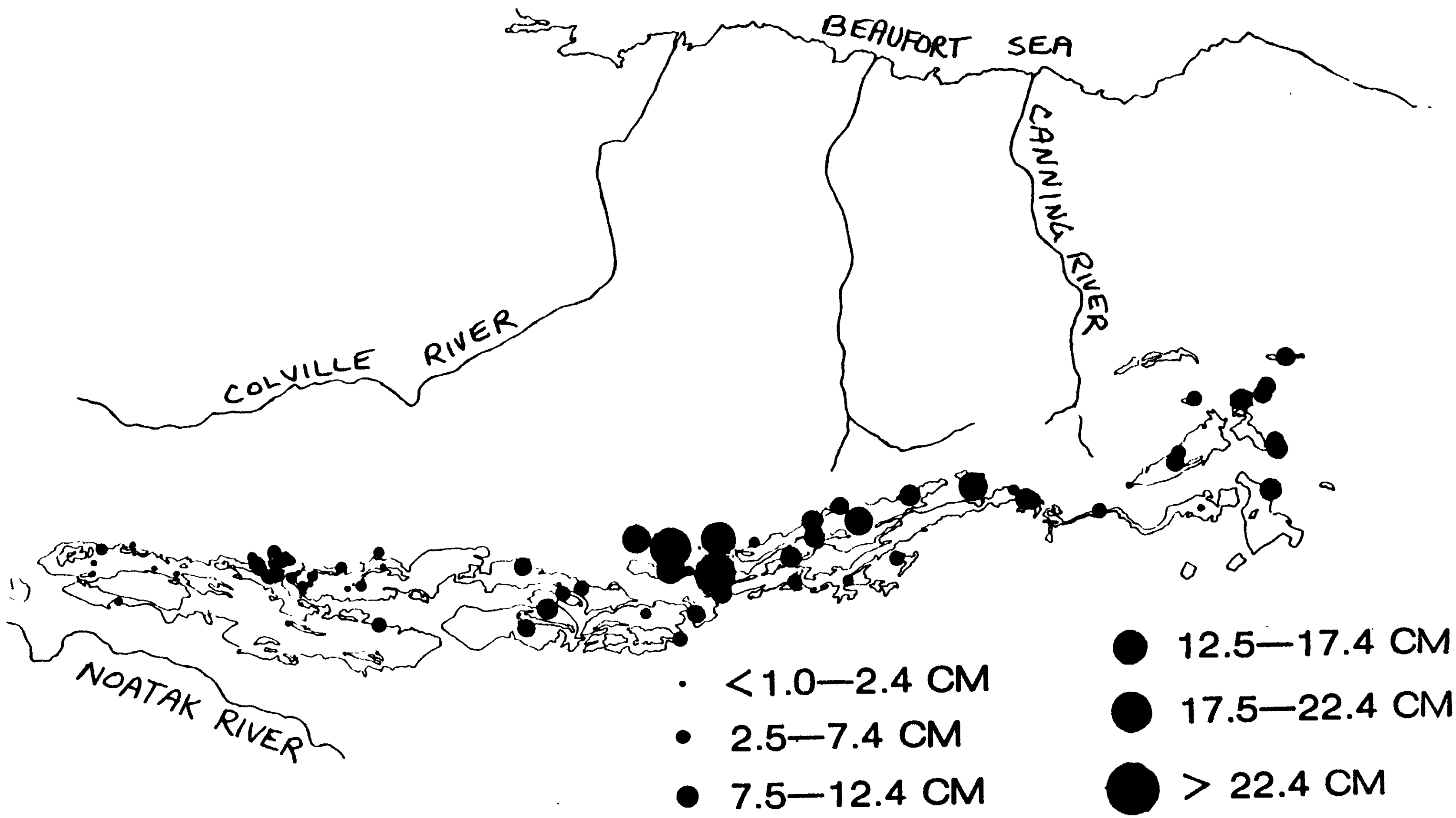


Figure 9.--Map showing distribution of the largest conglomerate clasts in the Kanayut Conglomerate.

Kekiktuk Conglomerate

Maximum clast size data was collected at a total of 28 stations from the Kekiktuk Conglomerate in 1978 and 1979 (fig. 10). Twenty-six of the stations are located in the northeastern Brooks Range; two others are located in the Howard Pass quadrangle in western exposures of the Kekiktuk Conglomerate.

The largest clast sizes are in the northernmost locations and these decrease sharply in size toward the south. However, large clast sizes were also recorded in the southeasternmost and easternmost locations and clast sizes seem to decrease in size toward the northwest and west from these locations. The two stations located in Howard Pass quadrangle do not allow determination of direction of sediment transport in that area, but they are intermediate in size; sediment transport in this area may be unrelated in terms of depositional systems to that in the northeast.

Large clast sizes in the northern and easternmost locations suggest that sediment transport in the Kekiktuk Conglomerate was from those directions. The direction of sediment transport in the westernmost exposures of the Kekiktuk Conglomerate is not known, but it probably was independent of that in the east, suggesting that sediment transport in the Kekiktuk was affected by local uplifts and paleogeography.

CONGLOMERATE CLAST COMPOSITION

Introduction

The clast compositions of conglomerate from the Kanayut Conglomerate, Kekiktuk Conglomerate, Hunt Fork Shale, and Beaucoup Formation were determined by counting in the field. Forty-one pebble counts of one hundred randomly selected clasts larger than 1 cm in diameter were made at 31 separate locations during 1979 (Table 1). One count is from the Beaucoup Formation, two from the Hunt Fork Shale, 18 from Kekiktuk Conglomerate, and 3, 2, 11 and 4 from

