CHAPTER 3

PETROLOGY AND RESERVOIR QUALITY OF SANDSTONES FROM THE KAHILTNA ASSEMBLAGE AND YENLO HILLS GRAYWACKE: INITIAL IMPRESSIONS

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INTRODUCTION

The Division of Geological & Geophysical Surveys (DGGS) and Division of Oil & Gas (DOG) are currently conducting a study of the hydrocarbon potential of Alaska's frontier basins, including the natural gas potential of the greater Susitna basin (LePain and others, 2011). The Tertiary stratigraphic section of Susitna basin includes some of the same coal-bearing units that are prolific gas reservoirs in neighboring Cook Inlet basin and has large structures that could act as hydrocarbon traps. The present-day Susitna basin is a Cenozoic feature, but very little is known regarding the pre-Cenozoic stratigraphy beneath the basin. Based on regional studies to date, the Cretaceous strata surrounding the basin appear very different than in Cook Inlet basin (Hampton and others, 2007; Kalbas and others, 2007). As part of this project, two days were spent during the 2011 field season examining Susitna basin outcrops (at reconnaissance scale) of the Kahiltna assemblage and Yenlo Hills graywacke. Several samples from Yenlo Hills, Little Peters Hills, and Colorado Creek drainage were collected for petrographic analysis (fig. 3-1). During the 2014 field season, three additional days were spent revisiting the 2011 locations plus additional outcrops of the Kahiltna assemblage and Yenlo Hills graywacke. This report summarizes initial impressions of the petrology and reservoir quality of these units and incorporates modal analyses of thin sections from 17 of the samples collected in 2011 (table 3-1).

KAHILTNA ASSEMBLAGE

Based on modal analyses of six outcrop samples, Kahiltna sandstones in the Susitna basin area are largely quartzolithic with an average modal composition of $Q_{t83}F_4L_{13}$, $Q_{m6}F_4L_{t90}$, $Q_{m77}P_{18}K_5$, $Q_{p88}L_{vm1}L_{sm11}$ (figs. 3-2 and 3-4) and a plagioclase/feldspar (P/F) ratio of 0.56 (see table 3-2 for explanation of grain parameters). The average grain size is 0.32 mm (lower

Table 3-1. Samples of sandstones collected during the 2011 Susitna basin field season that are included in this report.

Sample Number	General Location	Specific Location	Latitude	Longitude	Unit
11DJM035A	Susitna basin	Little Peters Hills	N 62.31761	W 150.84175	Kahiltna assemblage
11DJM036B	Susitna basin	Little Peters Hills	N 62.30777	W 150.84300	Kahiltna assemblage
11DL008A	Susitna basin	Colorado Creek	N 63.30653	W 149.72969	Kahiltna assemblage
11DL008C	Susitna basin	Colorado Creek	N 63.30715	W 149.72787	Kahiltna assemblage
11DL008D	Susitna basin	Colorado Creek	N 63.30741	W 149.72209	Kahiltna assemblage
11DL008E	Susitna basin	Colorado Creek	N 63.30880	W 149.72160	Kahiltna assemblage
11DL001A	Susitna basin	Yenlo Hills	N 62.07430	W 151.25990	Yenlo Hills graywacke
11DL001B	Susitna basin	Yenlo Hills	N 62.07430	W 151.25990	Yenlo Hills graywacke
11DJM015A	Susitna basin	Yenlo Hills	N 62.13672	W 151.24072	Yenlo Hills graywacke
11DJM022A	Susitna basin	Yenlo Hills	N 62.13464	W 151.23534	Yenlo Hills graywacke
11DJM029A	Susitna basin	Yenlo Hills	N 62.14265	W 151.23117	Yenlo Hills graywacke
11DJM041B	Susitna basin	Yenlo Hills	N 62.12816	W 151.26662	Yenlo Hills graywacke
11DJM043B	Susitna basin	Yenlo Hills	N 62.12530	W 151.25369	Yenlo Hills graywacke
11DJM045B	Susitna basin	Yenlo Hills	N 62.12339	W 151.24704	Yenlo Hills graywacke
11DJM047B	Susitna basin	Yenlo Hills	N 62.11818	W 151.23755	Yenlo Hills graywacke
11DJM049B	Susitna basin	Yenlo Hills	N 62.11288	W 151.21432	Yenlo Hills graywacke
11DJM050B	Susitna basin	Yenlo Hills	N 62.13498	W 151.28378	Yenlo Hills graywacke

