CHAPTER 2

RECONNAISSANCE STRATIGRAPHIC STUDIES IN THE SUSITNA BASIN, ALASKA, DURING THE 2014 FIELD SEASON

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INTRODUCTION

The Susitna basin is a poorly-understood Cenozoic successor basin immediately north of Cook Inlet in south-central Alaska (Kirschner, 1994). The basin is bounded by the Castle Mountain fault and Cook Inlet basin on the south, the Talkeetna Mountains on the east, the Alaska Range on the north, and the Alaska–Aleutian Range on the west (fig. 2-1). The Cenozoic fill of the basin includes coal-bearing nonmarine rocks that are partly correlative with Paleogene strata in the Matanuska Valley and Paleogene and Neogene formations in Cook Inlet (Stanley and others, 2013, 2014). Mesozoic sedimentary rocks are present in widely-scattered uplifts in and around the margins of the basin; these rocks differ significantly from Mesozoic rocks in the forearc basin to the south. Mesozoic strata in the Susitna region were likely part of a remnant ocean basin that preceded the nonmarine Cenozoic basin (Trop and Ridgway, 2007). The presence of coal-bearing strata similar to units that are proven source rocks for microbial gas in Cook Inlet (Claypool and others, 1980) suggests the possibility of a similar system in the Susitna basin (Decker and others, 2012). In 2011 the Alaska Division of Geological & Geophysical Surveys (DGGS) and Alaska Division of Oil and Gas, in collaboration with the U.S. Geological Survey, initiated a study of the gas potential of the Susitna basin (Gillis and others, 2013). This report presents a preliminary summary of the results from 14 days of helicopter-supported field work completed in the basin in August 2014. The goals of this work were to continue the reconnaissance stratigraphic work begun in 2011 aimed at understanding reservoir and seal potential of Tertiary strata, characterize the gas source potential of coals, and examine Mesozoic strata for source and reservoir potential.
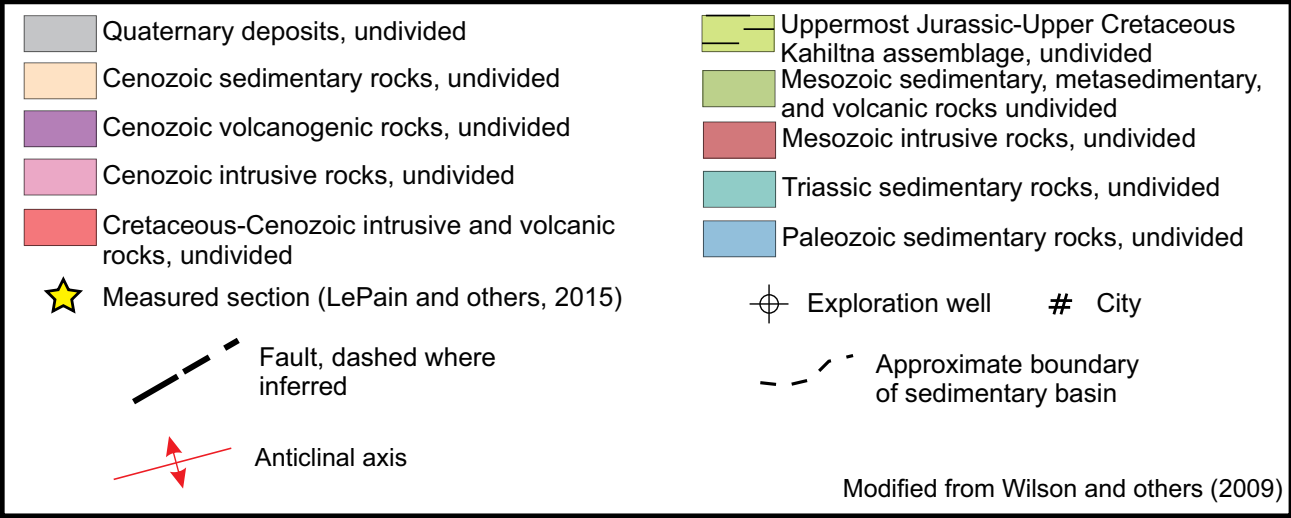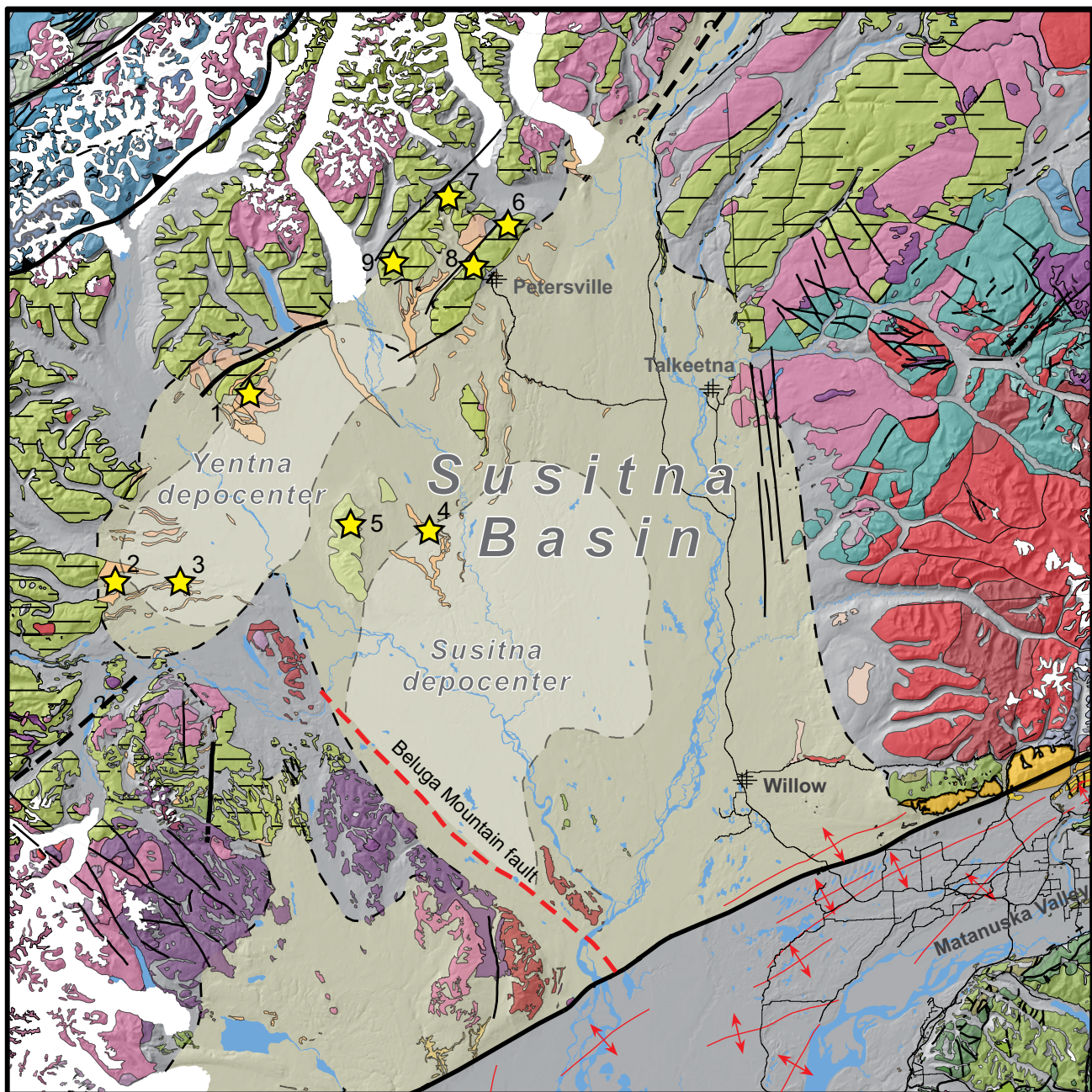
COAL-BEARING TERTIARY STRATA