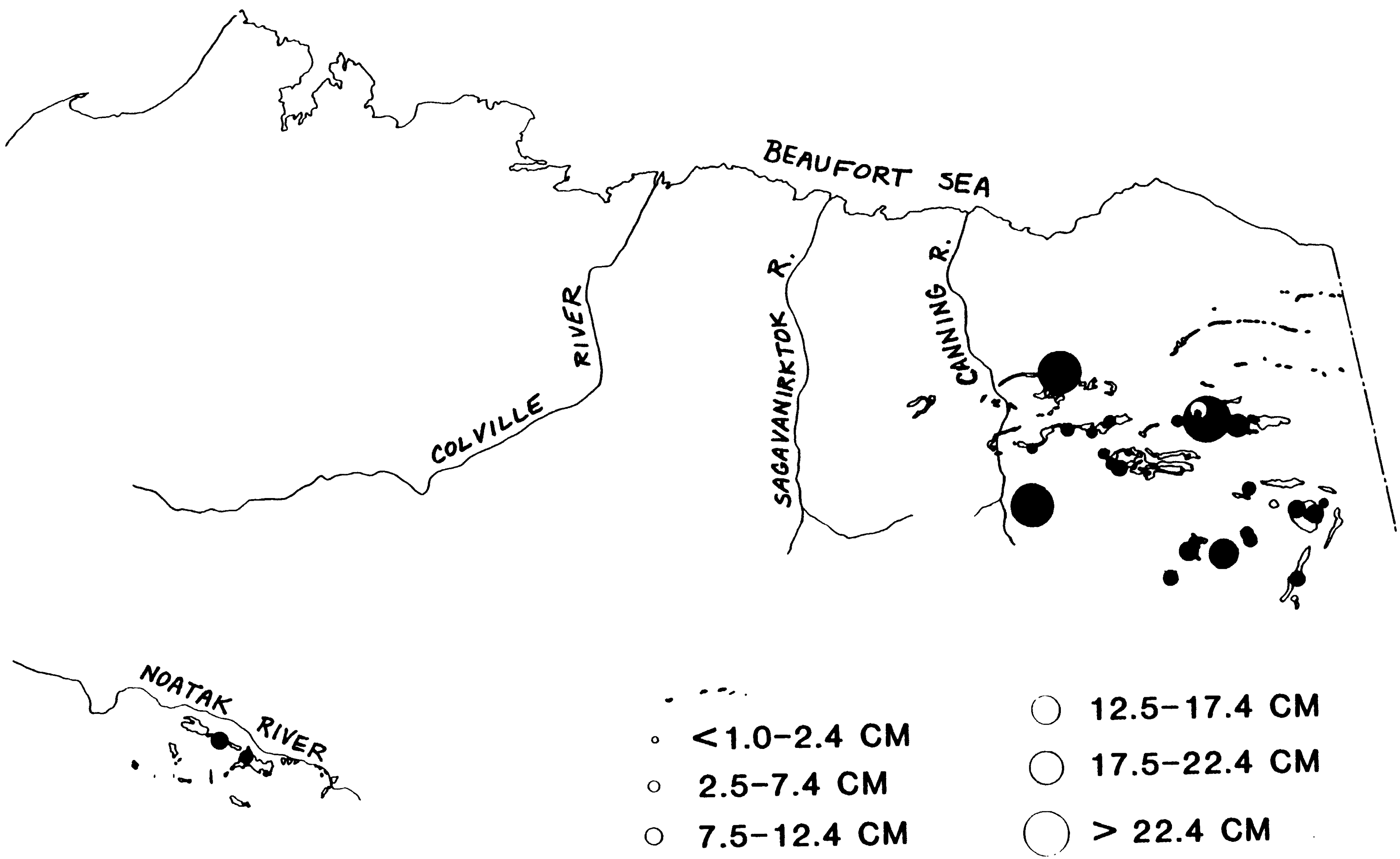


Figure 10.--Map showing distribution of the largest conglomerate clasts in the Kekiktuk Conglomerate.

Table 1.--Maximum clast size and percentage of each clast type from pebble counts of the Kanayut Conglomerate, Beaucoup Formation, Kekiktuk Conglomerate and Hunt Fork Shale.

Field station	Maximum clast size	White chert	Gray chert	Black chert	Red chert	Green chert	Vein quartz	Quart-zite	Argillite-phyllite	Carbon-ate	Green-stone	Un-known
Kekiktuk Conglomerate												
79ABe95	4	4	0	0	0	41	46	1	8	0	0	0
79ABe95	5	23	0	0	0	23	36	0	18	0	0	0
79ABe99	8	32	3	5	0	0	51	0	9	0	0	0
79ABe158	8	26	27	23	0	0	23	1	0	0	0	0
79ABe159	5	13	26	21	0	0	37	0	3	0	0	0
79ABe167	18	2	22	12	0	0	40	6	15	0	0	3
79ABe167	13	1	18	20	0	0	40	16	3	0	0	2
79ABe167	2	3	7	2	0	0	87	0	1	0	0	0
79ABe172	5	0	0	0	0	0	10	76	0	0	14	0
79ABe172	5	8	27	10	0	0	37	18	0	0	0	0
79ABe175	5	7	11	6	0	0	65	7	4	0	0	0
79ABe177	3	25	56	17	0	0	2	0	0	0	0	0
79ABe181	8	1	29	21	0	0	34	14	1	0	0	0
79ABe184	4	0	35	22	0	0	40	3	0	0	0	0
79ABe185	4	19	36	29	0	0	5	6	5	0	0	0
79ABe185	4	25	22	3	0	0	44	4	2	0	0	0
79ABe185	4	7	25	21	0	0	41	5	1	0	0	0
79ABe186	8	11	61	25	0	0	2	1	0	0	0	0
Kanayut Conglomerate, Stuver Member												
79ABe22	5	20	35	30	0	0	11	4	0	0	0	0
79ABe30	1	21	16	2	0	0	61	0	0	0	0	0
79ABe31	3	16	49	22	0	0	9	4	0	0	0	0
79ABe106	2	18	21	16	0	0	43	0	2	0	0	0
Kanayut Conglomerate, middle conglomerate member												
79ABe114	2	9	19	38	0	0	17	0	17	0	0	0
79ABe136	5	14	44	22	0	0	19	1	0	0	0	0
79ABe136	5	1	49	37	0	0	12	0	1	0	0	0
79ABe166	3	10	26	11	0	0	43	5	5	0	0	0
79ABe171	5	13	18	3	0	0	58	8	0	0	0	0
79ABe186	4	3	35	40	0	0	16	1	3	0	0	2
79ABe196	5	3	41	40	0	0	11	4	1	0	0	0
79ABe198	4	13	42	27	0	0	14	4	0	0	0	0
79ABe199	5	7	59	22	0	0	11	1	0	0	0	0
79ABe201	5	4	35	19	27	0	13	2	0	0	0	0
79ABe203	5	11	50	23	0	0	13	2	0	1	0	0
Kanayut Conglomerate, lower shale member												
79ABe43	5	28	33	22	0	0	17	0	0	0	0	0
79ABe206	5	10	45	33	4	0	7	1	0	0	0	0
Kanayut Conglomerate, basal sandstone member												
79ABe73	3	12	37	23	0	0	18	2	8	0	0	0
79ABe73	3	4	50	23	0	0	18	1	4	0	0	0
79ABe73	5	20	25	31	0	0	19	1	4	0	0	0
Hunt Fork Shale												
79ABe52	6	3	21	42	0	0	27	3	4	0	0	0
79ABe133	3	4	31	55	0	0	0	1	9	0	0	0
Beaucoup Formation												
79ABe161	6	31	30	14	0	0	10	0	15	0	0	0

the basal sandstone, lower shale, middle conglomerate, and Stuver Members, respectively, of the Kanayut Conglomerate. The size of the longest axis of the largest clast from each pebble count was also noted.