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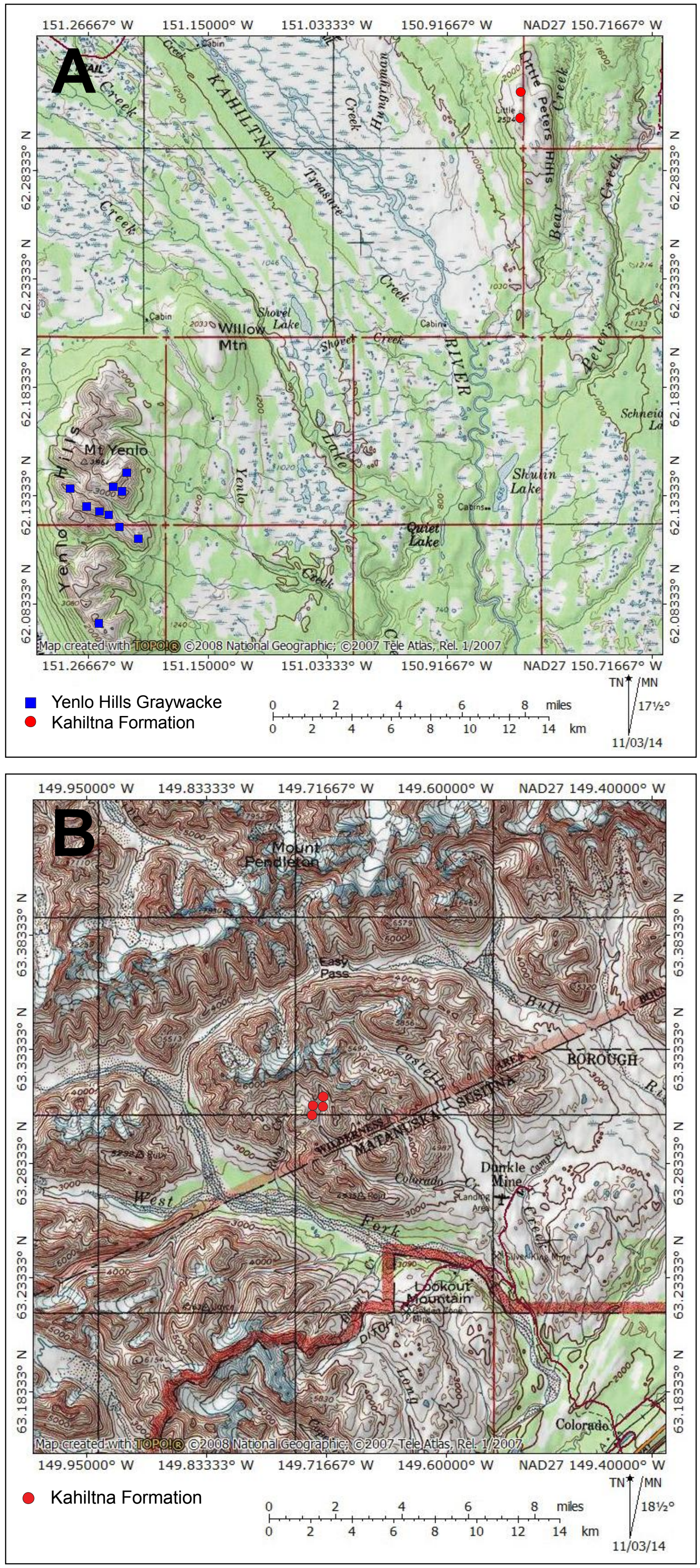

Figure 3-1. **A.** Topographic map, showing locations of Yenlo Hills graywacke samples collected from Yenlo Hills, and Kahiltna sandstones collected from Little Peters Hills. **B.** Topographic map, showing locations of Kahiltna sandstones collected from the Colorado Creek drainage northwest of Lookout Mountain.

