Structural and Stratigraphic Implications of Detailed Geologic Mapping of Ellesmerian and Brookian Units in the Echooka and Ivishak Rivers Region, East-Central North Slope, Alaska

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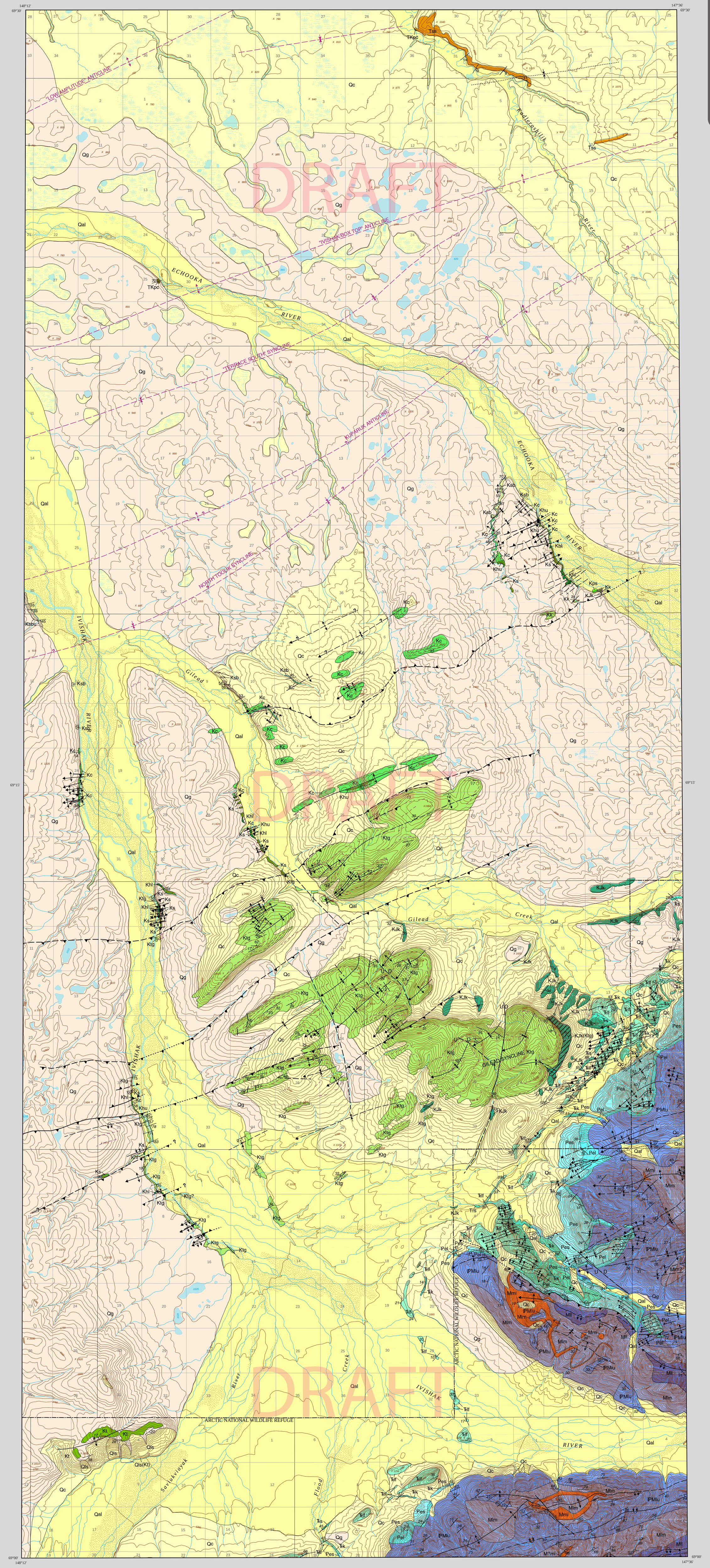
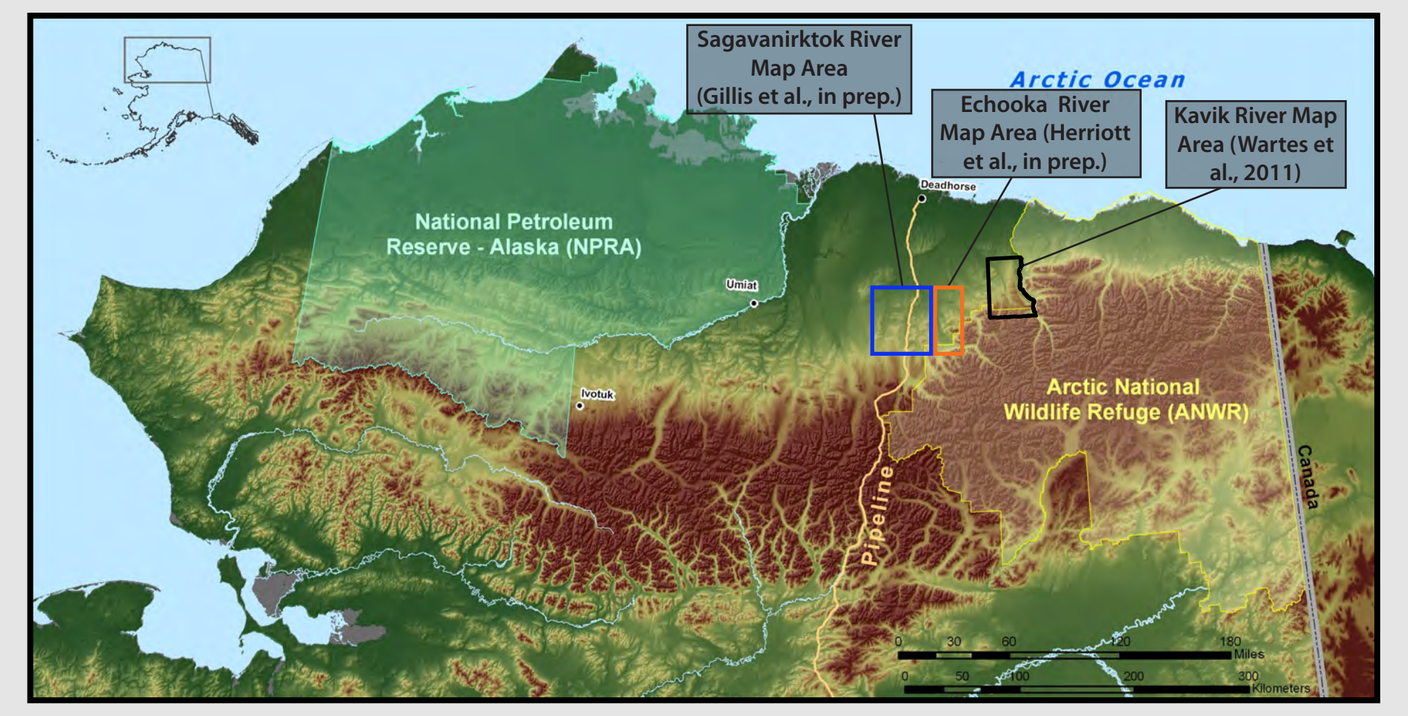
The Echooka and Ivishak rivers area geologic map and accompanying figures and captions presented here are preliminary and have not yet undergone rigorous technical and peer review. We will formally publish this map (Herriott et al., in preparation), as well as our observations and conclusions regarding the study area, through our Division of Geological & Geophysical Surveys publications group. Please contact trystan.herriott@alaska.gov for further information regarding this poster.