Three stratigraphic sections were measured in the Tertiary fill of the basin to better understand fluvial styles and sand-body geometries, and to collect samples of sandstone for reservoir quality analysis and coal for high-pressure methane adsorption testing and organic geochemistry. Coal seams sampled as part of this work are discussed by Harun and others (2015). One section is at Fairview Mountain in the northwestern corner of the basin and two are along Johnson Creek on the basin's west side (fig. 2-1, locations 1–3). These sections are in the northern half of the basin where Reed and Nelson (1980) applied Cook Inlet stratigraphic nomenclature, with minor modifications, to the Tertiary stratigraphy. They mapped the Tyonek(?) Formation, assigned a Miocene age, and divided it into two mappable members: a sandstone member and a conglomerate member. They also mapped the Sterling(?) Formation and assigned a Pliocene age. The measured section at Fairview Mountain is in the conglomerate member of the Tyonek(?) Formation and is 79 m thick, and the sections on Johnson Creek include one each in the sandstone member of the Tyonek(?) and the Sterling(?) Formations, which are 27 m and 35 m thick, respectively. Finally, we briefly discuss an outcrop of moderately to steeply dipping sandstone and pebble-cobble-boulder conglomerate that was measured in 2011 and revisited in 2014 to collect additional samples for isotopic age dating (fig. 2-1, location 4).