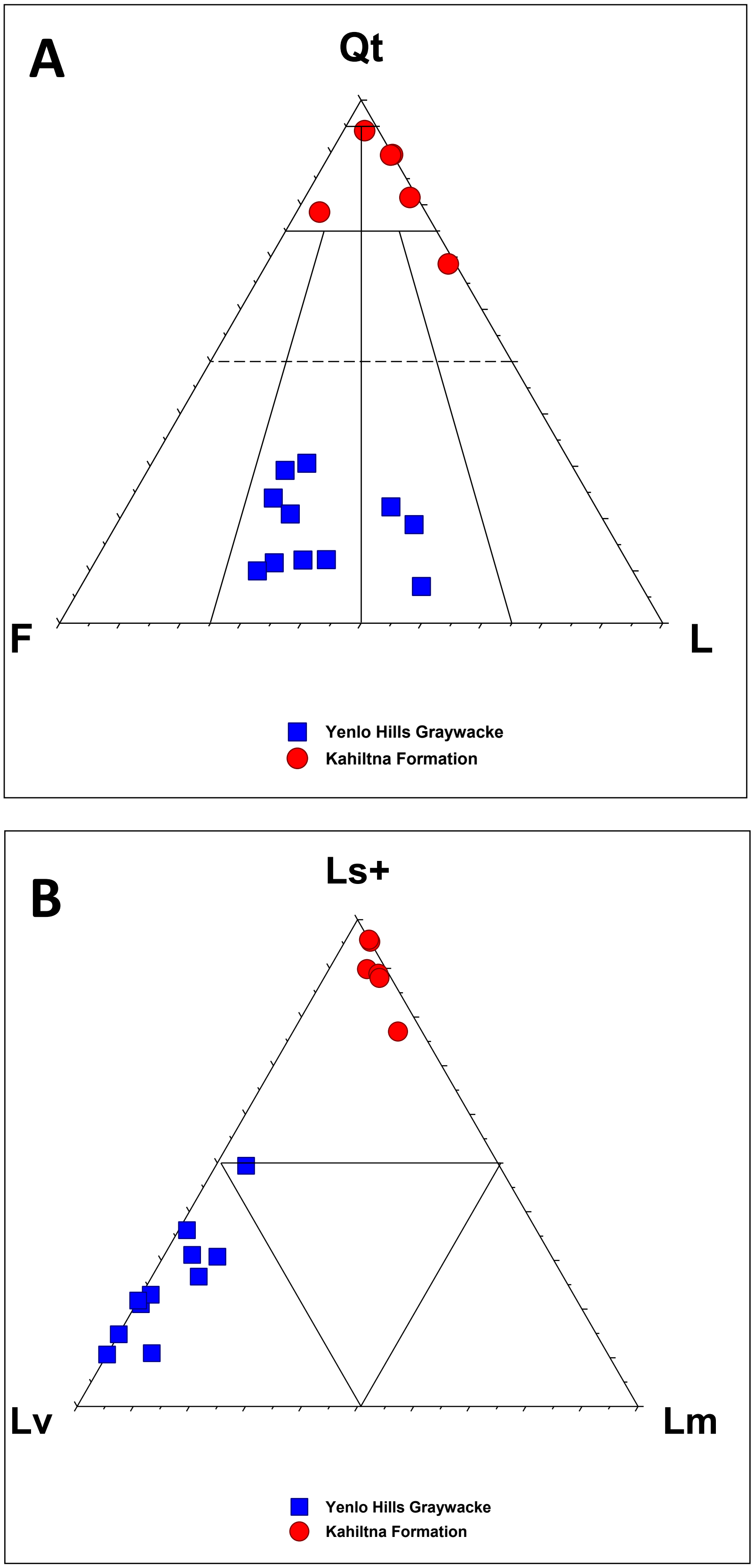

Figure 3-2. **A.** Ternary diagram of total quartz (Qt)–Feldspar (F)–Lithic grains (L), showing the composition of the entire population of grains. The Kahiltna sandstones are more quartzose (chert plotted with quartz) compared to the Yenlo Hills graywackes, which contain abundant plagioclase and VRFs. **B.** Ternary diagram of Sedimentary lithic grains including chert (Ls^{+})–Volcanic lithic grains (Lv)–Metamorphic lithic grains (Lm), showing the composition of just the polycrystalline grains. The Kahiltna sandstones are enriched in sedimentary detritus (including chert) compared to the Yenlo Hills graywacke, which contain significant volcanic material.

Table 3-2. Classification of Grain Parameters

A. Quartzose grains

Qm = Monocrystalline quartz
Qp = Polycrystalline quartz (including chert)
Qt = Total quartzose grains (Qm + Qp)

B. Feldspar grains

P = Plagioclase
K = Potassium feldspar
F = Total feldspar grains (P + K)

C. Lithic grains

Ls^+ = Sedimentary rock fragments (including chert)
Lv = Volcanic rock fragments
Lm = Metamorphic rock fragments
Lp = Plutonic rock fragments
Lsm = Sedimentary and metasedimentary rock fragments
Lvm = Volcanic and metavolcanic rock fragments
L = Lithic grains (Ls^+ + Lv + Lm + Lp)
Lt = Total lithic grains (L + Qp)