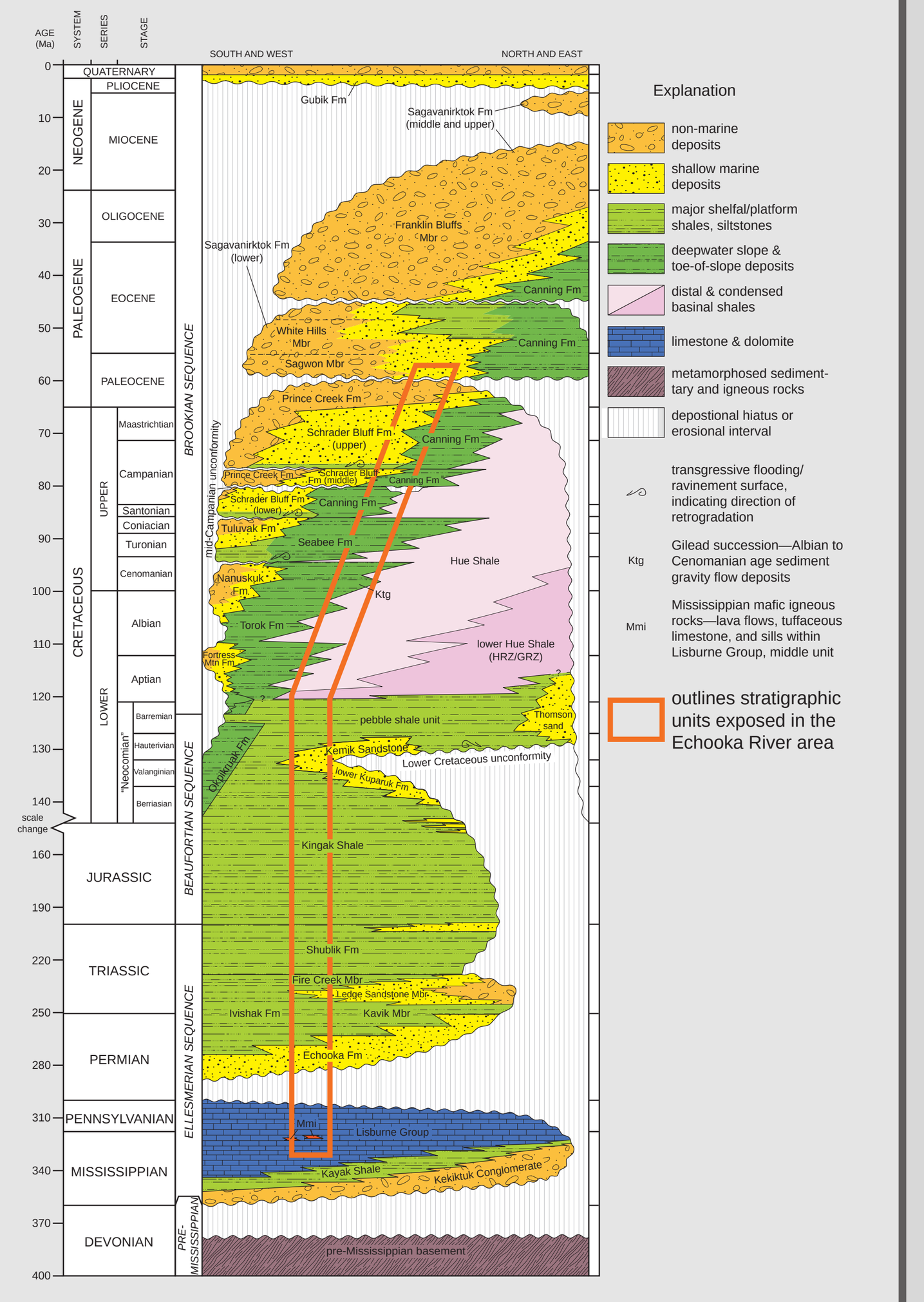
Geologic Mapping and Regional Context

List of Map Units

Location Map



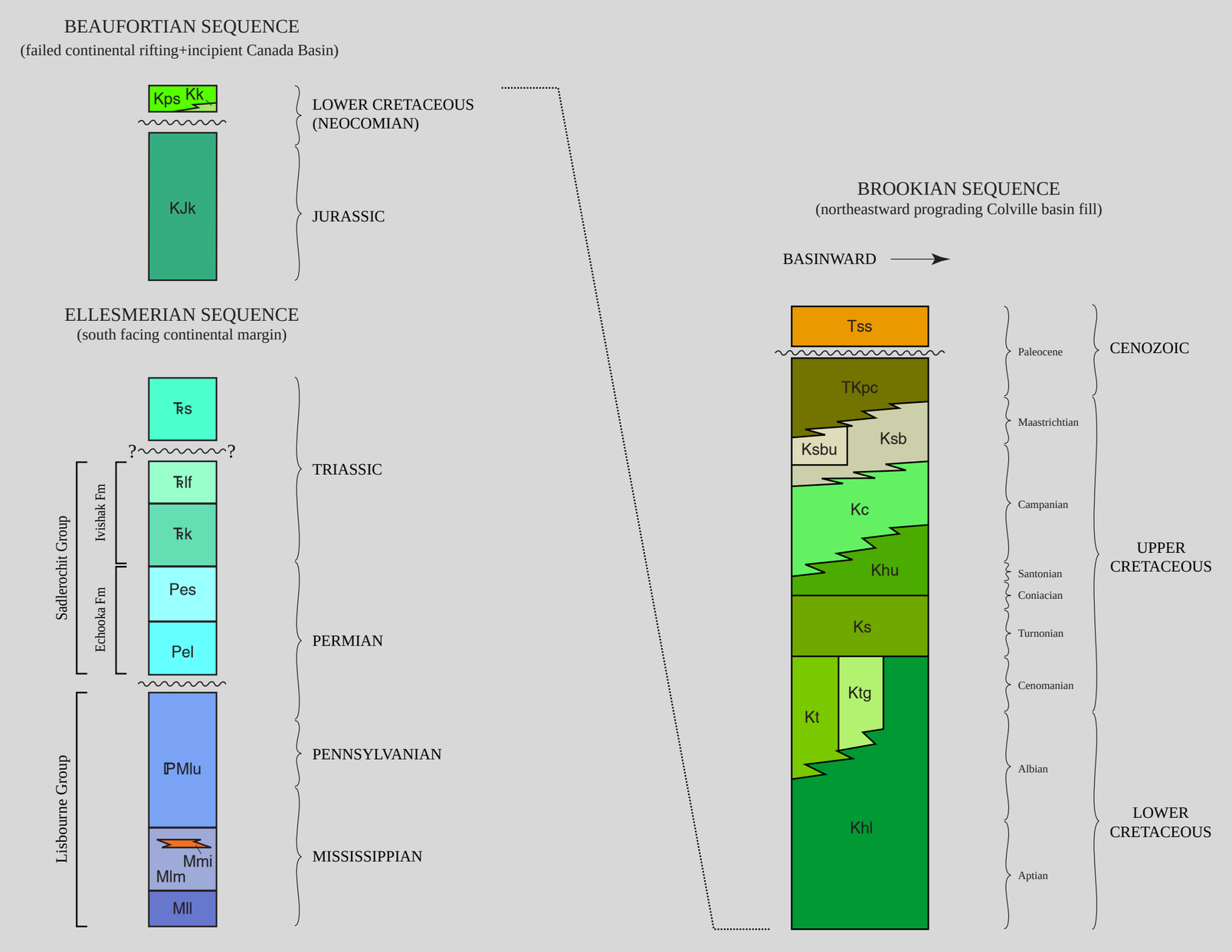
Chronostratigraphy



Chronostratigraphic column for the northern Brooks Range and Colville basin, northern Alaska. Brookian sequence chronostratigraphy after Decker et al. (in review), revised after Mull et al. (2003); pre-Brookian sequence chronostratigraphy modified after Garrity et al. (2005). Stratigraphic units exposed within the study area are within the red outline.