The conglomerates, in general, are characterized by a high chert content and lesser amounts of quartz and quartzite. They are compositionally very mature, as indicated by a plot of the compiled 1978 and 1979 data on a ternary diagram with mature (quartzose) clasts, carbonate clasts, and immature (other lithic) clasts as poles (fig. 11). This diagram, designed to display compositional maturity, visually shows that all but two of the conglomerates contain more than 80 percent chert + vein quartz + quartzite and only five samples contain less than 90 percent of these constituents. Thus, the Kanayut, Kekiktuk, Hunt Fork, and Beaucoup conglomerates have similarly high compositional maturity. This maturity can result from a compositionally mature provenance, extensive chemical weathering, or extreme physical abrasion during transport. Despite the gross compositional similarity of these conglomerates, minor differences differentiate them.

Beaucoup Formation

Five pebble counts from conglomerate of the Beaucoup Formation were reported by us (Nilsen and others, 1980a, Table 2) and one new pebble count is added in this report (Table 1). These data show that Beaucoup Formation conglomerate contains more than 75 percent chert clasts and minor but significant amounts of argillite clasts (as much as 15 percent) and locally large amounts of carbonate detritus (as much as 23 percent). Vein quartz is locally an important constituent (as much as 10 percent) but it and quartzite are rare or absent in most places. A ternary diagram with vein quartz, quartzite and chert as poles (fig. 12c) illustrates the dominance of chert relative to quartzite and vein quartz. In this diagram, Beaucoup Formation conglomerate

Figure 11.--Immature clast (argillite, siltstone, sandstone and greenstone)--carbonate clast--mature clast (chert, vein quartz, and quartzite) ternary diagram from pebble counts made during the 1978 and 1979 field seasons. A, Kekiktuk Conglomerate. B, Kanayut Conglomerate; filled circles = conglomerate from the Hunt Fork Shale. C, Conglomerate from the Beaucoup Formation.

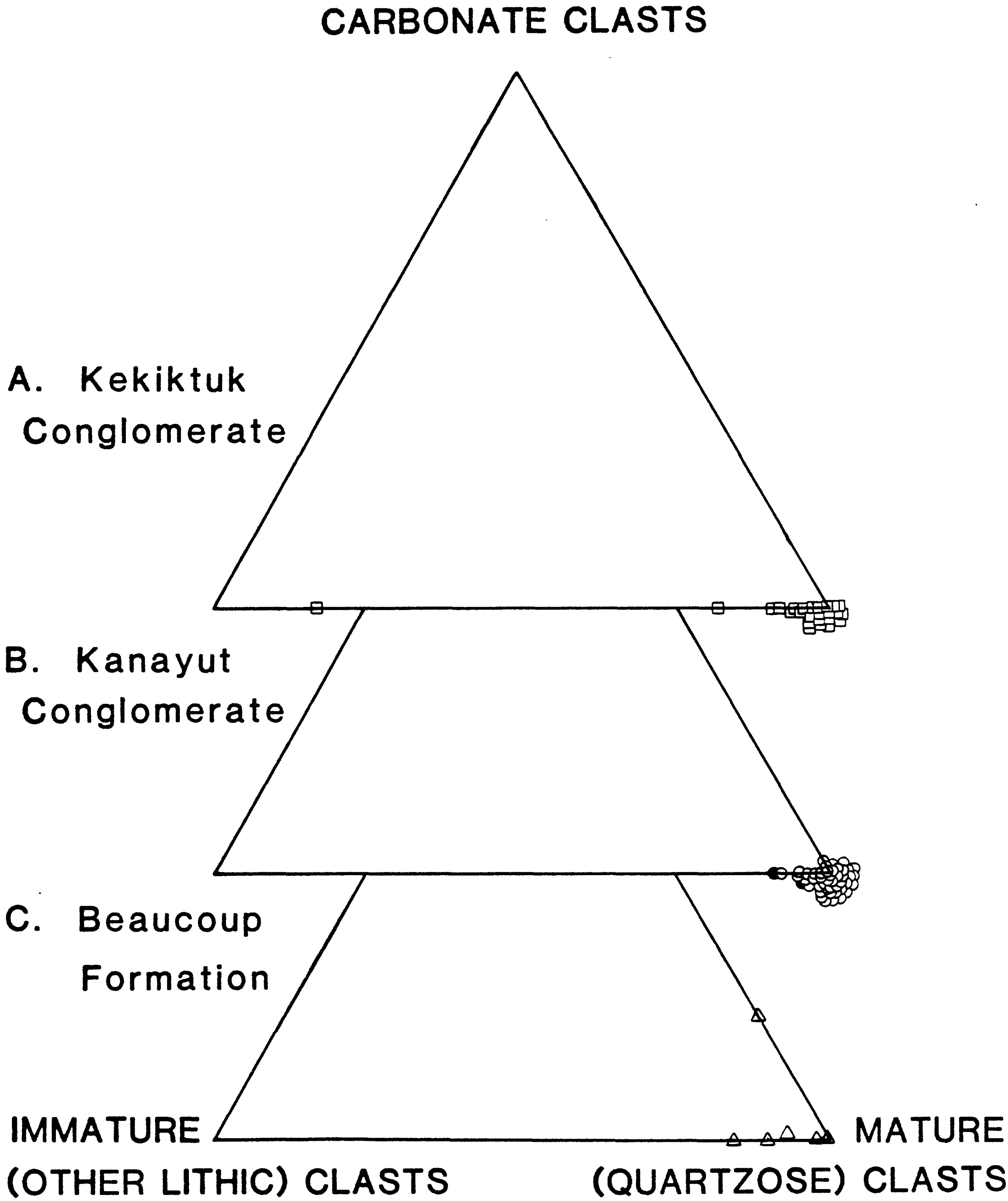
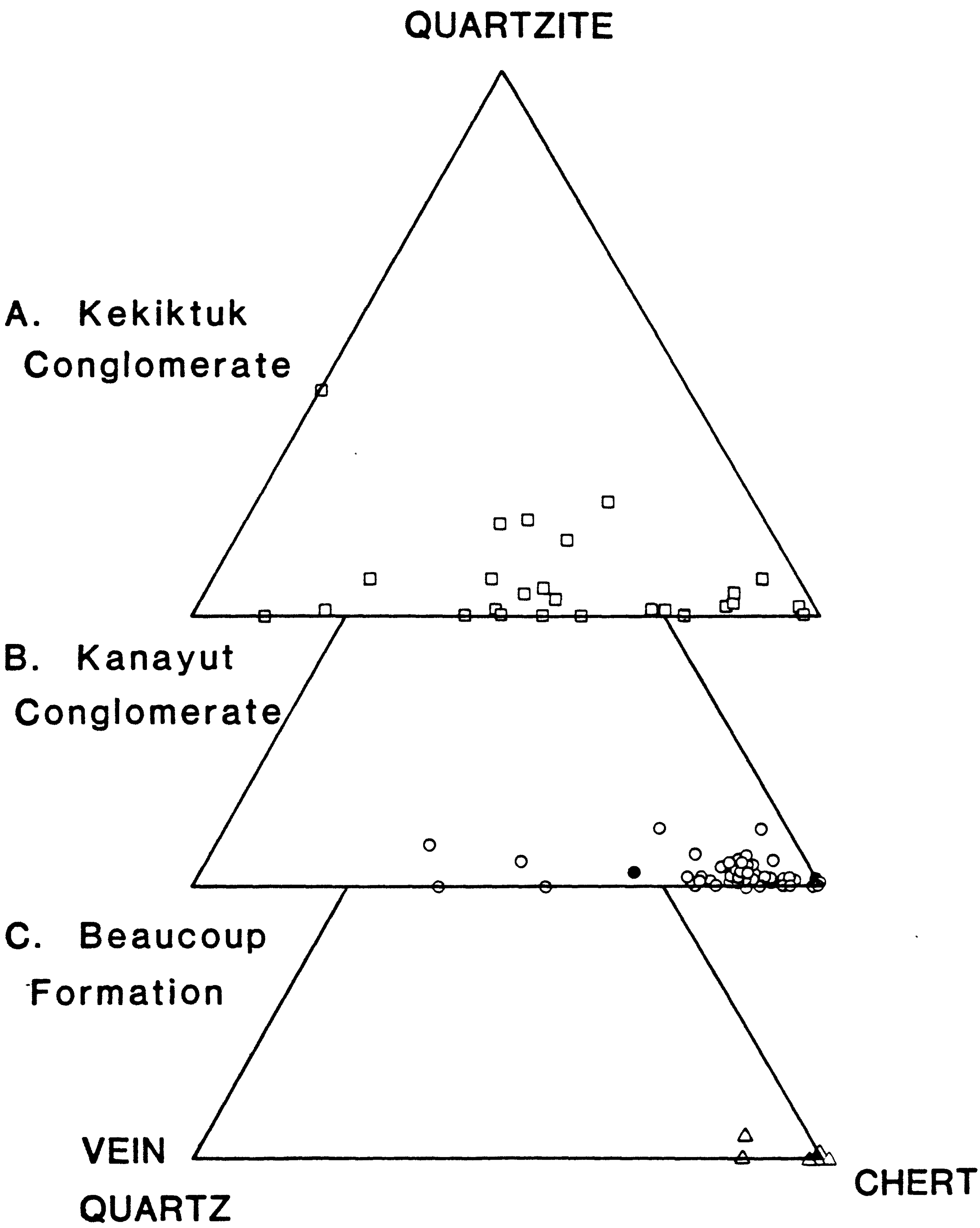