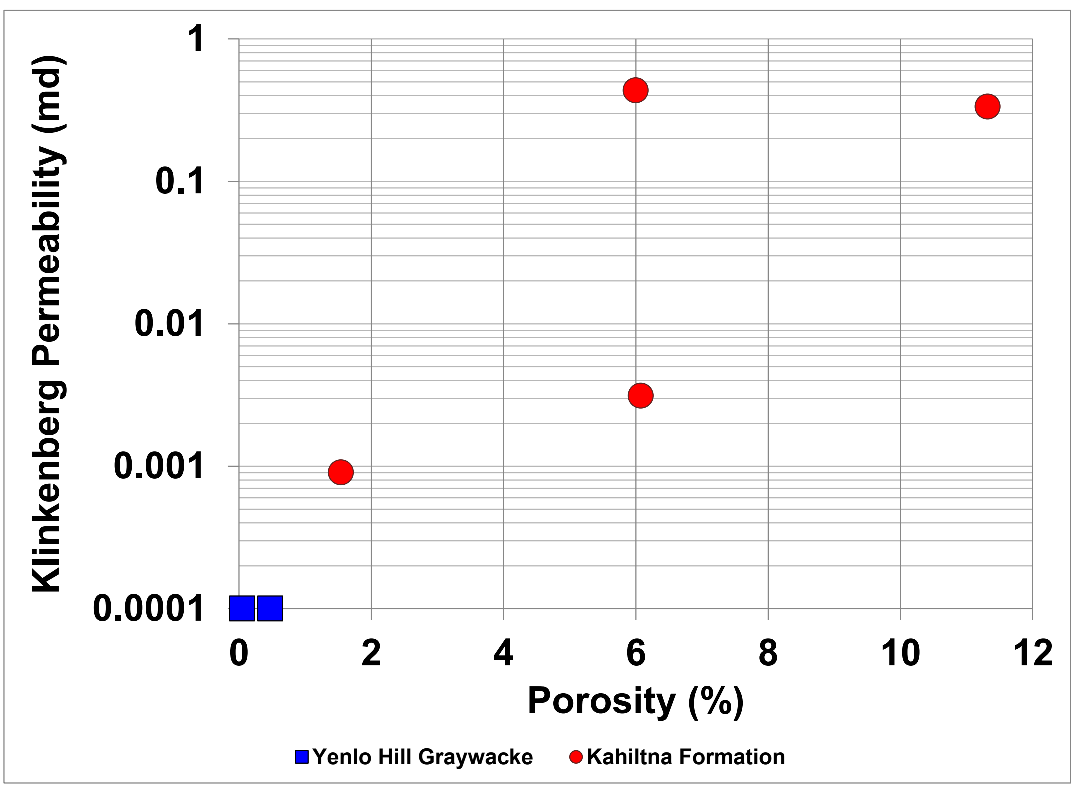

Figure 3-3. Porosity–permeability cross plot. Based on a limited dataset, the reservoir quality of the Kahiltna sandstones is fairly poor (porosity [φ] <12%, permeability [k] < 1 md) while that of the Yenlo Hills graywacke is very poor (φ <1%, k < 0.0001 md).