Map Symbols

Correlation of Bedrock Map Units



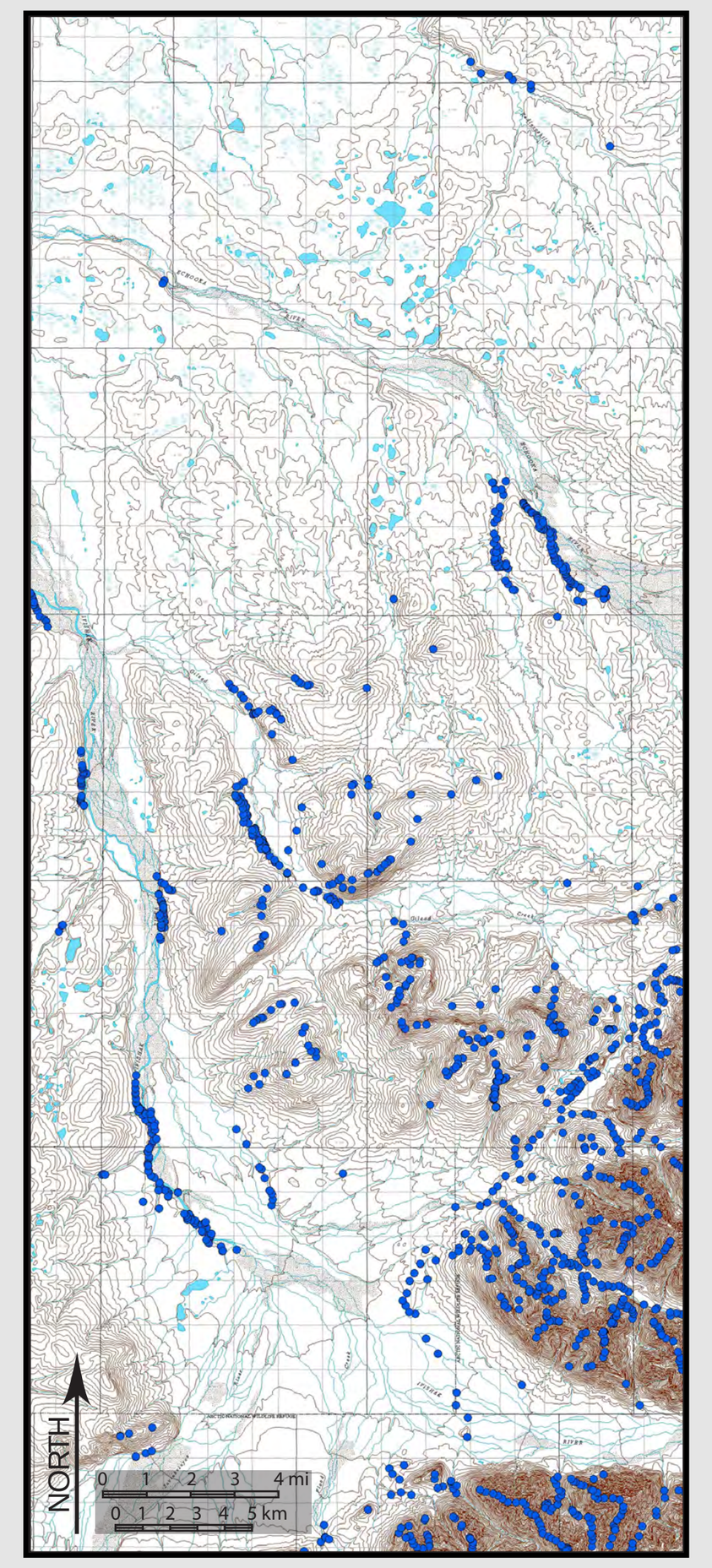
References Cited

Decker, P.L., LePain, D.L., Wartes, M.A., Gillis, R.J., Mongrain, J.R., Kirkham, R.A., and Shellenbaum, D.P. (in review) Sedimentology, Stratigraphy, and Subsurface Expression of Upper Cretaceous Strata in the Sagavanirktok River Area, east-central North Slope, Alaska: Alaska Division of Geological & Geophysical Surveys Preliminary Interpretive Report XXXX-XX.

Abstract

The North Slope foothills belt provides a unique opportunity to examine surface exposures of stratigraphic intervals that bear on the region's petroleum resources as well as local oil and gas prospectivity in the southern Colville basin. To this end, geologists from Alaska Division of Geological & Geophysical Surveys (DGGS), Alaska Division of Oil and Gas, and University of Alaska Fairbanks in 2009 extended our understanding of the region's geology by mapping ~500^2 miles adjacent to other recent DGGS mapping in the foothills belt. The map area lies in a key structural position that spans the transition from higher-relief basement-involved structures in the east and south to thin-skinned deformation of Brookian strata in the west and north. Local structure is strongly influenced by mechanical stratigraphy and generally comprises: 1) detachment folds in the Ellesmerian sequence, which constitutes the basement-cored Echooka anticlinorium's roof layer; and 2) a complex fold-and-thrust belt in the Brookian foreland basin deposits, which lie north of the prominent topographic range front. The Ivishak River's southern extent within the fold-and-thrust belt marks an abrupt transition westward from open and upright folds to tight and strongly overturned folds northwest of the southwest-plunging Echooka anticlinorium. This may reflect strain partitioning between northwest-striking transverse faults or transfer of displacement to shallower detachments at a lateral ramp. Key stratigraphic observations include new insights into the mid-Cretaceous Gilead succession, a >850-m-thick sand-rich, locally petroliferous package comprising dominantly sediment gravity flow deposits. We interpret these facies to record deposition in toe-of-slope to basin-axial environments, a setting that may have prospective subsurface equivalents to the west. Gilead strata thin and fine markedly from south to north across the map area, condensing entirely into Cretaceous Hue Shale. Additionally, we recognize two mappable units within the distal Hue Shale that are regionally separated by an intervening tongue of sand-prone Upper Cretaceous Seabee Formation; the latter formation—stratigraphically encased by excellent Hue source-rock facies—commonly exhibits a strong hydrocarbon odor. Also highlighted by this study are rare occurrences of volcanic and hypabyssal(?) rocks within the Carboniferous Lisburne Group that crop out southeast of the mountain front near the Ivishak River. Pending analytical results, these igneous rocks may provide local absolute age control and yield insight into the tectonic setting of this vast carbonate platform.