Figure 12.--Vein quartz-quartzite-chert ternary diagrams from pebble counts made during the 1978 and 1979 field seasons. A, Kekiktuk Conglomerate. B, Kanayut Conglomerate; filled circles = conglomerate from the Hunt Fork Shale. C, Conglomerate from the Beaucoup Formation.



occupies a restricted area at the chert pole. Kanayut and Kekiktuk conglomerates (fig. 12a, b), in contrast, have more variable chert/vein quartz/quartzite ratios and are enriched in vein quartz and quartzite relative to Beaucoup Formation conglomerate.

Figure 13 shows clast size versus percent of clast lithology for the various conglomerates. This diagram again shows the depletion of vein quartz and quartzite and enrichment of chert in Beaucoup Formation conglomerate relative to conglomerate of the Kekiktuk and Kanayut Conglomerates. In addition, it shows that coarser Beaucoup Formation conglomerate is enriched in chert relative to finer grained conglomerate (fig. 13b). A reciprocal relationship is not apparent for vein quartz and quartzite (fig. 13a, c), however, indicating that argillite and carbonate clasts are more abundant in finer than coarser Beaucoup Formation conglomerate. This is interpreted to result from the increasing effect of abrasion with larger clast size.

Hunt Fork Shale

Conglomerate is rare in the Hunt Fork Shale and is associated with shallow-marine sandstone bodies. Two pebble counts from conglomerate of the Hunt Fork Shale were made during the 1979 field season and are presented in Table 1. These counts suggest that the conglomerate of the Hunt Fork Shale, like the Kanayut Conglomerate, is dominated by chert clasts, has subordinate and variable amounts of vein quartz and contains minor amounts of quartzite and argillite clasts. The sandstone and conglomerate of the Hunt Fork Shale is interpreted to reflect nearshore deposition in the prograding Kanayut fluvial-deltaic complex (Nilsen and others, 1980a). The two Hunt Fork pebble counts are consistent with this interpretation, exhibiting compositional similarity to and plotting well within the fields of the Kanayut data (figs. 11B, 12B, and 13).

Figure 13.--Plots of maximum clast size versus percentage of clast lithology for the Kanayut Conglomerate, Kekiktuk Conglomerate, and conglomerate from the Beaucoup Formation from pebble counts made during the 1978 and 1979 field seasons. A, Vein quartz. B, Chert. C, Quartzite. Symbols: Beaucoup Formation (DB) = triangles and dotted lines; Hunt Fork Shale = filled circles; Kanayut Conglomerate (DK) = open circles and dashed line; Kekiktuk Conglomerate (MKK) = squares and solid line.