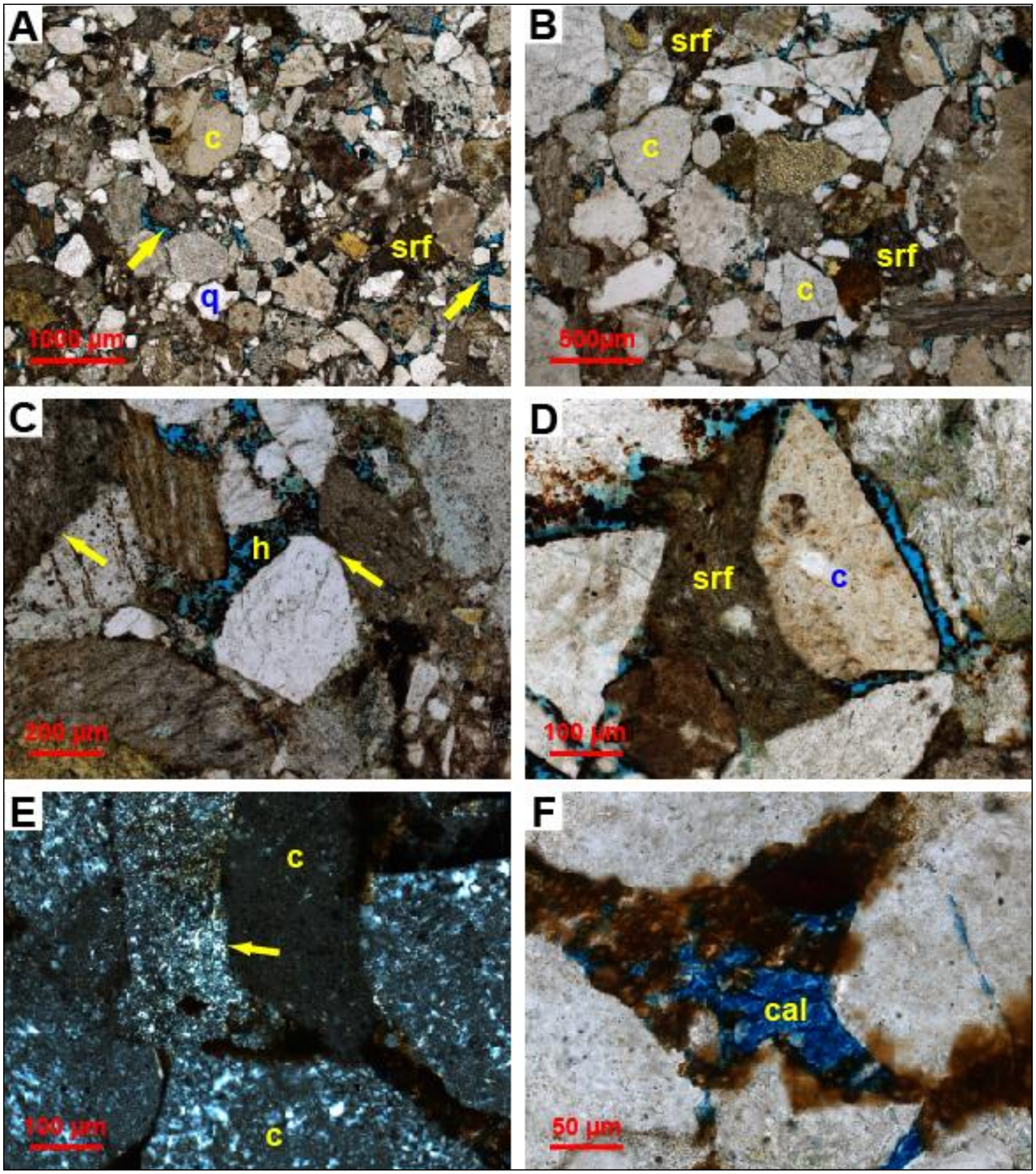

Figure 3-4. Photomicrographs of Kahiltna sandstones. **A.** Medium-grained (upper), moderately sorted sandstone consisting largely of quartz (q), chert (c), and argillaceous sedimentary rock fragments (srf). Minor remnant intergranular pores (arrows) are scattered throughout the rock. Sample 11DL008A; plane-polarized light. **B.** Chert (c) and argillaceous sedimentary rock fragments (srf) comprise the majority of the rock framework. Primary intergranular porosity is almost completely occluded by compaction and ductile grain deformation. Sample 11DL008A; plane-polarized light. **C.** Long and concavo–convex grain contacts (arrows) are evidence of significant compaction. Residual intergranular pores are lined and partially occluded by authigenic iron oxide cement (hematite?) (h). Sample 11DL008A; plane-polarized light. **D.** Mudstone rock fragment (srf) that has been ductilely deformed between more mechanically resistant chert grains (c). Sample 11DL008A; plane-polarized light. **E.** Several chert grains with typical "salt and pepper" extinction showing evidence of chemical compaction (arrows). Sample 11DL008A; crossed polarizers. **F.** Ferroan-calcite cement (cal) occluding remnant intergranular pore. Sample 11DL008C; plane-polarized light.

medium) with an average Folk sorting (Folk, 1974) of 1.19 (poor). The rock framework predominantly consists of chert (range 22–82 percent, average 55 percent; figs. 3-4B–3-4F) with lesser amounts of quartz (both polycrystalline [Q_p] and monocrystalline [Q_m]; range 6–59 percent, average 27 percent; fig. 3-4A). The average Q_p/Q ratio is 0.75, indicating the bulk of quartz is polycrystalline in character; the actual amount of monocrystalline quartz is fairly low, averaging only 6 percent (range 1–14 percent). Additional minor components include metamorphic rock fragments (average 6 percent), sedimentary rock