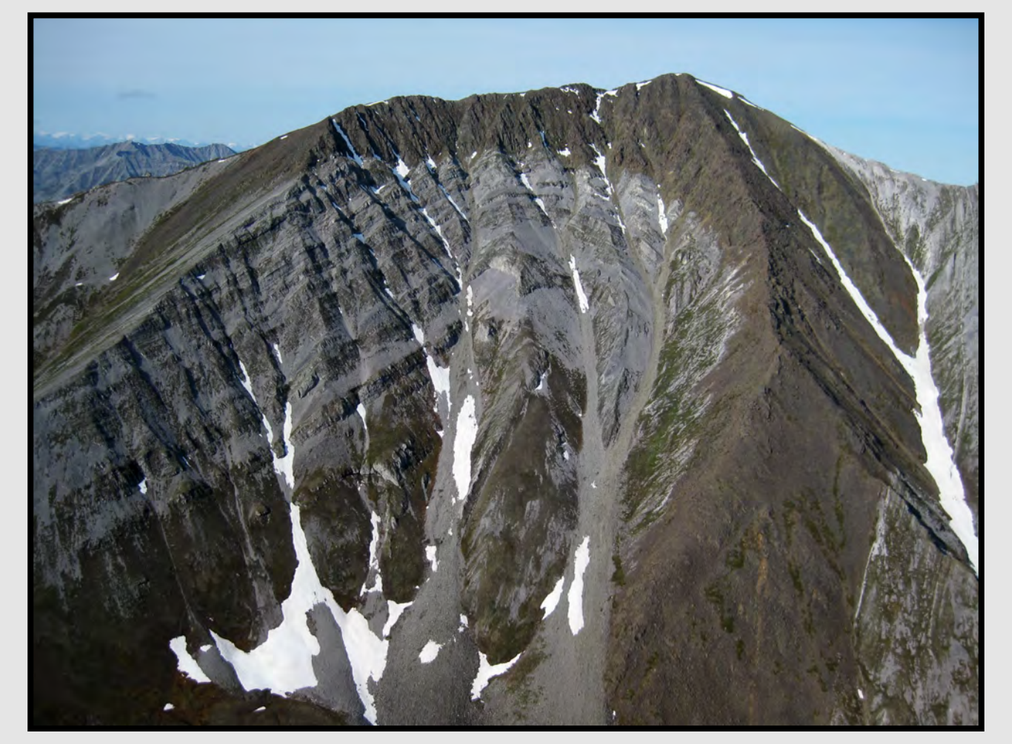
Station Map



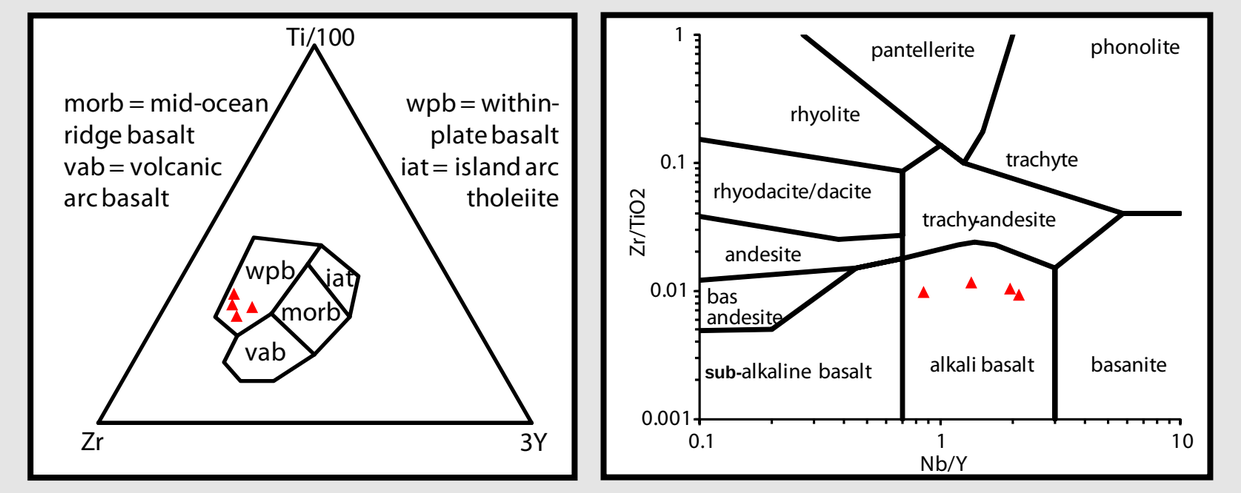
Detailed geologic observations were made at 1,311 locations (blue dots) during the 2000 through 2009 field seasons. Renewed sedimentologic, stratigraphic, and structural studies within the ~500 square mile study area were conducted primarily during 2007-2009, with most of the geologic mapping completed during summer 2009.

Stratigraphy and Sedimentology

Lisburne Group—Mafic Igneous Rocks



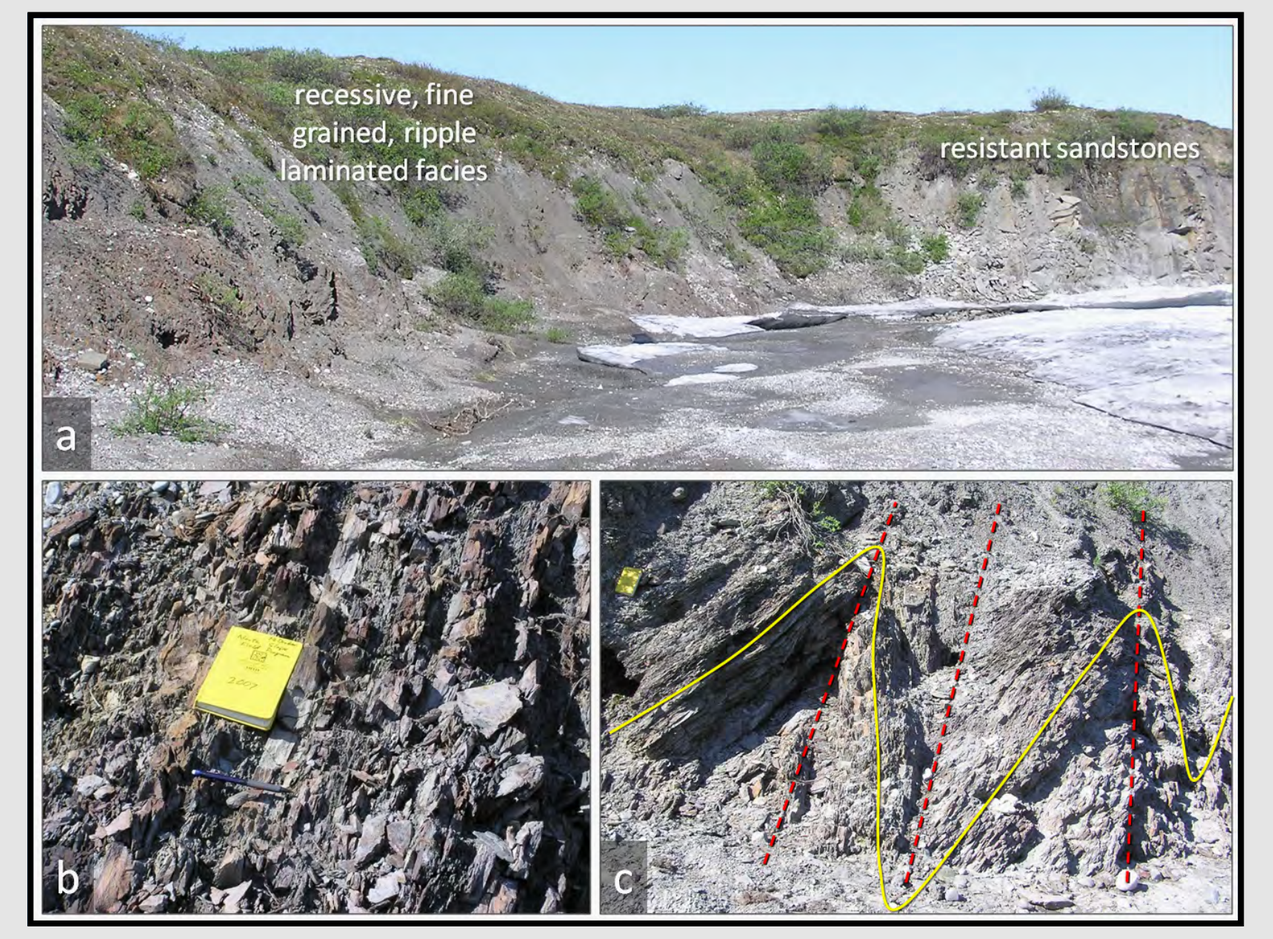
Upper Mississippian mafic igneous rocks are rare in the north-central and northeastern Brooks Range, but they occur within Upper Mississippian Lisburne Group limestone (our informal Mlm unit) north and south of the Ivishak River. The igneous occurrences include mafic sills (upper left) tuffaceous limestones (lower left), and mafic lava flows (below). The prominent "diabase" sill (upper left) exposed immediately south of the current study area was originally reported by Keller et al. (1961); Reiser et al. (1979) suggested this sill may represent an intrusive equivalent of the volcanic rocks to the north (i.e., those observed during the current study).



