Supplemental Material: Ulungarat Basin: Record of a major Middle Devonian to Mississippian syn-rift to post-rift tectonic transition, eastern Brooks Range, Arctic Alaska

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Describes the organization, sedimentology, and depositional environments of the Ulungarat Basin succession including description of type sections of the Ulungarat and Mangaqtaaq formations. Table S1 is published fossil and radiometric age constraints used to construct the mid-Paleozoic tectonostratigraphic chart (Fig. 12), including basis for age assignment and list of source references. A reference list of all sources cited in Table S1 is included.

ULUNGARAT FORMATION

The Ulungarat Formation is a 395-meter-thick, coarsening- and thickening-upward, terrigenous clastic succession that records a variety of shallow marine and non-marine basin margin depositional environments. On the basis of variations in lithology and internal organization, the Ulungarat Formation is divided into four informal members labeled, from base to top, A, B, C, and D (Fig. 6). The formation consists of shallow marine deposits overlain by a coarsening- and thickening-upward fluvial succession.

Member A

At the type locality, member A of the Ulungarat Formation is a 159-m-thick fine-grained, upward-coarsening, fossiliferous mudstone to siltstone succession with sandstone interbeds increasing in thickness and abundance up-section (Fig. 3, loc. B; Fig. 6). A mixed shallow-marine invertebrate fauna has been recovered from member A (Fig. 6). Typically, the basal one-third of member A is a green-gray to black, structureless mudstone and siltstone containing abundant large linguloid brachiopods. The upper two-thirds of member A is characterized by upward-thickening and -coarsening amalgamated sandstone beds. Sandstone beds have an irregular sharp base with a basal deposit composed of shells of a mixed fauna of marine invertebrates and/or shale rip-up clasts (Fig. 6A). The marine fauna include bryozoans, brachiopods, gastropods, trilobites, and bivalves (Fig. 6).

Significant lateral variation occurs at the top of member A (Fig. S1). Eight kilometers southwest of the type section (Figs. 3 and S1, loc. A), the lower 60 m is similar to the type section, but the upper 30 m includes a 12-m-thick sandstone interval overlain by 20-cm-thick maroon mudstone. The sandstone interval has a sharp base, contains well-sorted 2–4-cm-thick sandstone beds having indistinct low-angle cross-stratification, and is topped by a 20-cm-thick interval of ripple-cross-laminated sandstone beds 1–2-cm-thick. Molds of several different species of large-ribbed bivalves are preserved on the upper surface of this bed. Gray muddy siltstone abruptly overlies the sandstone and grades upward to a maroon mudstone. Scattered, structureless 1–10-cm-thick beds of fine-grained sandstone and fossiliferous limestone are interbedded with the mudstone. The interbedded, bioturbated maroon mudstone, sandstone, and limestone contain a more diverse faunal assemblage than is found lower in member A. The interval present at the top of member A at location A is not present at the type locality.

Member A of the Ulungarat Formation is interpreted to record increasingly proximal deposition in an upward-shallowing marine setting (Figs. 6 and S1). At location A, the well-sorted sandstone beds with low-angle cross-stratification and large-ribbed bivalves indicate a high-energy environment. The overlying fine-grained sediments with a shallow-marine faunal assemblage (bryozoan, gastropods, brachiopods) suggest a low-energy setting with deposition from suspension under generally quiet conditions. Thin bioturbated sandstone beds interbedded in the mudstone may be storm-wash-over or crevasse-splay deposits. The proximity of these contrasting deposits suggests a very shallow, protected environment behind a barrier, perhaps a bay-mouth bar and interdistributary bay in a delta-plain setting. The sharp upper contact at the top of member A, with only locally preserved interpreted distributary-bay deposits, suggests erosion and reworking of the delta-plain succession by progradation of the overlying fluvial system.