The measured section in the conglomerate member of the Tyonek(?) Formation at Fairview Mountain includes at least two complete fluvial cycles, at least one incomplete fluvial cycle, and multiple seams of lignitic coal in a thick mudstone package (fig. 2-2a). The lower complete fluvial cycle includes more than 9 m of pebble conglomerate and lenses and interbeds of coarse- to very-coarse-grained sandstone. The top of the cycle consists of a 0.5-m-thick bed of sandstone with a prominent fining-upward grain size trend (medium lower to fine lower). A prominent erosion surface at the base of this cycle truncates steeply dipping beds of cross-bedded, fine- to coarse-grained sandstone (fig. 2-2b). It is unclear whether these dipping beds belong to this fluvial cycle or to an underlying cycle. The upper complete fluvial cycle is approximately 15 m thick and includes a 4-m-thick stepped, coarsening-upward succession (erosion surfaces separating beds of successively coarser-grained material) at its base. Otherwise this cycle is similar to the lower cycle. Sandstones throughout are quartzo-feldspathic and weakly cemented. These cycles are separated by a 53-m-thick mudstone package comprising many thin (30 cm or less) beds of fine-grained sandstone, a few thicker, fining-upward bedsets of fine-grained sandstone-siltstone (up to 2.2 m thick), and at least seven lignitic coal seams from 10 to 90 cm thick. Siltstones are typically argillaceous, and a few thin beds of faintly-laminated claystone are present. The upper 3.5 m of the measured section consists of interbedded pebble and cobble conglomerate that is part of a thicker, coarse-grained fluvial succession that is inaccessible due to

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Legend:

- Quaternary deposits, undivided
- Cenozoic sedimentary rocks, undivided
- Cenozoic volcanogenic rocks, undivided
- Cenozoic intrusive rocks, undivided
- Cretaceous-Cenozoic intrusive and volcanic rocks, undivided
- ★ Measured section (LePain and others, 2015)
- Uppermost Jurassic-Upper Cretaceous Kahiltna assemblage, undivided
- Mesozoic sedimentary, metasedimentary, and volcanic rocks undivided
- Mesozoic intrusive rocks, undivided
- Triassic sedimentary rocks, undivided
- Paleozoic sedimentary rocks, undivided
- ⊕ Exploration well   # City
- ▬ ▬ Fault, dashed where inferred
- ▬ ▬ Approximate boundary of sedimentary basin
- ↔ Anticlinal axis

Modified from Wilson and others (2009)

steep topography. This part of the section may represent the base of the Sterling(?) Formation (fig. 2-2a). This section is interpreted as the product of mixed-load, low- to moderate-sinuosity streams that likely included braided and meandering reaches (Miall, 2006). Flows were routinely able to move cobble- and pebble-sized material as bedload, indicating that stream gradients were moderate. Active channel tracts were flanked by poorly drained flood basins that included topogenous mires (McCabe, 1984). The steeply dipping strata at the base of the section are interpreted as a slump block or the limb of a soft-sediment fold, but a tectonic origin is also possible.