*XRF geochemical analyses and discrimination plots by Rainer J. Newberry

Below is an excerpt from Herriott et al., an abstract submitted to the sixth International Conference on Arctic Margins, Fairbanks, AK, 31 May–2 June 2011: "Despite probable shifts of major element compositions in some samples due to chemical alteration, high Cr, V, and Ti concentrations indicate basaltic parent rocks. Moreover, Nb/Y–Zr/TiO2 volcanic classification plots indicate the samples were originally alkali basalts or fragments thereof. Ti/100–Zr–3Y and 2Nb–Zr/4–Y trace element tectonic discrimination diagrams chiefly suggest within-plate basalt and within-plate alkalic basalt origins, respectively. These are the first geochemical results to demonstrate that magmatism in the parautochthon is related to extension."

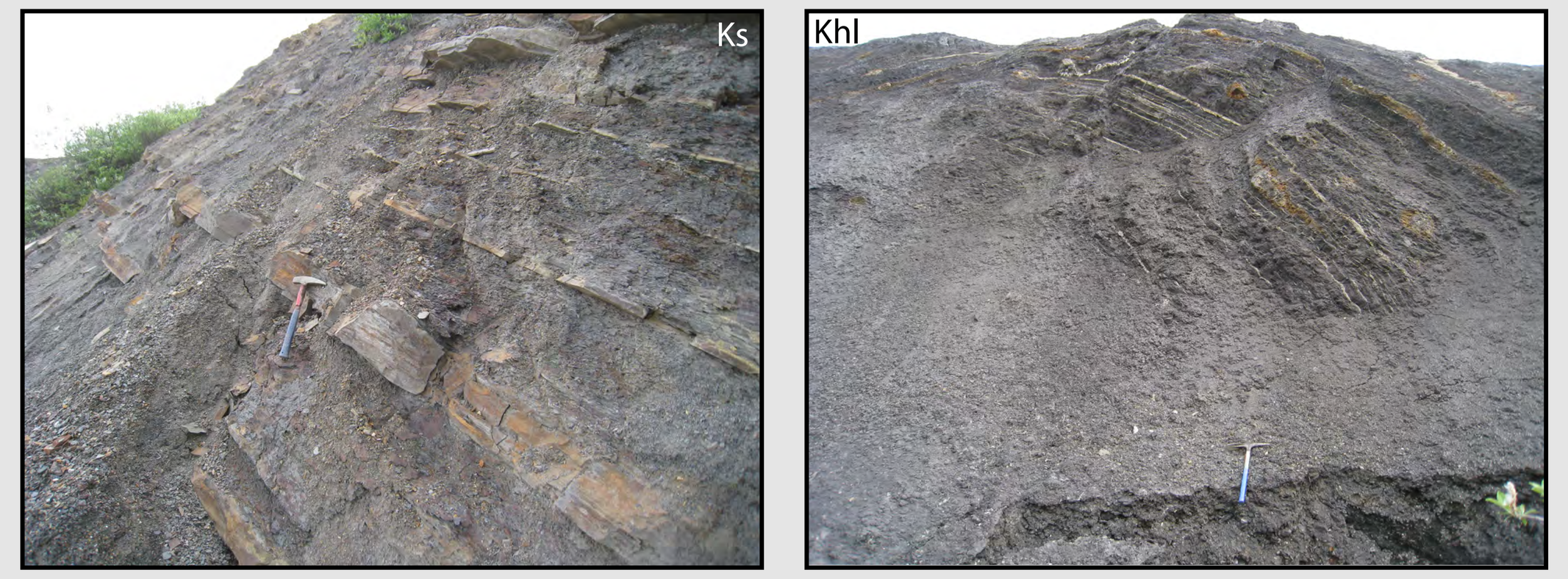
Gilead Succession



The Gilead succession (informal unit; "Gilead sandstone" of Reifenstuhl (1991) and "Gilead Creek sandstone" of Pessel et al. (1990)), a >850-meter-thick package of interbedded sandstone, siltstone, and shale, is interpreted as having been deposited in a deepwater marine environment, possibly along a basin axis facies belt. Two end member facies associations, occurring in alternating, up to tens of meters-thick-successions, were identified and described by Decker et al. (2008). The coarser-grained facies (lower photograph; bed "a" is 3.5 meters thick) consists of medium- to very thick-bedded, commonly fine- to coarse-grained amalgamated sandstones; these strata are interpreted as deposits of high-density sediment gravity flows (e.g., hyperpycnites). The finer-grained facies (upper photographs) comprises thin-bedded, ripple-laminated, very fine-grained sandstone, siltstone, and shale; these strata are interpreted as deposits of low-density sediment gravity flows. Subsurface equivalents to the sand-rich Gilead succession (one such interval has been identified in the Lupine Unit 1 well) may provide reservoir targets in the gas-prone foothills belt. All photographs and interpretations are from Decker et al. (2008).

Lower Hue–Seabee–Upper Hue

The Hue Shale is subdivided into upper and lower parts by an intervening tongue of sand-prone Seabee Formation (lower left). These three mappable units are typically distinguishable in outcrop even where the stratigraphic or structural context is poorly understood. Although both the upper and lower Hue comprise organic-rich dark gray to black shale, the lower unit contains light green-gray-yellow bentonite seams (lower right); the upper Hue has intercalated rusty orange-brown siliceous vitric tuffs (upper right). The Seabee, stratigraphically encased by these excellent source rocks, is commonly petroliferous and exhibits a diagnostic iridescent orange-purple weathering surface (upper left).