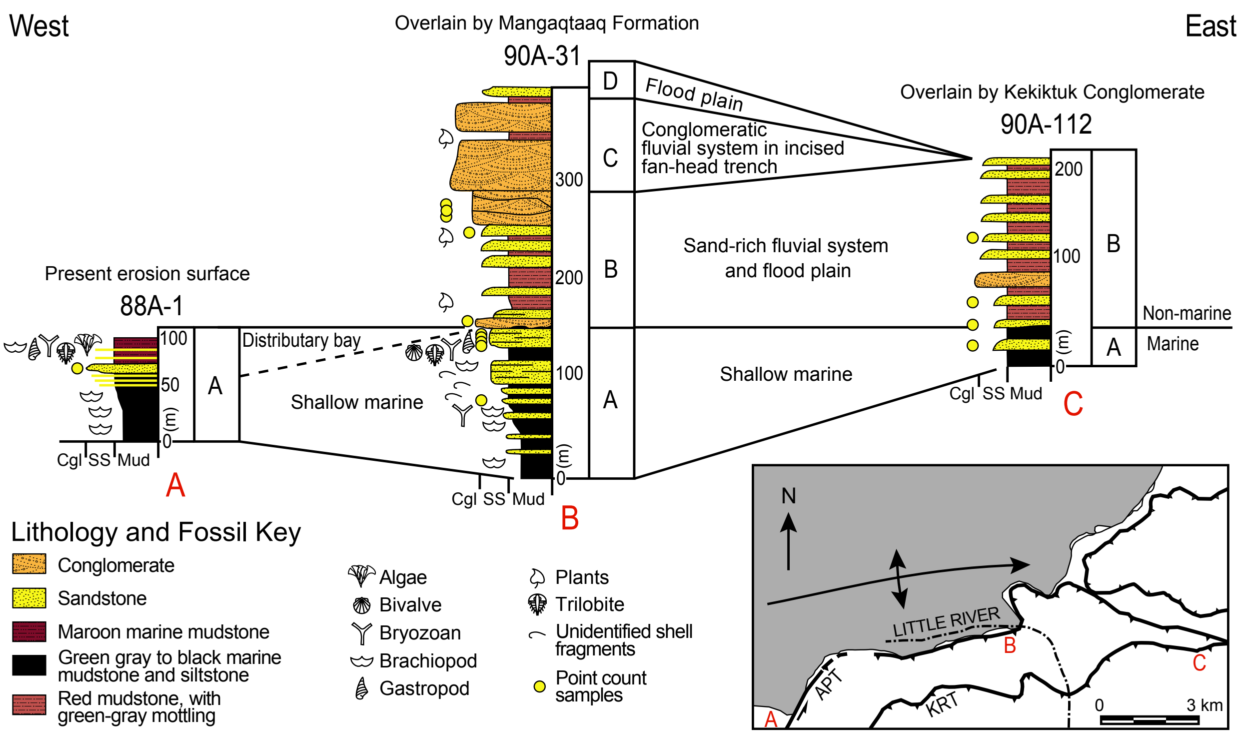

Figure S1. Measured stratigraphic columns showing lateral variability of Ulungarat Formation within Continental Divide succession across the study area, including lithology, depositional setting, age-diagnostic fossils, sedimentary structures, and point-count sample locations. Locations A, B, and C are shown on inset map. (A) Ulungarat Formation (88A-1) deposited directly on Romanzof formation. (B) Ulungarat Formation type section (90A-31; see Fig. 6) in Aichilik Pass thrust sheet. Base of section at B is cut by Aichilik Pass thrust, and depositional contact with Romanzof formation is not observed. Top of section B is bounded by a low-angle disconformity overlain by Mangaqtaaq Formation. (C) Ulungarat Formation (90-112) in Kongakut River thrust sheet. Base of section C is cut by Kongakut River thrust, and depositional contact with Romanzof formation is not observed. Top of section C is unconformably overlain by Mississippian Kekiktuk Conglomerate (Mkt-2).

Member B

Member B of the Ulungarat Formation is composed of chert-granule to -pebble conglomerate, chert arenite, and siltstone in channelized fining-upward intervals in an overall coarsening-upward succession that is 129-m-thick at the type locality (Fig. 3, loc. B; Fig. 6). The conglomerate consists of angular to poorly rounded clasts up to a maximum of 4 cm-in-diameter. The lower half of member B is dominated by rose-red mudstone with green-gray mottling, displaying mud cracks (Fig. 6B). The upper half of member B is dominated by stacked, fining-upward pebbly sandstone, sandstone, and siltstone beds (Fig. 6C). Each upward-fining interval is 1–3-m-thick and has a concave-upward base that truncates underlying deposits. Coarse-grained, locally conglomeratic, sandstone beds organized as trough and tabular sets of planar cross-stratified deposits fill the basal scours. Sandstone beds at the top of each interval are ripple cross-laminated and are interbedded with and overlain by horizontally laminated siltstone.

Member B is interpreted to consist of channel, point-bar, and flood-plain deposits of a sand-rich, meandering fluvial system (Figs. 6 and S1). Within member B, progradation of the fluvial system is indicated by the upward-coarsening and -thickening of the channel-fill deposits and the upward change from dominance of flood-plain deposits to dominance of coarse-grained channel-fill deposits. The vertical change from flood-plain dominated deposition to dominance of fluvial channels indicates an upward increase in stream gradients that is consistent with deposition associated with a fluvial-dominated alluvial fan.