The measured section in the sandstone member of the Tyonek(?) Formation along Johnson Creek includes a lower, fine-grained succession 13 m thick overlain by 14 m of sandstone and pebbly sandstone (fig. 2-2c). The lower, fine-grained succession includes four lignitic coal seams from 0.1 to 1.4 m thick and two fining-upward successions 2.5 to 4.2 m thick. The fining-upward successions begin with a pebble lag overlain by ripple cross-laminated sandstone that includes abundant carbonaceous material draping foresets and minor scour surfaces, and terminate in siltstone or interlaminated siltstone and fine-grained sandstone. The upper, sandstone succession consists of trough cross-bedded, medium- to very-coarse-grained sandstone and numerous pebble lags up to 10 cm thick (fig. 2-2d). Pebble- and granule-sized clasts also line scour pits associated with trough cross-beds; clasts in this size range are commonly dispersed in sandstone beds. Sandstones are quartzo-feldspathic and largely uncemented. This section is interpreted as the product of mixed-load, moderate-sinuosity streams. Stream gradients were moderate and flows were commonly able to move pebble- and granule-sized material as bedload. Active channel tracts were flanked by poorly drained flood basins where peat accumulated in topogenous mires (McCabe, 1984). The two fining-upward successions near the base of the lower, fine-grained unit are interpreted as minor crevasse channel-fills.

The measured section in the Sterling(?) Formation along Johnson Creek is 38 m thick and includes a lower, 9-m-thick, poorly exposed, fine-grained interval and an upper, 29-m-thick, coarse-grained interval (fig. 2-2e). More coarse-grained material is exposed above the 38 m level but is inaccessible. The lower interval includes a chocolate-brown sandstone with black grains that is possibly volcanogenic. The upper, coarse-grained interval consists of clast-supported pebble conglomerate with subordinate pebbly sandstone. Bed boundaries are difficult to identify in the conglomeratic part where sandstone is lacking, as much of it likely comprises amalgamated beds. Low-angle foresets and large trough cross-beds are abundant in the pebbly sandstones and conglomerates (fig. 2-2f). Sandstones are quartzo-feldspathic and weakly cemented. The Sterling(?) Formation at this location dips moderately toward the west and is truncated by a horizontal erosion surface that separates it from horizontal beds of Quaternary(?) pebble and cobble conglomerate. The succession documented in this measured section records deposition in moderate-gradient, low- to moderate-sinuosity, gravelly streams characterized by relatively deep channels into which gravelly barforms migrated, and within which moderate- to large-scale, three-dimensional, gravelly dunes migrated downstream.

An outcrop along Lake Creek east of the Yenlo Hills, mapped by Reed and Nelson (1980) as the sandstone member of the Tyonek(?) Formation, stands out in sharp contrast to all other exposures of Tertiary strata in the basin studied by our group. Bedding dips steeply toward the west. The lower half of the exposure consists of interbedded pebble conglomerate, fine- to coarse-grained sandstone, and coal-bearing argillaceous mudstone consistent with Reed and Nelson's sandstone member; the upper half of the exposure consists of a thick succession of amalgamated clast-supported, cobble and boulder conglomerates with minor lenses of coarse- to very-coarse-grained pebbly sandstone. The contact between the two successions is sharp (fig. 2-2g). Clasts in the upper half of the exposure include a subequal amount of mafic/intermediate volcanics and granitoids, and minor lithic sandstone, argillite, and vein quartz. A small population of latest Miocene to Pliocene age detrital zircons place constraints on the maximum age of this succession (Bob Gillis, DGGS, unpublished data), which is likely younger than the Tyonek Formation in Cook Inlet basin. The lower, finer-grained succession is the product of dilute stream flow in a moderate- to high-sinuosity fluvial system, whereas the upper, conglomeratic succession records a steep alluvial gradient and consists of facies typically present in alluvial fan systems. Facies strongly suggest a nearby source for the cobble and boulder conglomerates, but mafic volcanic and granitoid clasts do not resemble lithologies recognized in nearby exposures of Mesozoic strata, such as the Yenlo Hills. More work is needed to understand the significance of this location.

Figure 2-1 (left). Generalized bedrock geology of the Susitna basin, showing locations discussed in this report. Numbered yellow stars mark locations of : 1. Conglomerate member of the Tyonek(?) Formation, Fairview Mountain; 2. Sandstone member of the Tyonek(?) Formation, Johnson Creek; 3. Sterling(?) Formation, Johnson Creek; 4. Sandstone member of the Tyonek(?) Formation, Lake Creek; 5. Graywacke of Yenlo Hills; 6. Kahiltna assemblage, northern Peters Hills; 7. Kahiltna assemblage, northern Dutch Hills; 8. Kahiltna assemblage, central Peters Hills; 9. Kahiltna assemblage, southern Dutch Hills. Black lines show faults. Red lines show anticlinal fold axes and red arrows show dip direction of fold limbs.