Structural Geology

Mechanical Stratigraphy

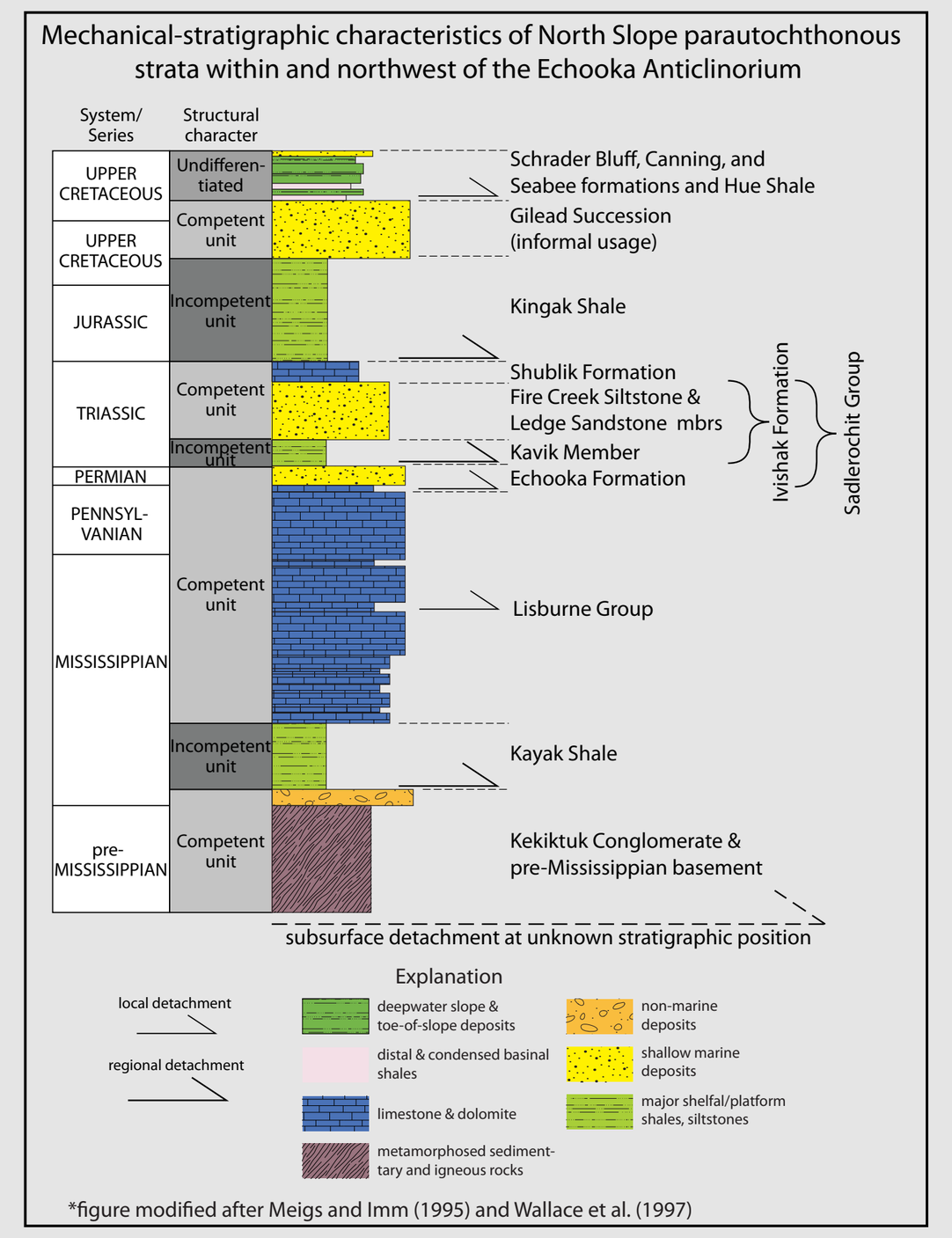
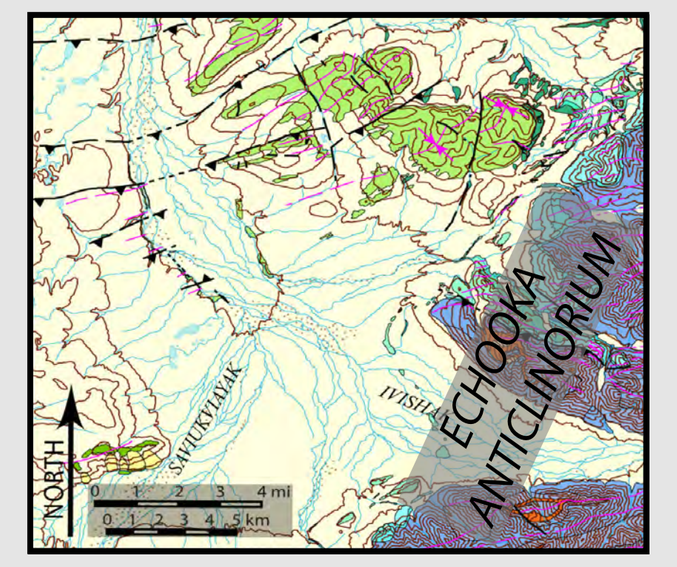
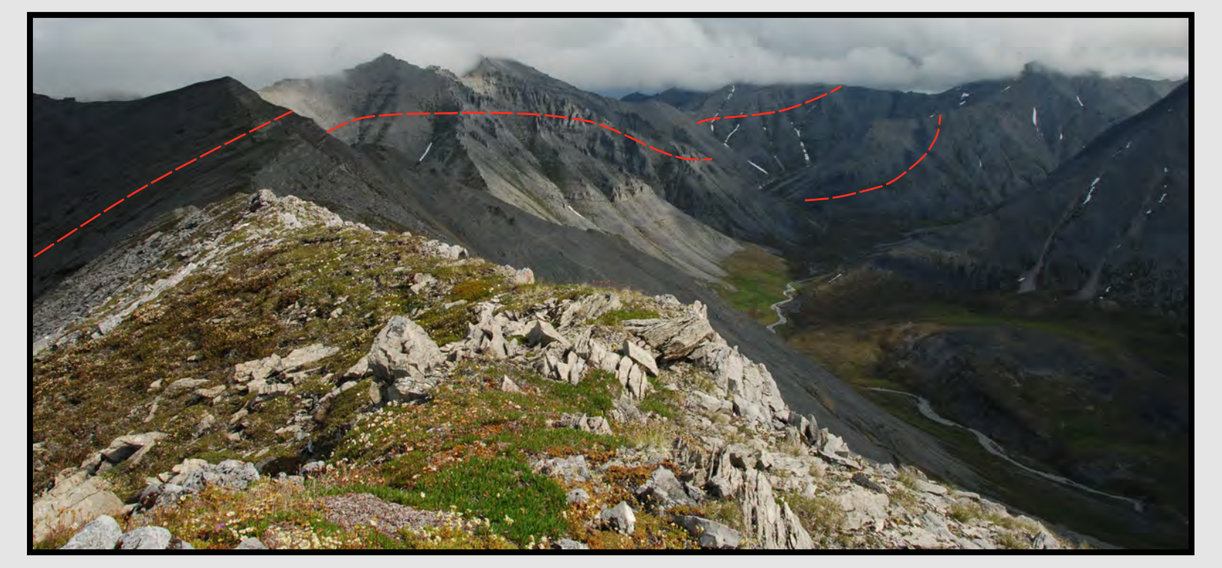


*figure modified after Meigs and Imm (1995) and Wallace et al. (1997)

The mechanical properties of lithostratigraphic units greatly influence the occurrence and geometries of faults and folds within a deformed stratigraphic succession. Detachments form in structurally incompetent rock units—e.g., shale—which also commonly exhibit relatively small, short wavelength folds and varying degrees of penetrative deformation. Fold geometries in structurally competent units—e.g., limestone, sandstone, or conglomerate—are largely dictated by the overall thickness of the unit and its internal properties (e.g., bedding thickness and relative abundance of competent rock types), with thin competent units generally forming shorter wavelength folds than thick competent units. Ramps form in these competent units and serve to connect detachments at different structural and stratigraphic levels. Structural thickening of incompetent units also accommodates volume changes within tightening anticlinal cores beneath competent units. Furthermore, disharmonic folding of competent units may be permitted if a sufficiently thick intervening incompetent unit is present.