Member C

Member C of the Ulungarat Formation is 85-m-thick at the type locality and is characterized by amalgamated, channelized successions of massive to horizontally-stratified, conglomerate and conglomeratic sandstone deposits which fill major erosional scours incised into finer-grained deposits (Fig. 3, loc. B; Fig. 6). The thick successions of conglomerate and sandstone are confined within major erosional topographic lows dissected into the underlying mudstone and thin sandstone beds (Fig. 6D). At the largest scale, this erosional topography is a concave-up surface 50–75-m-wide and 20–30-m-deep, marked by erosional scours. Internally, the fill is composed of clast-supported, chert-pebble to -cobble conglomerate beds that are 1–3-m-thick, are erosional into underlying beds, and onlap the underlying confining major erosional surface. Shale rip-up clasts are present at the base of some beds. The conglomerate beds are massive to horizontally-stratified, in places faintly trough cross-stratified, and crudely fine upward. The upper surfaces of the major multistory channel complexes are flat and overlain by the same type of deposits that underlie the major erosional scours.

Brown-red mudstone and interbedded thin, fining-upward sandstone cycles underlie, are lateral to, and overlie the cliff-forming conglomerates (Fig. 6). Fining-upward cycles of coarse- to fine-grained sandstone, 10–60-cm-thick, extend laterally across outcrop exposures. Horizontal and ripple cross-laminated, fine-grained sandstone beds are present at the tops of the cycles. The sandstone beds are erosional into and overlain by intervals of brown-red mudstone with green-gray mottling, similar to that observed in member B.

The alternation of incised channel-fill deposits and laterally equivalent unconfined flow deposits characterizes member C (Fig. 6). These relationships are interpreted to record the alternation of entrenched channel systems containing proximal fluvial deposits and laterally-equivalent unconfined flow deposits. Laterally, beyond the confined deposition of the entrenched channel successions, thin, upward-fining sandstone beds with basal concave-upward erosional scours record deposition in minor channels. The lateral continuity of these thin sandstone beds suggests less confined bedload transport, whereas interbedded mudstones record deposition from suspension during the waning phase of flood events. The truncation of the finer-grained strata by major erosional surfaces beneath the entrenched channel systems indicates that a drop in base level caused dissection.

Member D

Member D of the Ulungarat Formation is 21-m-thick at the type locality where it is a succession of mottled, red mudstone with sparse, laterally-discontinuous sandstone lenses (Fig. 3, loc. B; Fig. 6). The base of member D is placed at the top of the uppermost interval of thick channelized conglomerate beds. The top is placed at the lowest appearance of oncolytic, black algal limestone or calcareous black mudstone characteristic of the Mangaqtaaq Formation. Member D is approximately 80% mudstone, with sandstone lenses generally 8–10-m-across and 2–3-m-thick characterized by concave upward bases and fining upward from coarse- to fine-grained chert arenite.

The mottled rose-red and green-gray mudstone is similar to the mottled mudstone in member B and is interpreted to be flood plain deposits (Fig. 6). The infilling of erosional channel scours by upward-fining sandstone intervals reflects waning-flow deposition. The sandstone beds are interpreted to record channel migration over the flood plain. Significant reduction in sand dispersal and deposition compared with member C is indicated by an overall decrease in grain size and by the dominance of flood-plain deposits. This suggests a decreased supply of coarse-grained sediment from the source terrain or lateral variability of the depositional system.

Lateral Variation

The Ulungarat Formation is thickest in the area of the type section in the Aichilik Pass thrust sheet (Figs. 3 and S1, loc. B). To the southwest, the marine deposits of member A are thinner and, at the top, include an interval not present at the type section (Figs. 3 and S1, loc. A). At this location, the fine-grained lower 30 m of member A has the same lithology and organization as at the type locality, but the overlying interval of alternating sandstone and mudstone is much thinner and interpreted to be interdistributary bay deposits. This thinner, less sandy succession, with preserved fine-grained deposits at the top may reflect deposition in a less active part of the delta at some distance from the overlying active fluvial channels of member B.

In the Kongakut River thrust sheet to the southeast of the type locality (Figs. 3 and S1, loc. C), the Ulungarat Formation has the same coarsening- and thickening-upward organization as in the area of the type section, but the succession is thinner and finer-grained. At the base of the succession, member A is less than 20-m-thick. A coarsening- and thickening-upward interval of fining-upward fluvial cycles overlies member A and is 150–190-m-thick, but thick conglomeratic beds seen in other locations are absent here. The succession is unconformably overlain by the Kekiktuk Conglomerate (Fig. 3, loc. C).