fragments (average 4 percent), and plagioclase (average 3 percent). Accessory grains include plutonic and volcanic rock fragments, K-feldspar, and micas. The high ratio of chert to monocrystalline quartz and the presence of sedimentary and metamorphic rock fragments (mainly phyllite and schist) suggests the rocks were most likely derived from a recycled orogen provenance (Hampton and others, 2007; Kalbas and others, 2007; Hults and others, 2013). Although all the analyzed samples have a fairly similar detrital composition, differences were noted in their degree of deformation. Samples from the Colorado Creek area (fig. 3-1B) have a sedimentary texture little affected by metamorphism. In contrast, those from Little Peters Hills (fig. 3-1A) show a penetrative deformation most likely related to regional metamorphism.

Overall reservoir quality of the Kahiltna sandstones is generally poor with porosities less than 12 percent and permeabilities less than 1 millidarcy (md). (fig. 3-3). Primary depositional porosity has been reduced mainly by mechanical compaction, as indicated by a fairly low average intergranular volume (IGV) of 14 percent. Remnant primary intergranular porosity is evident in some samples (figs. 3-4C, D) while in others it has been occluded by late-stage ferroan calcite cement (fig. 3-4F). Many of the intergranular pores are lined by small crystals (<10 µm) of authigenic iron-oxide, probably hematite, of uncertain origin (figs. 3-4C, D, F). They may be replacing or masking early-formed, authigenic, pore-lining ferruginous clays, such as chlorite or mixed-layer chlorite/smectite, and may be solely a product of outcrop weathering. The presence of concavo–convex contacts between chert grains (fig. 3-4E) suggests that chemical compaction (pressure solution) likely contributed to porosity destruction, particularly in samples from Colorado Creek that have seen minimal regional metamorphism.