MESOZOIC ROCKS

Mesozoic sedimentary rocks of the Kahiltna assemblage were examined at five locations (fig. 2-1) in the Peters Hills (locations 6 and 8), Dutch Hills (locations 7 and 9), and Yenlo Hills (location 5). These rocks likely represent the foundation upon which much of the Cenozoic basin developed. Rocks at the latter location have been mapped as the graywacke of Yenlo Hills by Wilson and others (2012) and detrital zircon data suggest they are slightly older than the Kahiltna assemblage to the north (Hults and others, 2013). In the Peters and Dutch Hills argillite appears to be the dominant lithology in the Kahiltna, but the unit commonly includes thin-bedded, fine-grained sandstones and locally envelops multi-meter-thick packages of amalgamated thick-bedded, fine- to medium-grained sandstone (fig. 2-2h). Many of the thin-bedded sandstones appear massive or display subtle normal grading, but plane-parallel (horizontal) lamination is locally prominent. Most of the thick-bedded sandstone (bed thickness greater than a few decimeters) appears massive and some includes dark gray to black mudstone (argillite) rip-up clasts up to 10 cm long. An exposure in the southern Dutch Hills includes small, poorly preserved and carbonized plant fragments, and sole marks, including poorly developed (equivocal?) flute casts that demonstrate bedding at that location is overturned toward the north (fig. 2-1, location 9). Sandstones are lithic-rich, tightly cemented, and lack visible porosity. Features observed in thin- and thick-bedded sandstones are commonly attributed to low- and high-density turbidites, respectively (Lowe, 1982; Talling and others, 2012). Given the isolation of the exposures examined, it is not possible to place them with confidence in a depositional profile, but the features observed are consistent with deposition in base-of-slope or basin-floor positions. Sandstone is abundant in the Yenlo Hills outcrop visited (fig. 2-1, location 5) and most had massive textures, consistent with deposition from high-density, non-turbulent flows.
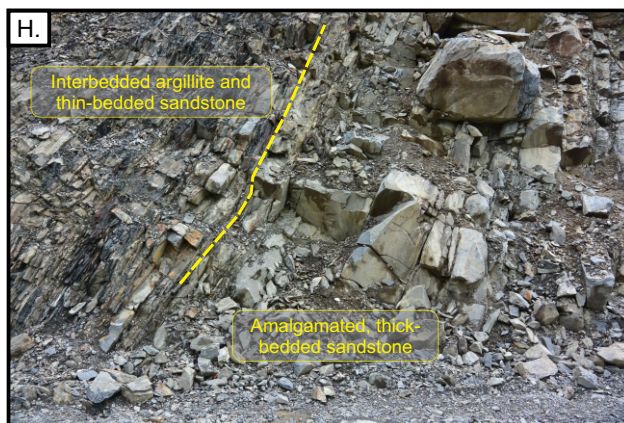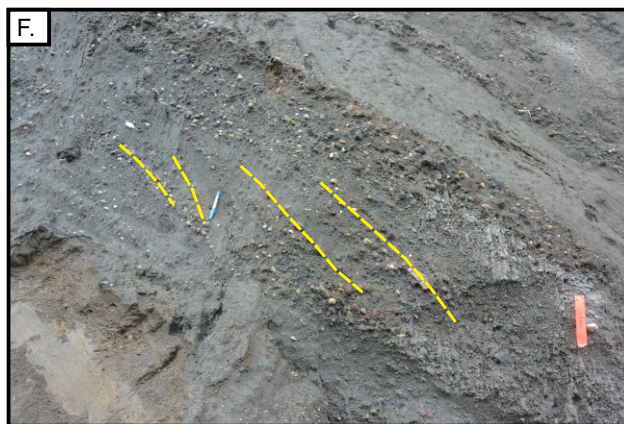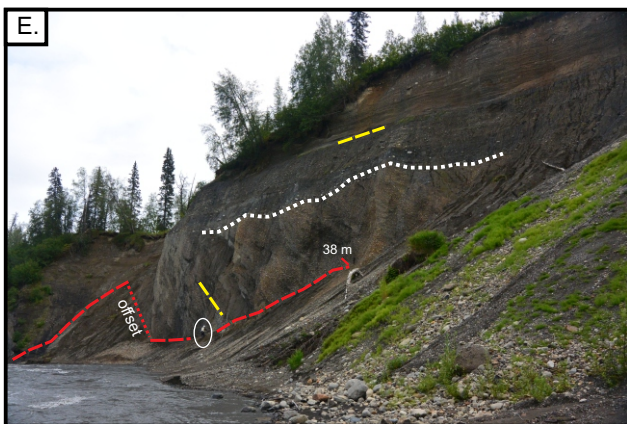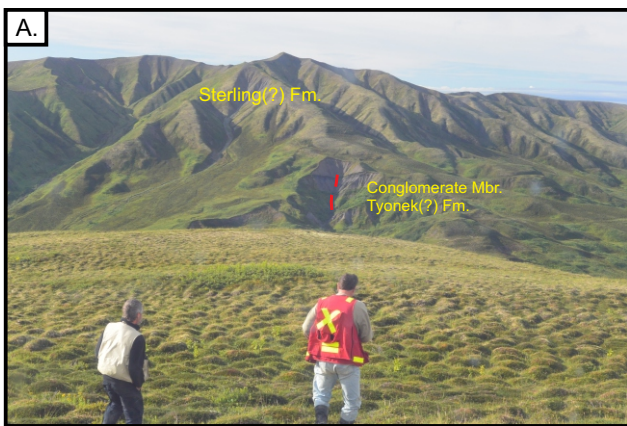
DISCUSSION