The thinner marine succession in the Kongakut River thrust sheet may be due to topography on the depositional surface or to thrust truncation of the lower part. The thinner non-marine interval could be due to erosion prior to deposition of the Kekiktuk Conglomerate. Alternatively, the difference in thickness and organization may be due to lateral facies changes. The thinner, finer-grained non-marine succession and the lack of entrenched upper-fan deposits suggest that these more southern exposures may record deposition at a greater distance from the source area. Alternatively, this change may indicate that coarse-grain flow has been diverted to another area.

Depositional Setting

The Ulungarat Formation is interpreted to record the progradation of an alluvial fan over a delta. At the base of the formation, the shallow-marine succession of member A coarsens- and thickens-upward from mudstone to siltstone to amalgalmated sandstone beds with marine fauna, indicating deposition in an upper prodelta to subaqueous delta plain. The sharp upper contact with overlying delta plain of member B and locally preserved inferred interdistributary bay deposits of member A suggest reworking of much of the delta plain succession by the overlying fluvial system.

The upward-coarsening and -thickening sandstone and conglomerate deposits of non-marine members B and C of the Ulungarat Formation are interpreted to record a fluvial-dominated alluvial fan. The coarsening- and thickening-upward succession with angular to poorly rounded clasts suggests deposition close to a source area by high-energy streams. The thick deposits filling major erosional channels (member C) are interpreted to be main distributary channels on an upper alluvial fan.

The Ulungarat Formation is interpreted to have been deposited in a topographically immature setting with considerable relief. Coarse-grained deposits and the prograding character of the depositional system suggest nearby active faulting. Based on lithologic similarity, proximity, and large clast size, the Romanzof formation is the most likely source terrain. The relationships suggest that the cherts formed a highland adjacent to the southward-prograding depositional system.

MANGAQTAAQ FORMATION

The Mangaqtaaq Formation is a 135-m-thick, cyclic succession of black algal limestone, sandstone, and interbedded mudstone, that can be traced along strike for only 10 km (Fig. 3). The lower half of the formation consists of 5–10-m-thick cyclic repetitions of (1) algal limestone and interbedded sandstone with (2) thin intervals of recessive-weathering black mudstone. The upper half of the formation is dominated by black mudstone (Fig. 7).

Limestone with Sandstone Interbeds

Black limestone beds 5–10-m-thick (Fig. 7A) contain calcareous algae, peloids, gastropods, ostracods, serpulid-like worm tubes, black lithoclasts, and micritic mud. Calcareous blue-green algae form a variety of laminated stromatolite structures and large oncolites (Fig. 7B). Sandstone interbeds contain a mixture of fine- to medium-grained, terrigenous and carbonate clasts. Contacts with overlying and underlying algal limestones are sharp. Sandstone beds vary in thickness from a few centimeters to 100 cm and are locally overlain by horizontally-laminated black mudstone containing plant fragments. Both symmetrical and asymmetrical ripples are present, with mud drapes locally covering some surfaces. The algal limestone beds record a shallow-water environment. Based on lithologic similarity, the coarse-grained, angular to subrounded chert sands and pebbles are interpreted to have been eroded from the underlying Ulungarat and Romanzof formations. The carbonate sands were eroded from units within the Mangaqtaaq Formation.

Black Mudstone Intervals

Black, calcareous, finely-laminated and -interbedded mudstone and siltstone dominate the upper half of the Mangaqtaaq Formation. The finely laminated, recessive-weathering mudstone and siltstone are interlaminated on the scale of 2–4 mm. It is unclear if the rhythmic interbedding of the mudstone and siltstone represents varves or thin, distal turbidity currents. Preservation of lamination indicates that the area was free of bioturbation.

Depositional Setting

The Mangaqtaaq Formation records deposition in a hydrologically closed basin. Two contrasting depositional environments, a shore complex and deeper-water deposits, are recognized based on apparent differences in water depth. Deposits of the shore complex record a shallow water setting occupied by blue-green algae and a restricted population of grazing organisms. Small streams and sheet floods disrupted the algal-matt environment depositing a mixed carbonate and terrigenous-clastic bedload. These deposits indicate erosion of stromatolite and oncolite areas, mixing of carbonate detritus with terrigenous clastic grains, and deposition of the mixed sands, possibly during storm events. The fine grain size and laminations of the black mudstone intervals are characteristic of deposition in relatively quiet, stagnant bottom waters free of bioturbation, suggesting a deeper water setting. Deposition of the black mudstone and siltstone over the algal matt and sandstone shore complex deposits suggests that periodic rise in water level caused the former shore complex to be inundated by deeper water.