Echooka Anticlinorium

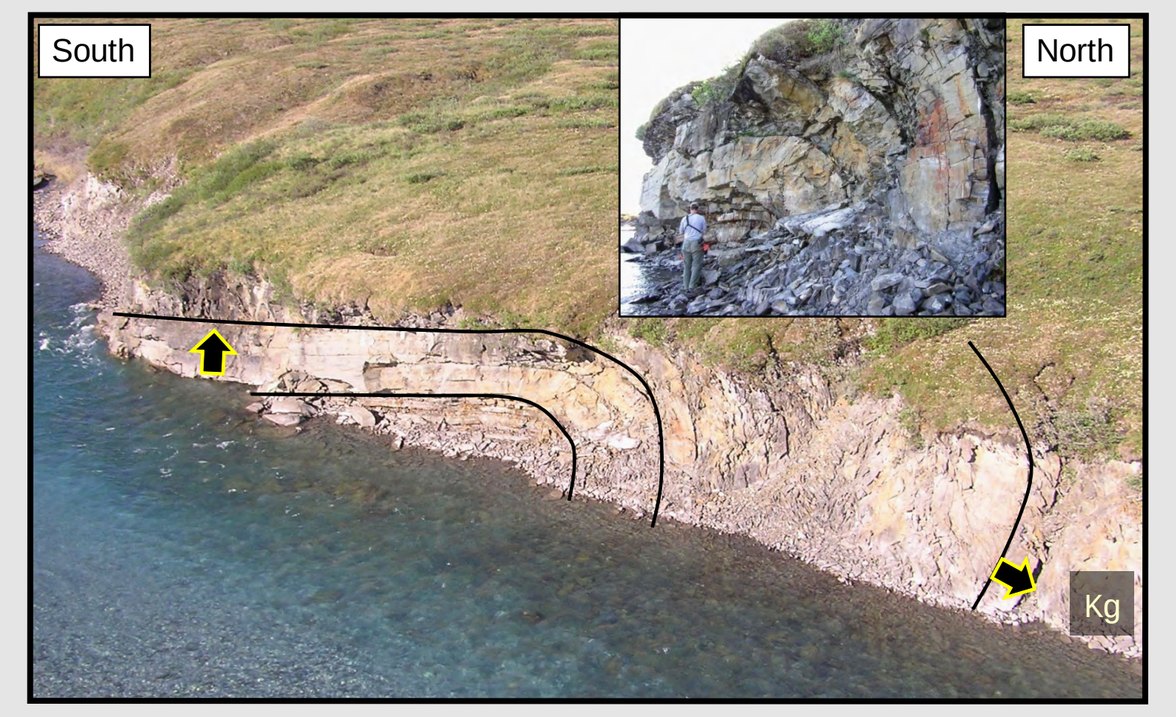


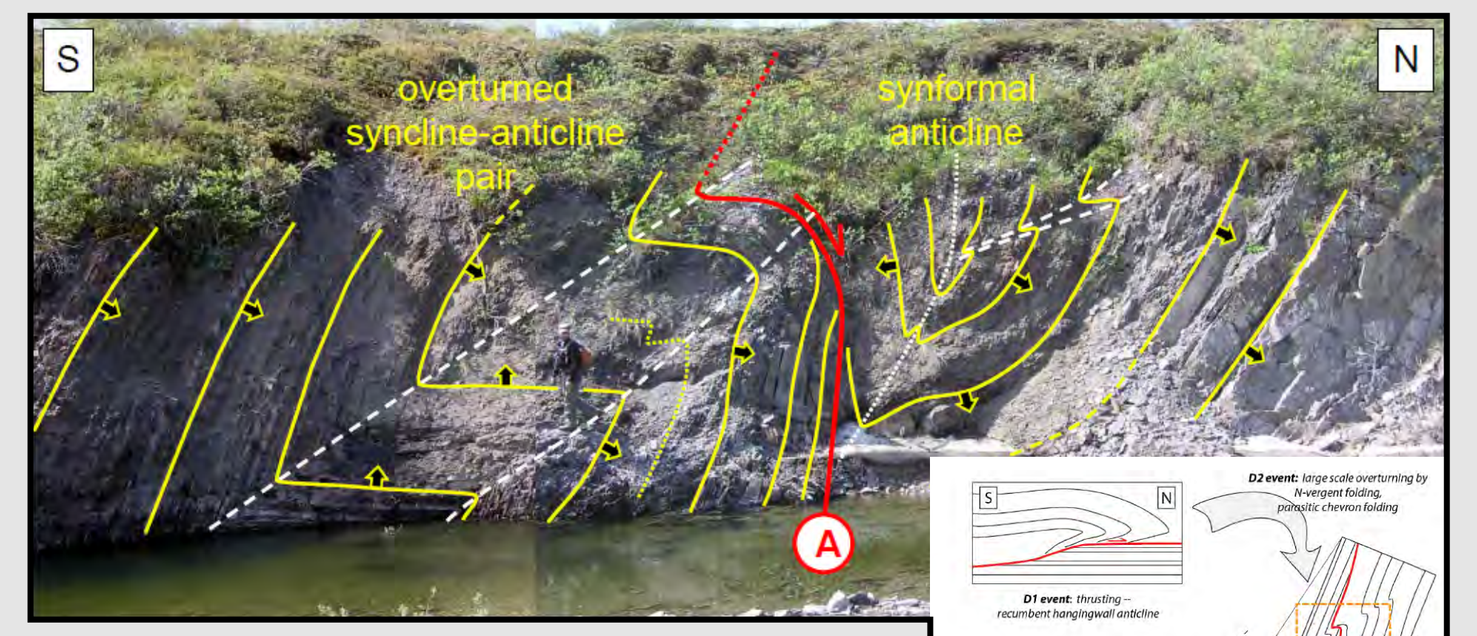


The southwesternmost extent of the sub-Mississippian basement-cored Echooka anticlinorium lies within the southeastern part of the map area (see simplified geologic map). Ellesmerian sequence strata comprise the detachment-folded roof layer, which is well exposed in the field area. Open box folds within the middle and upper parts of the Lisburne Group limestone are common in the roof layer (lower right). The Echooka anticlinorium's northwest limb coincides with the topographic range front along this segment of the northeastern Brooks Range (upper photograph; view toward ESE), with exposures (from right background to left foreground) of gray Lisburne limestone, black flatirons of the Echooka Formation, recessive weathering Kavik Member, and orange-brown Ledge Sandstone Member.