YENLO HILLS GRAYWACKE

Based on modal analyses of 11 outcrop samples, Yenlo Hills graywacke in Susitna basin are largely feldspatholithic with an average modal composition of $Q_{t18}F_{48}L_{34}$, $Q_{m8}F_{47}L_{t45}$, $Q_{m14}P_{84}K_{2}$, $Q_{p24}L_{vm66}L_{sm10}$ (figs. 3-2 and 3-5) and a P/F ratio of 0.98. The average grain size is 0.10 mm (upper very-fine) with an average Folk sorting of 2.60 (very poor; figs. 3-5A, B). The rock framework predominantly consists of plagioclase (range 26–48 percent, average 38 percent; figs. 3-5B, C) and volcanic rock fragments (VRFs; range 15–42 percent, average 23 percent; figs. 3-5B, D). Additional components include monocrystalline quartz (average 6 percent), polycrystalline quartz (average 3 percent), chert (average 6 percent), and heavy minerals (average 8 percent). Accessory grains include sedimentary and plutonic rock fragments, micas, and K-feldspar. Conspicuous among the sedimentary rock fragments are grains of detrital carbonate composed of 5–20 µm-sized calcite crystals (fig. 3-5E); little micrite was seen in the few samples analyzed. Matrix consisting largely of detrital clay is a significant component in most samples (range 5–39 percent, average 19 percent) and effectively occludes remnant intergranular pores. It is suspected that much of this clay has been recrystallized, resulting in a mixture of detrital and regenerated clays (fig. 3-5F). The prevalence of plagioclase and VRFs, along with the dearth of K-feldspar, suggests the sandstones were derived from an undissected volcanic arc terrane. The most likely provenance is volcanic flows, ignimbrites, and tuffs of the Jurassic magmatic arc (Reed and Lanphere, 1973; Reed and Nelson, 1980; Hults and others, 2013; Karl and others, 2013; Karl and others, 2015).

The labile nature of the detrital mineralogy results in a rock framework that is highly susceptible to diagenetic alteration. In general, plagioclase is chemically unstable in the diagenetic environment, while VRFs are both chemically and mechanically unstable. Notably, authigenic cements are not a major component of the graywackes; the bulk of porosity loss is the result of mechanical compaction and clay matrix. Plagioclase is typically altered to albite and sericite but no obvious zeolites were observed, possibly because the extensive matrix limited isochemical diagenesis. Based on two analyzed samples, reservoir quality of the Yenlo Hills graywacke is very poor, with porosities less than 1 percent and permeabilities less than 0.0001 md (fig. 3-3).