The limited fauna — blue-green algae, ostracods, gastropods — indicate deposition in a shallow-water, restricted environment. Abundant plant fossils, absence of conodonts or any other definitive marine fauna, and blue-green algae characteristic of either lacustrine or very shallow, restricted-marine conditions characterize the formation. We favor a lacustrine interpretation based on stratigraphic position between fluvial deposits, limited lateral extent, and lack of a definitive marine fauna.

KEKIKTUK CONGLOMERATE

The Kekiktuk Conglomerate is an upward-fining and -thinning succession of chert- and quartz-pebble to -cobble breccia and conglomerate, fine- to coarse-grained sandstone, and interbedded black shale. To the north in the West Fork Valley succession, where the Kekiktuk Conglomerate directly overlies Romanzof formation with high-angle discordance (Fig. 3, loc. G), outcrops of Kekiktuk Conglomerate are discontinuous and generally less than 15-m-thick. To the south in the Continental Divide succession, the Kekiktuk Conglomerate unconformably overlies the Ulungarat Formation, or locally the Mangaqtaaq Formation and is 40–70-m-thick.

Continental Divide Succession

The Kekiktuk Conglomerate of the Continental Divide succession at location E (Figs. 3 and 8) is characterized by cliff-forming, multistory and multilateral, amalgamated, channelized conglomerate and sandstone cycles, in an overall fining-upward succession 40-m-thick. Internally, this interval is characterized by smaller scale conglomerate and sandstone cycles 2–3-m-thick and by coarse- to medium-grained tabular sets of planar cross-stratified sandstone beds 2-m-thick. Each conglomerate and sandstone cycle begins with clast-supported, moderately-sorted, chert-pebble and -cobble conglomerate. Cobbles up to 17 cm in size fill the basal scour. Conglomerate beds are massive to horizontally-stratified, and crudely fine upward. Commonly, only the lower conglomeratic part of each cycle is preserved beneath the conglomerate-filled erosional scour at the base of the next overlying cycle. The conglomerate is overlain in some places by trough cross-stratified pebbly sandstone beds 8–10-cm-thick. Where preserved, the top of each cycle consists of plane-bedded, fine-grained sandstone beds. The upper surface of the cliff-forming exposure is a dip slope with abundant plant fossils.

Eight kilometers to the east (Figs. 3 and S2, loc. F), the Kekiktuk Conglomerate of the Continental Divide succession has a different organization. The basal 40-m-interval consists of a series of conglomerate and sandstone bodies interbedded with black siltstone and mudstone. Maximum pebble size is 3 cm. Each successively higher body contains less conglomerate. These conglomerate and sandstone bodies are laterally extensive, tabular, and elongate. Above a basal scour, each body consists of clast-supported conglomerate beds that are massive to trough-cross-stratified with an upward decrease in scale of trough-cross-stratification and an accompanying change from conglomerate to pebbly sandstone. Above the basal conglomerate, low-angle cross-stratified, fine-grained sandstones continue the fining-upward trend into horizontally stratified siltstone beds. Above this basal 40-m-interval, higher conglomerate and sandstone bodies are thinner and finer-grained in an overall fining-upward succession. Individual sandstone bodies fine upward to asymmetrical ripple cross-laminated, fine-grained sandstone and siltstone beds. Between channelized successions, intervening siltstone and mudstone contain plant fossils and coal.