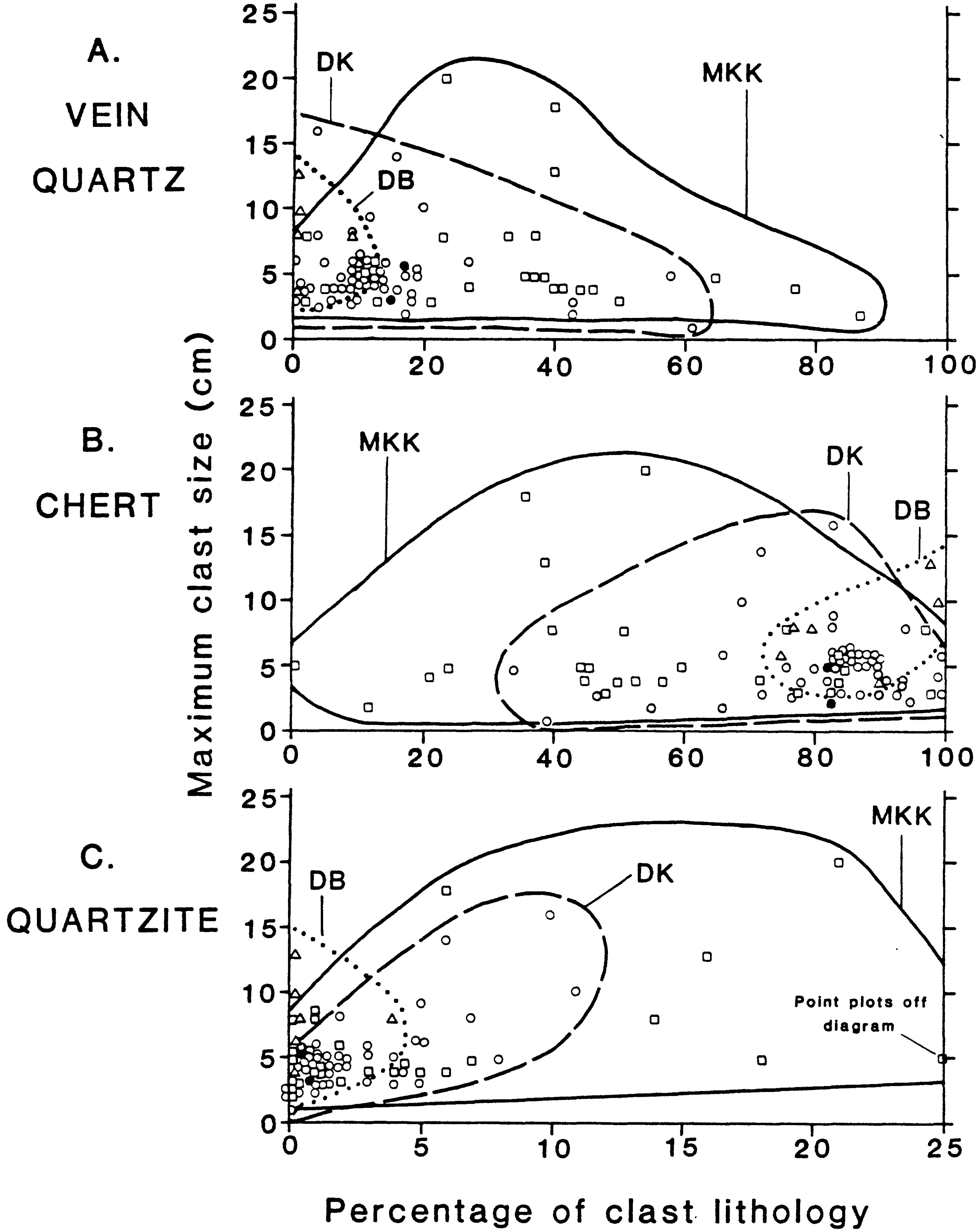


Figure 13.--Plots of maximum clast size versus percentage of clast lithology.

Kanayut Conglomerate

Twenty-seven pebble counts from the fluvial lower shale, middle conglomerate, and Stuver Members of the Kanayut Conglomerate were reported by Nilsen and others (1980a, Table 2). We have since reassigned two of these 1978 pebble counts (Nilsen and others, 1980a, Table 2, middle conglomerate member, station 78 ABe46) to the Kekiktuk Conglomerate. Twenty new pebble counts from the Kanayut Conglomerate are presented in this report (Table 1), including 3 from the basal sandstone member from which previously there had been no data.

The data show that Kanayut Conglomerate is dominated by chert clasts, which range in abundance from 34 to 100 percent, averaging 81 percent. Vein quartz averages 14 percent but ranges up to 61 percent in abundance. Quartzite clasts are a minor but persistent constituent (average 3 percent) that locally comprise as much as 21 percent of the clasts. Other clasts include argillite and carbonate which are locally present in very minor amounts.

Most Kanayut Conglomerate pebble counts cluster near the chert pole but are displaced toward the vein quartz pole (fig. 12b). Several counts plot away from the main cluster near the middle part of the vein quartz-chert join. These conglomerates exhibit no consistent stratigraphic, geographic, or clast size similarities and are therefore interpreted to represent local compositional variations.

Clast size versus percent of clast lithology diagrams for the combined 1978 and 1979 Kanayut Conglomerate data (fig. 13) show that the Kanayut is moderately enriched in chert, moderately depleted in vein quartz and quartzite and falls into an intermediate position relative to Beaucoup and Kekiktuk Conglomerates. It also reveals a consistent relationship between percent of quartzite clasts and clast size (fig. 13c). Larger-sized Kanayut Conglomerate is enriched in quartzite relative to smaller-sized conglomerate. This may reflect either a larger initial average clast size or a greater durability for the quartzite clasts.

The percentage of vein quartz and chert clasts in the Kanayut Conglomerate exhibits little or no relationship to clast size. This modified our previous observation that vein quartz abundance increases with increasing clast size whereas the abundance of chert decreases proportionally with increasing clast size (Nilsen and others, 1980a).

We suggest that the generally constant conglomerate composition throughout the very extensive Kanayut depositional system indicates that Kanayut detritus was probably derived from a single major source terrane.

Kekiktuk Conglomerate

Six pebble counts from the Kekiktuk Conglomerate were reported by Nilsen and others (1980a, Table 2). In this report we present eighteen new pebble counts (Table 1) and reassign two of the 1978 pebble counts to the Kekiktuk Conglomerate (see Kanayut Conglomerate, above). These data show that Kekiktuk Conglomerate is characterized by great variability in composition.

Chert is commonly the dominant constituent, averaging 54 percent, but it ranges in abundance from being absent to 98 percent. Vein quartz is mostly a secondary but important constituent, averaging 35 percent and ranging from 2 to 87 percent in abundance. Quartzite is a common minor component, averaging 4 percent and ranging up to 18 percent. Other clast types, which average 7 percent in abundance, include phyllite, argillite and greenstone. They are generally locally abundant and geographically restricted.