The quartzo-feldspathic composition of sandstones documented in Tertiary exposures is likely to have good reservoir potential in the subsurface if not too deeply buried. Common interbedded argillaceous mudrocks indicate that effective seal facies are present in the basin. Characteristics of Mesozoic strata examined in outcrop suggest they have poor reservoir potential (Helmold and LePain, 2015). More detailed reports summarizing our stratigraphic work, including analytical data on reservoir quality, coal quality and gas holding capacity of coals, and source rock potential of coals will be released in 2015.

AKNOWLEDGMENTS

Figure 2-2 (right). Selected photographs showing outcrops discussed in this report. **A.** View toward the east, across the saddle at the head of Cottonwood Creek, showing the coal-bearing conglomerate member of the Tyonek(?) Formation and overlying conglomerates of the Sterling(?) Formation at Fairview Mountain (location 1, fig. 2-1). Red dashed line shows location of measured stratigraphic section. **B.** Close-up view showing the erosional truncation of moderately dipping mudstone and sandstone at the base of a pebble conglomerate succession, conglomerate member, Tyonek(?) Formation, Fairview Mountain. White dotted line shows the contact between pebble conglomerate and sandstone; yellow dashed lines show bedding in sandstone **C.** Overbank mudstones, sandstones, and coal overlain by pebbly sandstone, sandstone member, Tyonek(?) Formation, Johnson Creek (location 2, fig. 2-1). View toward the southwest. **D.** Close-up view of pebbly sandstone succession, showing trough cross-bedding and pebble lags in the sandstone member, Tyonek(?) Formation, Johnson Creek. Yellow dashed line at right marks the base of a pebble lag and the yellow dashed line at left shows contact between sets of trough cross-bedding. Exposed part of trowel is 20 cm long. **E.** View toward the southeast, showing pebble and cobble conglomerates in the Sterling(?) Formation along Johnson Creek (location 3, fig. 2-1). Dashed red line shows approximate line of measured section. Interbedded mudstone, sandstone, and lignitic coal are visible near creek level at the left edge of the photograph. Top of measured section is marked by 38 m measurement. Nearly flat-lying unconformity surface (dotted white line) separates the Sterling(?) Formation from overlying Quaternary gravels. The yellow dashed lines show the orientation of bedding. Geologist in white oval for scale. **F.** Close-up view showing low-angle foreset stratification (yellow dashed lines) in pebbly sandstone in the Sterling(?) Formation along Johnson Creek. Red surveyor's flag is located 13 m above the base of our measured stratigraphic section. **G.** View toward the north showing the erosional contact (dotted white line) between the lower, sandstone–mudstone succession and upper, cobble–boulder conglomerate succession on Lake Creek (location 4, fig. 2-1). The sandstone bed immediately below the contact is approximately 5 m thick. **H.** View toward the north, showing the contact (yellow dashed line) between amalgamated, thick-bedded sandstones and interbedded argillites and thin-bedded sandstones in Kahiltna assemblage (location 8, fig. 2-1). See text for discussion and preliminary interpretation.

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