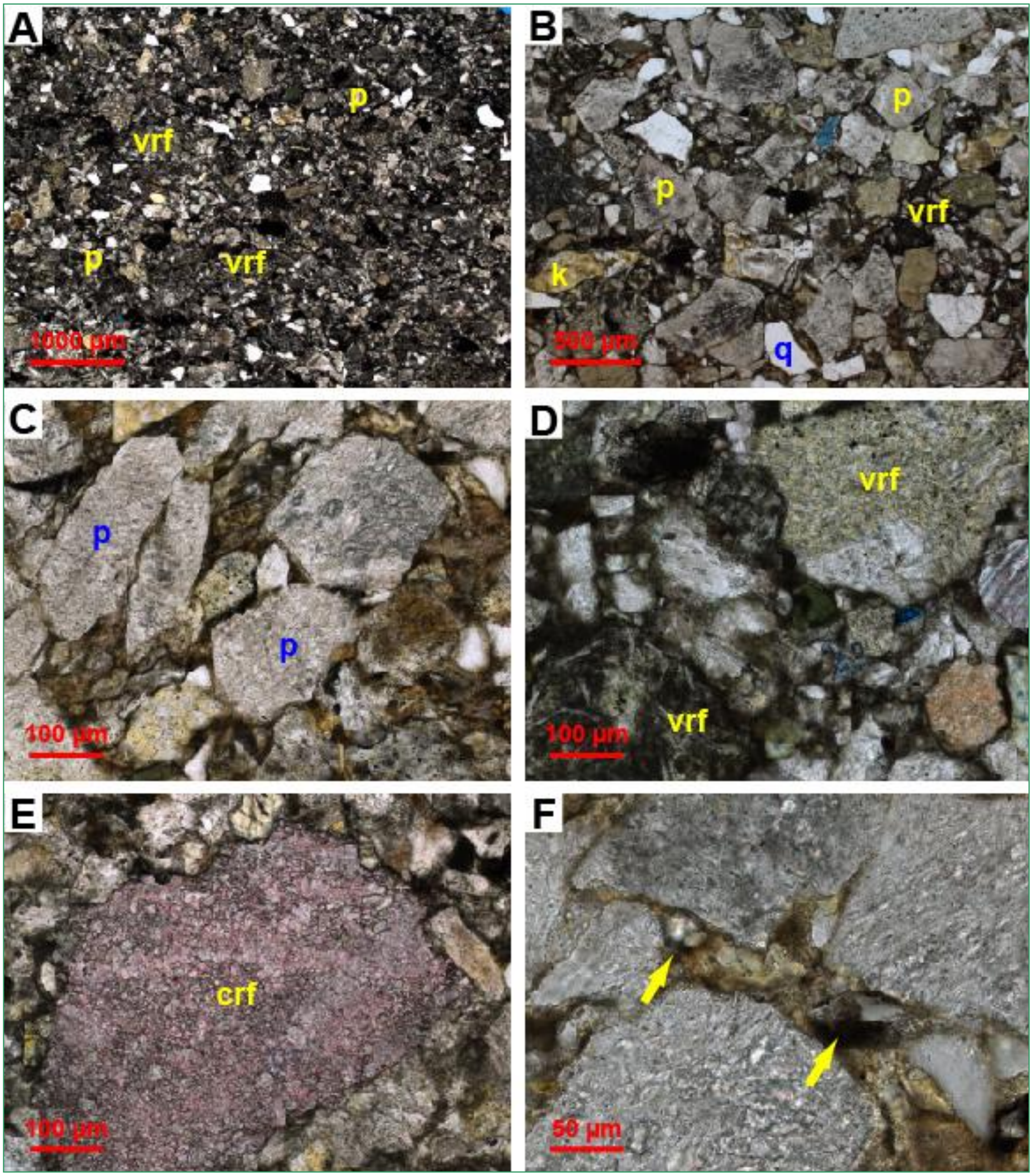

Figure 3-5. Photomicrographs of Yenlo Hills graywacke. **A.** Fine-grained (upper), moderately-sorted sandstone consisting largely of plagioclase (p) and volcanic rock fragments (vrf). The primary pore system has been almost completely destroyed by substantial mechanical compaction. Sample 11DL001A; plane-polarized light. **B.** Sandstone consisting largely of subhedral to euhedral plagioclase (p), with minor quartz (q), K-feldspar (k), and volcanic rock fragments (vrf). Porosity reduction has been accomplished mainly by compaction. Sample 11DJM022A; plane-polarized light. **C.** The brownish color and murky nature of the plagioclase (p) indicates it has been highly altered, mainly through albitization and sericitization. Sample 11DJM015A; plane-polarized light. **D.** Intermediate to mafic volcanic rock fragments (vrf) consisting largely of plagioclase microlites. Sample 11DJM029A; plane-polarized light. E. Oversized carbonate rock fragments (crf, pink stain) are a minor, but conspicuous, component of many of the sandstones. Sample 11DL001B; plane-polarized light. **F.** A combination of detrital matrix and authigenic/recrystallized clay filling intergranular pores between altered plagioclase. Sample 11DJM015A; plane-polarized light.

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