The vein quartz-quartzite-chert ternary diagram illustrates the compositional variability of the Kekiktuk Conglomerate (fig. 12a). Figure 13 confirms the variability of composition of the Kekiktuk Conglomerate and shows that it has a distinctly wider range of composition than either the conglomerate of the

Beaucoup Formation or the Kanayut Conglomerate. Pebble counts plot adjacent to or on the vein quartz-chert join, but are widely distributed along the join. Although clast lithologies range greatly in abundance, there appears to be no regular relationship between clast size and percent of vein quartz, chert or quartzite (fig. 13).

The composition of the lowermost conglomerate beds of the Kekiktuk locally reflects the underlying bedrock lithology. For instance, the Kekiktuk Conglomerate at station 79 ABe172 rests unconformably on pre-Devonian green phyllite and greenstone. The basal conglomerate at this location is more angular and is dominated by red and green phyllite and greenstone clasts with distinctly lesser amounts of vein quartz, quartzite and chert than at other locations. Likewise, Kekiktuk Conglomerate at the type section near Lake Peters rests unconformably on pre-Devonian phyllite. The abundance of phyllite clasts decreases upward stratigraphically from 15 percent near the base to 1 percent near the top of the section. The compositional variations, lack of compositional sorting, and compositional relation to underlying pre-unconformity units indicate that the Kekiktuk is derived at least in part from local source areas.

PALEOCURRENTS

Introduction

Nilsen and others (1980a) 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. Data from both years were compiled and presented in map form by Nilsen and others (1980b).

Sedimentary features measured include medium-scale tabular and trough cross-strata (254 measurements), conglomerate imbrication and long-axis orientation (136 measurements), primary current lineation (41 measurements), ripple markings (13 measurements), aligned plant fragments (4 measurements), pebble trains, flute marks and channel margins (1 measurement of each). Restorations of paleocurrent directions to the horizontal were done manually on a stereonet. Computer-calculated vector means and standard deviations were determined for 22 locations at which more than four paleocurrent measurements were made and also for the total number of paleocurrent measurements from the various stratigraphic units. Bidirectional features such as primary current lineation were assigned a westerly or southerly sense because of the preponderance of unidirectional indicators with that orientation (figs. 14, 15).

Beaucoup Formation

A total of four paleocurrent determinations, including two of clast imbrication and long-axis orientation and two of trough cross-strata were made at two separate locations in the Beaucoup Formation in the eastern Brooks Range (Nilsen and others, 1980b, sheet 2). These measurements indicate sediment transport ranged from 355° to 15° with an azimuthal mean of 2°. This northerly transport

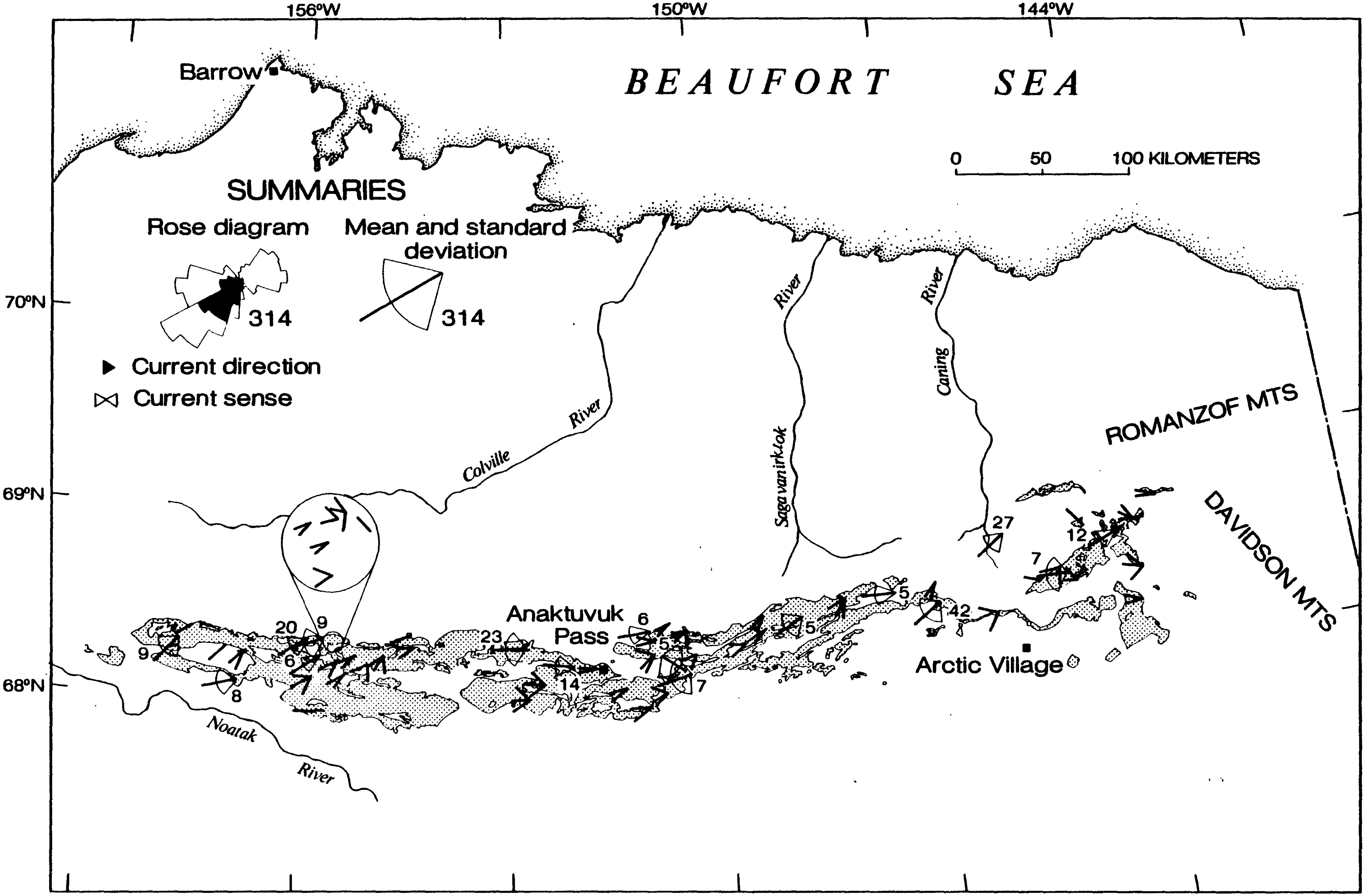


Figure 14.--Paleocurrent and summary rose diagram for the fluvial members of the Kanayut Conglomerate from measurements taken during the 1978 and 1979 field seasons.