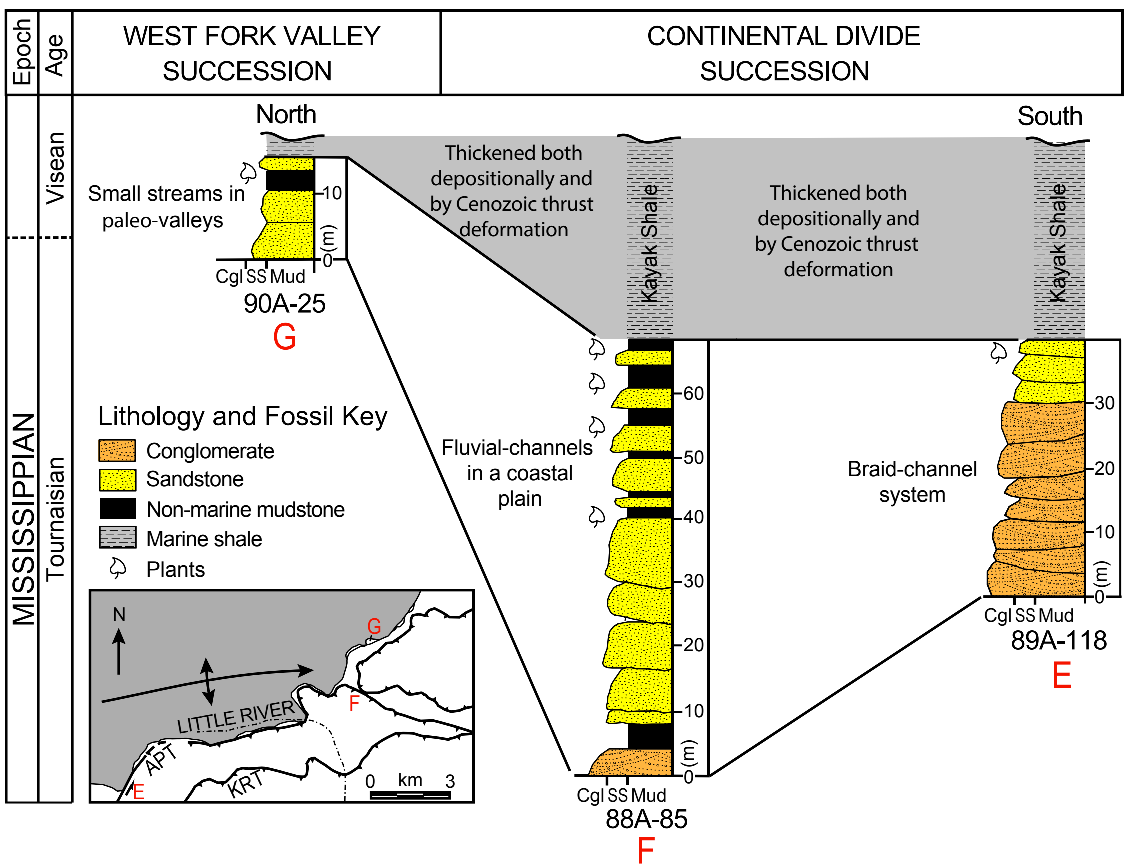

Figure S2. Measured stratigraphic columns showing lateral variability in lithology, depositional environment, and age of Kekiktuk Conglomerate in the Continental Divide succession and West Fork Valley succession. Locations E, F, and G are shown on inset map. (E) Kekiktuk Conglomerate (89A-118) of Continental Divide succession (see Fig. 8B). (F) Kekiktuk Conglomerate (88A-85) of Continental Divide succession. (G) Kekiktuk Conglomerate (90A-25) of West Fork Valley succession.

Differences in the vertical organization of the Kekiktuk Conglomerate of the Continental Divide succession at locations E and F (Figs. 3 and S2) could be a response to location F being more distal from a major source of sediment into the coastal plain during Early Mississippian time. The tabular, elongate geometry of the initial basal-40-m amalgamated conglomerate and sandstone channel-fills at location E (Figs. 3 and S2) is consistent with deposition in a laterally-shifting braided-channel complex. To the east at location F (Figs. 3 and S2), the internal organization of successively higher Kekiktuk Conglomerate intervals records a change in fluvial style from a braided system to a meandering system. The fining-upward character of each of these intervals records decreasing sediment supply and alluvial gradient due to relative sea-level rise. These deposits are the products of a fluvial system characterized by shallow channels and intervening bars with an upward change from a conglomerate-dominated system to a sand-dominated system.

Intervals of siltstone and mudstone present between the conglomerate and sandstone beds at location F contain abundant plant fossils and coal (Figs. 3 and S2). The alternation of mudstone intervals with fluvial deposits in a succession that is overlain by the marine Kayak Shale, suggests deposition in a coastal-plain setting. Successively higher conglomerate-sandstone bodies in the Kekiktuk Conglomerate of the Continental Divide succession are thinner and finer-grained and record an upward change from braided to meandering fluvial systems. These relationships suggest that the upward change reflects decreasing stream gradients in response to rising relative sea level.