Structural Style—Southernmost Brookian Foreland Basin Fold-and-Thrust Belt

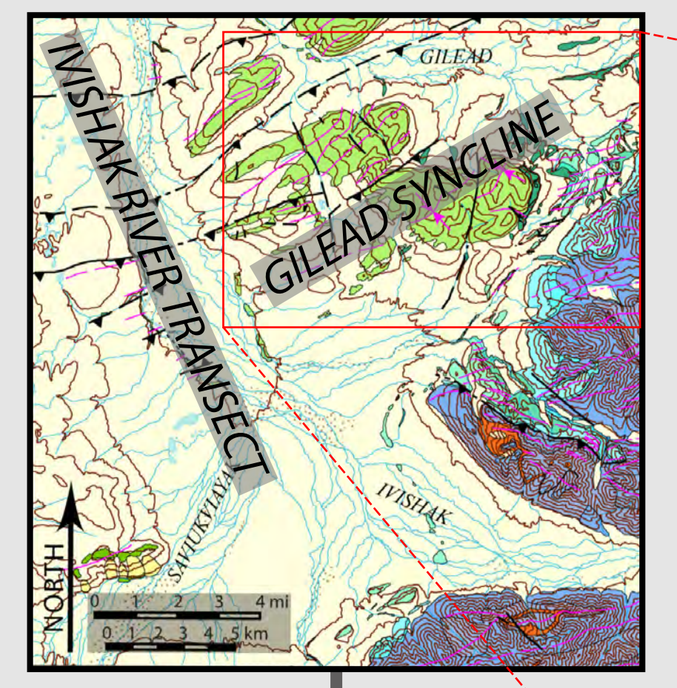
Ivishak River Transect

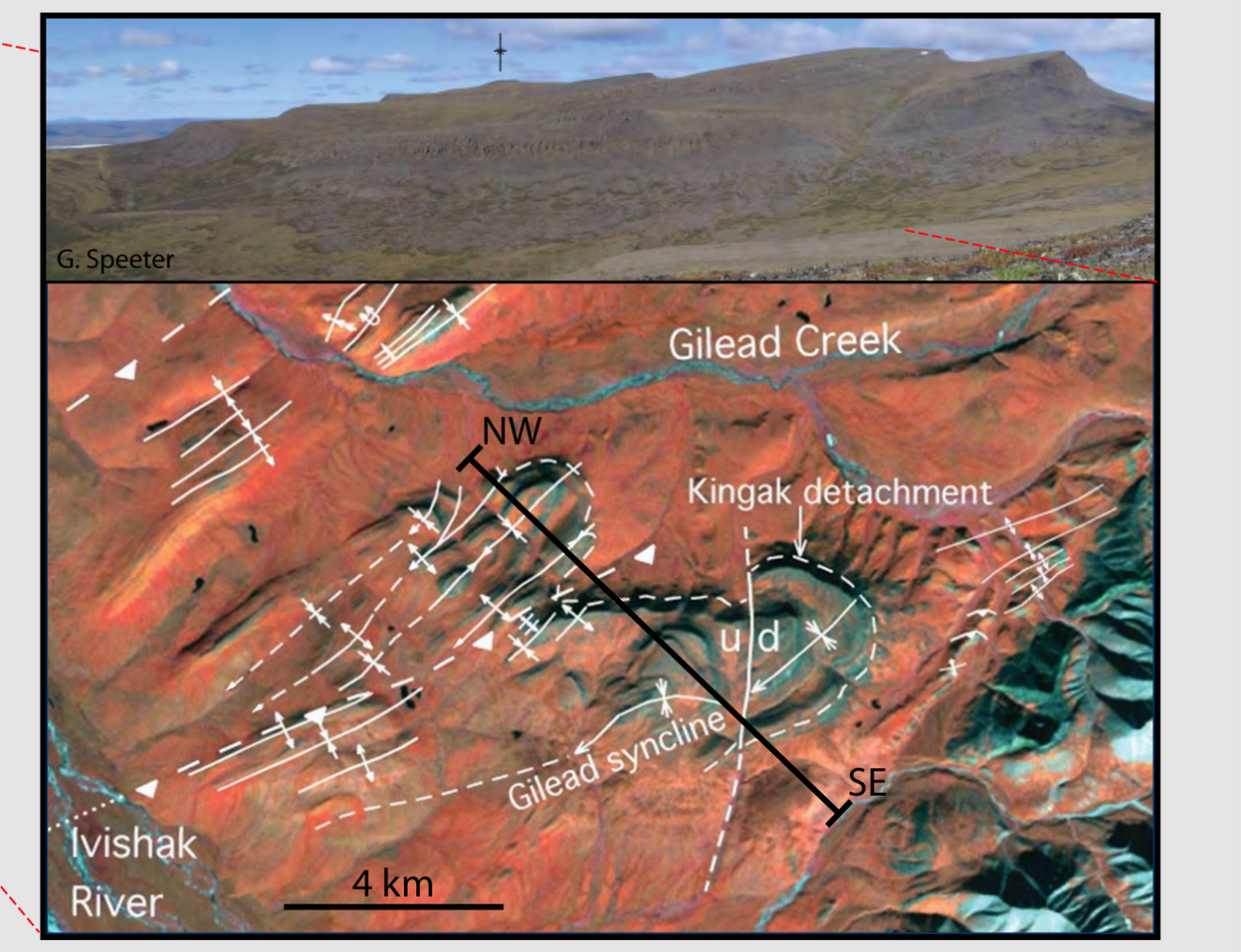


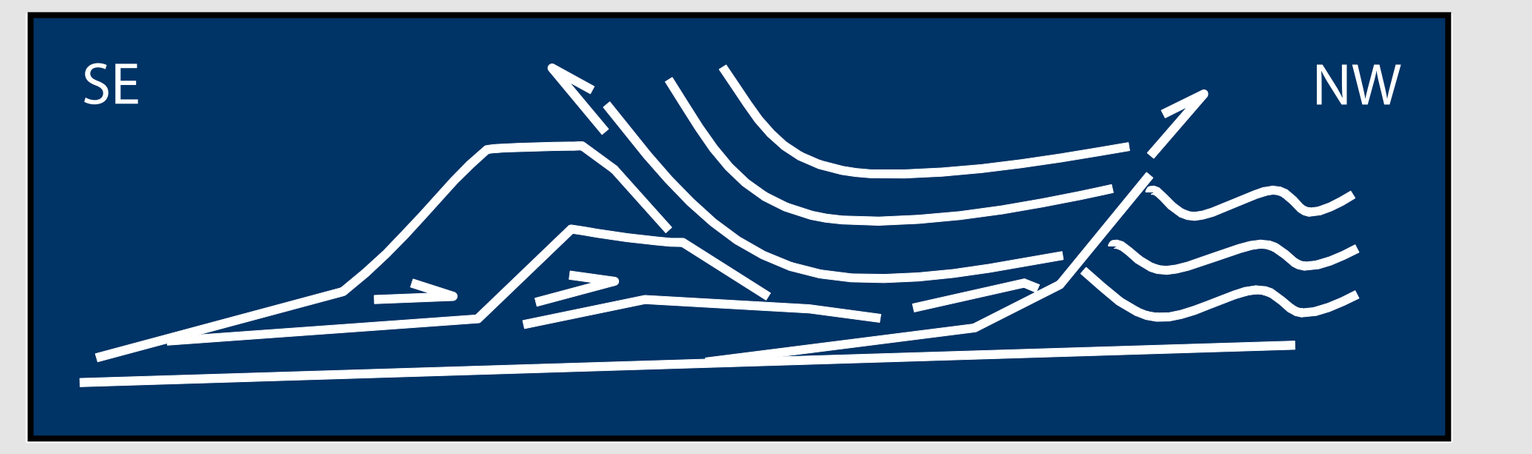


Gilead succession strata cropping out along the Ivishak River are intensely folded and faulted, with folds commonly being asymmetric, with gently south dipping backlimbs and steeply to gently overturned, thrust-truncated forelimbs (above figure; line drawing interpretation by P.L. Decker and modified after Decker et al., 2008). Some Ivishak River exposures of the Gilead succession exhibit especially complex structural relationships that may be suggestive of multiple phases of deformation (lower figure; see discussion and original figure captions in Decker et al., 2008).

Gilead Syncline







Although it has been previously suggested that the Gilead succession may be allochthonous, photogeologic mapping (upper figure; from Decker et al., 2008), geologic mapping, and detailed structural, sedimentologic, and stratigraphic studies of the Gilead syncline and surrounding areas are consistent with it being essentially autochthonous; the Gilead syncline may comprise a passive roof overlying structurally thickened Valanginian and older strata (see schematic cross-section above by W.K. Wallace).