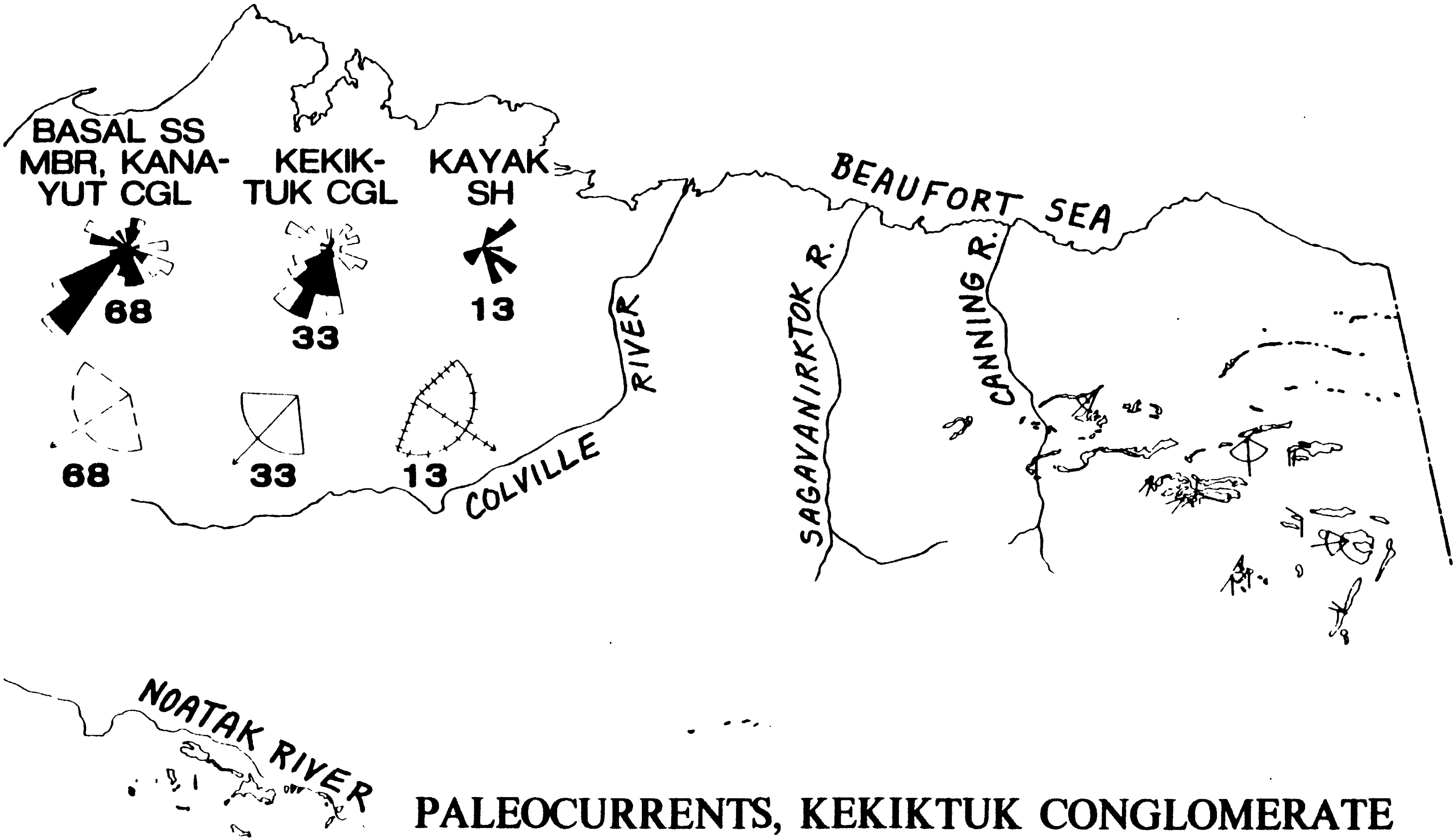


Figure 15.--Paleocurrent map of the Kekiktuk Conglomerate and summary rose diagrams of the basal sandstone member of the Kanayut Conglomerate, Kekiktuk Conglomerate, and Kayak Shale from measurements taken during the 1978 and 1979 field seasons.

contrasts sharply with the generally southwestward transport direction of the younger Endicott Group, but is probably not significant statistically.

Hunt Fork Shale

A total of ten paleocurrent determinations, including 3 of trough cross-strata, 3 of primary current lineations, 2 of tabular cross-strata, and 2 of oscillation ripple-markings were measured in the Hunt Fork Shale at 5 separate locations during the 1979 field season (Nilsen and others, 1980b, sheet 2). The azimuthal vector mean and standard deviation of all measurements from the Hunt Fork Shale is 228° $\pm$ 66. However, unidirectional indicators are bimodal, showing that sediment transport was both to the southwest and to the east (fig. 15).

The Hunt Fork Shale is interpreted to have been deposited under low- to high-energy marine conditions. The bimodal paleocurrent data may result from variable onshore and offshore sediment transport related to wave-, wind-, storm- and tidal-generated currents.

Basal Sandstone Member of Kanayut Conglomerate

A total of 68 paleocurrent measurements were taken from 13 separate locations in the marine basal sandstone member of the Kanayut Conglomerate and presented in map form and by summary rose diagram in Nilsen and others (1980b, sheet 2). These measurements include 41 tabular cross-strata, 15 trough cross-strata, 11 primary current lineations, and 1 clast imbrication and long-axis orientation. Both unidirectional and bidirectional indicators show that sediment transport was primarily to the southwest but was variable, with northerly, westerly and southerly transport directions prominently represented (fig. 15). The azimuthal vector mean and standard deviation of all measurements from the basal sandstone member is 244° $\pm$ 69°.

We believe that the basal sandstone member was deposited as primarily marine bars. The unimodal, but variable paleocurrent determinations result from dominantly offshore, but locally onshore and longshore, sediment transport related to wave-, wind-, storm- and tide-generated currents.

Fluvial Members of Kanayut Conglomerate

In our report of the 1978 field season, we plotted 158 paleocurrent measurements from the fluvial lower shale, middle conglomerate 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, 1980b, sheet 1). The measurements total 314 and include 119 clast imbrication and long-axis orientations, 94 trough cross-strata, 63 tabular cross-strata, 23 primary current lineations, 6 current ripple markings, 4 pebble trains, 2 localities of aligned plant fragments, 1 flute mark, and 1 channel margin orientation.