West Fork Valley Succession

The depositional character of the Kekiktuk Conglomerate varies within the West Fork Valley succession. Where deposition occurred along the margins of topographic highs in the underlying chert, poorly-sorted, matrix-supported chert breccia forms the basal deposits. The basal chert breccia usually becomes conglomeratic within one meter above the base, fines upward to fine-grained sandstone and siltstone, and is overlain by black mudstone with abundant plant fossils. Elsewhere along the unconformity surface, isolated (less than 15-m-thick by 10–20-m-across), lenticular conglomerate and sandstone bodies are present. Massive horizontally to trough cross-stratified, conglomerate and sandstone characterize these deposits. Conglomeratic beds, 50–100-cm-thick, are commonly lenticular and fill small channels cut into underlying conglomerate beds. Above the basal conglomeratic beds, deposits fine upward to fine-grained sandstone overlain by black mudstone containing plant fossils and coal.

The relationship of the character of Kekiktuk deposits of the West Fork Valley succession to paleo-relief on the unconformity surface suggests that the sediments were shed from paleo-highs of Romanzof formation chert that were both a sediment source and barrier to lateral migration. Angular chert clasts of the same composition as the nearby chert paleo-highs suggest local derivation. The more texturally mature conglomerate and sandstone beds were deposited in small fluvial channels above the unconformity surface. The fining-upward succession at the top of these deposits indicates waning-flow conditions that, together with the overlying mudstone, plant fossils, and coal, record abandonment of the channel.

Depositional Setting of the Kekiktuk Conglomerate

South (Continental Divide succession) to north (West Fork Valley succession) changes in the Kekiktuk Conglomerate suggest a northward-retrograding fluvial to marginal-marine system. Based on lithologic similarity, the closest source for these sediments is the Romanzof formation exposed beneath the sub-Kekiktuk unconformity to the north. To the south, in the Continental Divide succession, the thick, braided-channel system and overlying succession of black mudstone and fining-upward channelized sandstone intervals record migration of a retrograding fluvial system across a swampy delta plain or, alternatively, progradational pulses in a retrograding fluvial-deltaic system.

In the north (West Fork Valley succession), where deposited with high-angle discordance over deformed Romanzof formation, the Kekiktuk Conglomerate is characterized by thin, laterally-discontinuous colluvium deposits, small debris-flow deposits, and deposits of small, coarse-bedload streams. The associated black mudstone with plant fossils and coal, which interfingers laterally with, and overlies, the clastic deposits, is interpreted to be swampy flood plain deposits.

PUBLISHED FOSSIL AND RADIOMETRIC AGE CONSTRAINTS

Table S1. Published fossil and radiometric age constraints used to construct the mid-Paleozoic tectonostratigraphic chart (Fig. 12), including basis for age assignment and list of source references.

TABLE S1. AGE CONSTRAINTS FOR MIDDLE DEVONIAN - MISSISSIPPIAN ARCTIC ALASKA TECTONOSTRATIGRAPHIC CHART

Formation	Age	Basis for Age Assignment	References
South Arctic Alaska Margin			
Base Lisburne	top Tournaisian to bottom Visean (early Osagean) late Early Mississippian	Foraminifera and conodonts	Moore et al., 1992 and references therein
Base Kayak Shale	lower Tournaisian (late Kinderhookian)	Marine megafossils	Nilsen and Moore, 1984 and references therein
Kanayut delta (base Hunt Fork Shale)	Frasnian (early Late Devonian)	Marine megafossils and conodonts	Nilsen and Moore, 1984; Moore et al., 1992 and references therein
Beaucoup Formation	Latest Givetian to earliest Frasnian; Middle to Late Devonian	Conodonts; megafossils	Dumoulin and Harris, 1994
Ambler Group bimodal volcanism	396 +/-20 Ma; Lochkovian to mid-Frasnian (396 Ma is mid-Emsian)		Dillon et al., 1980
Ambler Group silicic volcanics	405-360 Ma; Mid-Emsian to mid-Frasnian; late Early to early Late Devonian (>400 Ma dates are inherited zircons)	U-Pb on zircons	Hoiland, 2019, and references therein
Ambler Group rhyolite porphyry	373-327 Ma; late Frasnian to mid-Serpukhovian	U-Pb and Pb-Pb on zircons	Dillon et al., 1980, cited in Hitzman et al., 1986

TABLE S1 (Cont.). AGE CONSTRAINTS FOR MIDDLE DEVONIAN - MISSISSIPPIAN ARCTIC ALASKA TECTONOSTRATIGRAPHIC CHART

Formation	Age	Basis for Age Assignment	References
South Arctic Alaska Margin			
Ambler Group dolomite lenses	Late Devonian to Mississippian(?)	Poorly preserved corals	Smith et al., 1978
Ambler Group Bornite carbonate sequence	Middle to Late Devonian or earliest Mississippian	Fossils	Patton et al., 1968, and Hitzman et al., 1982, cited in Hitzman et al., 1986
Angayucham terrane	Late Devonian		Moore et al., 1994
Angayucham terrane carbonates (limestone, metalimestone, marble)	Middle to early (or earliest) Late Devonian (Frasnian); 1 sample late Early Mississippian	11 samples: Conodonts (primarily); corals, crinoids, brachiopods, and cephalopods; 1 sample dated as late early Mississippian conodonts in "limestone and chert")	A.G. Harris, written commun., cited in Pallister et al., 1989
Angayucham terrane chert and cherty tuff	late Early to Late Mississippian, Triassic, and Early Jurassic	10 samples: Radiolaria	B. Murchey-Stenicker, written commun., cited in Pallister et al., 1989
Ulungarat Basin			
Base Lisburne	middle Visean (early late Meramecian)	Conodonts	A. Harris, 1991, written commun.; this paper
Upper Kayak Shale	middle Visean (early Meramecian)	Conodonts	A. Harris, 1991, written commun.; this paper
Lower Kayak Shale	middle Tournaisian (late Kinderhookian)	Conodonts; trilobites (*Linguaphillipsia*); plant spores	A. Harris, 1991, written commun.; Hahn and Hahn, 1993; Utting, 1991; this paper
Kekiktuk Conglomerate	pre-middle Tournaisian	based on conodonts in lower Kayak Shale	
Mangaqtaaq Formation	Late Devonian	Plant fossils	Maney, 1989, written commun.; this paper

TABLE S1 (Cont.). AGE CONSTRAINTS FOR MIDDLE DEVONIAN - MISSISSIPPIAN ARCTIC ALASKA TECTONOSTRATIGRAPHIC CHART

Formation	Age	Basis for Age Assignment	References
<u>Ulungarat Basin</u>			
Ulungarat Formation	Eifelian (early Middle Devonian)	Large inarticulate brachiopods identified as *Bicarinatina kongakutensis* n. sp.; *Ladjia* sp. (an ambocoelid brachiopod), fragments of nuculoid bivalves, nautiloid cephalopods, and ramose bryozoans; *Ulungaratoconcha heidelbergeri* sp. nov. (a murchisonid gastropod) and *Coelotrochium* sp. (a dasycladacean alga; indeterminate species of bivalves (including nuculoid bivalves) and several species of brachiopods (including reticularid brachiopods). Species identified include *Spinatrypa* sp. and *Naticopsis (Jedria)* sp. cf. N. (J.) costatus D'Archiac and DeVerneuil; crinoids, dendroid tabulate corals, reticularid brachiopods, dechenellid trilobites, belleropohontid and straparollid gastropods, several species of bivalves (including pectenoid and nuculoid bivalves), and stick-like bryozoan	Popov et al., 1994; Blodgett, 1992, written commun.; Blodgett, 2008; Blodgett and Cook, 2002; Blodgett et al., 2002; this paper
<u>NE Brooks Range (parautochthon)</u>			
base Lisburne	late Visean (earliest Chesterian)		Armstrong, 1974; Sadlerochit Mts.
Kayak Shale	middle Visean (Meramecian)		Moore et al., 1994 and references therein
Kekiktuk Conglomerate	latest Tournaisian to earliest Visean	Palynomorphs	LePain et al., 1994

TABLE S1 (Cont.). AGE CONSTRAINTS FOR MIDDLE DEVONIAN - MISSISSIPPIAN ARCTIC ALASKA TECTONOSTRATIGRAPHIC CHART

Formation	Age	Basis for Age Assignment	References
NE Brooks Range (parautochthon)			
Okpilak batholith	380 +/- 10 Ma; early Frasnian (mid-Eifelian to early Famennian error bars)	U-Pb on zircons	Dillon et al., 1987b
North Arctic Alaska (autochthon)			
Base Lisburne	middle Visean (Meramecian)	Foraminifera	Moore et al., 1992 and references therein
Kayak Shale	middle Visean (Meramecian)		Moore et al., 1992 and references therein; Woidneck et al., 1987
Kekiktuk Conglomerate	latest? Tournaisian to earliest Visean	Miospore flora	Ravn, 1991
Topagoruk #1 well	Early? to Middle Devonian	Plant fossils	Collins, 1958
Reactivation of basins	249-299 Ma; late Tournaisian to base Permian	Reflection seismic correlation	Fulk, 2010

TABLE S1 REFERENCES

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