Unidirectional indicators show a southwest transport of sediment and bidirectional indicators (those giving sense of transport only) a west to southwest transport (fig. 14). The azimuthal vector mean and standard deviation of all measurements from the Kanayut is $248 \pm 44°$. Vector means and standard deviations for locations having more than four measurements range from $224 \pm 41°$ to $278 \pm 12°$, showing that the data are consistent between locations. These data indicate that fluvial sediment transport of the Kanayut Conglomerate was toward the west or west-southwest throughout its entire length of exposure in the Brooks Range. Donovan and Tailleur (1975) previously determined southerly directions of transport for the Kanayut Conglomerate.

Kekiktuk Conglomerate

Five scattered paleocurrent measurements made in the fluvial Kekiktuk Conglomerate in the northeastern Brooks Range were plotted in our report of the 1978 field season (Nilsen and others, 1980a). During the 1979 field season, an additional 27 measurements were collected from the Kekiktuk Conglomerate. These were compiled and presented in map form with a summary rose diagram in Nilsen and others (1980b, sheet 2). An additional 16 paleocurrent measurements were collected in 1979 from probable Kekiktuk strata. Although their vector mean and stand deviation is virtually identical with that of unquestioned Kekiktuk Conglomerate, these data are not included in the paleocurrent map because of their questionable assignment to the Kekiktuk Conglomerate. All of the reported data are from the northeastern Brooks Range. The Kekiktuk Conglomerate in the western and central Brooks Range has generally undergone low-grade metamorphism and internal deformation, inhabiting the collection of paleocurrent data.

The 33 paleocurrent measurements from the Kekiktuk Conglomerate include 14 trough cross-strata, 12 localities of clast imbrication and long-axis orientation, 5 tabular cross-strata, 1 primary current lineation and 1 locality of aligned plant fragments. The vector mean and standard deviation of all Kekiktuk Conglomerate data is 235° ± 50°. Unidirectional paleocurrents indicate that sediment transport was dominantly toward the south-southwest, whereas bidirectional indicators (those giving sense of transport only) have a bimodal distribution suggesting that sediment transport was toward the southwest and northwest (fig. 15). Vector means and standard deviation for locations having more than four measurements range from 185° ± 58 to 273° ± 34°, showing that the data are not consistent between locations. Visual inspection of the paleocurrent map (Nilsen and others, 1980b, sheet 2) suggests that the easternmost paleocurrent data are west-directed whereas those in more northerly or westerly locations are south- or southwest-directed.

The fluvial Kekiktuk Conglomerate was deposited on an erosional unconformity and was, at least in part, derived from local source rocks. This information may suggest that variability in the paleocurrent data from the Kekiktuk Conglomerate results from the influence of irregular local paleogeography during Early Mississippian time.

Kayak Shale

Three paleocurrent measurements from current ripple markings in the shallow-marine or intertidal basal sandstone member of the Kayak Shale were previously reported (Nilsen and others, 1980a). An additional 10 measurements were collected during the 1979 field season, including 4 tabular cross-strata, 4 oscillation ripple markings and 2 additional current ripple markings, and plotted by Nilsen and others (1980b, sheet 2).

Although the vector mean and standard deviation of the compiled paleocurrent measurements from the Kayak Shale is 137° ± 77°, the rose diagram shows the striking variability of sediment transport direction (fig. 15). We attribute the variability of paleocurrent measurements 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 sedimentologic data collected during the 1979 field season in the eastern and western Brooks Range from the Upper Devonian and Lower Mississippian Endicott Group. The Upper Devonian Kanayut Conglomerate has been divided into a basal marine sandstone member and three successive fluvial members. It crops out for about 700 km along strike and about 50 km across strike in at least three major thrust plates in the central part of the Brooks Range. The basal marine sandstone member was probably deposited as channel-mouth bars, offshore bars, and spits. The overlying lower shale member is inferred to have been deposited by meandering streams over a large floodplain area. The middle conglomerate member, which contains the coarsest conglomerate and little or no shale, was probably deposited by braided streams. The Stuver Member is inferred to have been deposited by meandering streams and is overlain by intertidal and shallow-marine sandstone at the base of the Kayak Shale.

The orientations of crossbeds, current lineations, ripple marks and long axes of pebbles in the three fluvial members of the Kanayut consistently indicate sediment transport toward the southwest across the entire Brooks Range. The clast size of the conglomerate, as indicated by the mean size of the largest pebbles, decreases westward and southward across most of the area, although very large clast sizes are present in the central Anaktuvuk Pass area.

The composition of the large clasts in the Kanayut Conglomerate 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 of argillite and other rock fragments are rare.

The Lower Mississippian Kekitkuk Conglomerate rests unconformably on deformed pre-Upper Devonian rocks intruded by granites chiefly of Devonian age. It forms autochthonous outcrops north, east, and south of the allochthonous Kanayut Conglomerate. The Kekiktuk was deposited by braided and meandering streams. It contains a significantly greater percentage of quartz pebbles and more variable proportions of quartz and chert than the Kanayut Conglomerate.

The facies sequence in the Hunt Fork Shale and Kanayut Conglomerate suggests that the Kanayut comprises the marginal marine and fluvial parts of a prograding delta system. The consistent southwestward direction of paleocurrents in the fluvial deposits, together with the southwestward decrease of grain size, suggest an eastern 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. The high roundness and sphericity of the clasts and their compositional maturity indicate that the source terrane may also have included older conglomerates.

The Lower Mississippian Kekiktuk Conglomerate seems to have been derived from local sources on the periphery of the area presently underlain by the Kanayut Conglomerate. Local sources are indicated by both the extremely variable ratio of quartz to chert clasts and by the presence of some identifiable fragments of local basement rocks in the conglomerate. Because of the allochthonous nature of the Kanayut versus the autochthonous nature of the Kekiktuk and because their outcrop areas are mutually exclusive, paleogeographic relations between the two remain obscure.

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.

Brosgé, 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.

Brosgé, 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 Miscellaneous Geological Investigations 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 OF-71-56, 2 sheets, scale 1:250,000.

Brosgé, 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.

Brosgé, 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, Claire, and Laufeld, Sven, 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, Topagoruk 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., Brosgé, 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, <u>in</u> 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.

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., 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 733, 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., Moore, T. E., Dutro, J. T., Jr., Brosgé, W. P., and Orchard, D. M., 1980a, Preliminary report on the sedimentology and stratigraphy of the Kanayut Conglomerate and associated units, central and eastern Brooks Range, Alaska: U.S. Geological Survey Open-File Report 80-888, 40 p.

Nilsen, T. H., Moore, T. E., and Brosgé, W. P., 1980b, 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.

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., Brosgé, 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.

Tailleur, I. L., Brosgé, 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.