CHAPTER 7

PETROLOGY AND RESERVOIR QUALITY OF THE GAIKEMA SANDSTONE: INITIAL IMPRESSIONS

Kenneth P. Helmold[1] and Richard G. Stanley[2]

INTRODUCTION

The Division of Geological & Geophysical Surveys (DGGS) and Division of Oil & Gas (DOG) are currently conducting a study of the hydrocarbon potential of Cook Inlet basin (LePain and others, 2011). The Tertiary stratigraphic section of the basin includes coal-bearing units that are prolific gas reservoirs, particularly the Neogene sandstones. The Paleogene sandstones are locally prolific oil reservoirs that are sourced largely from the underlying Middle Jurassic Tuxedni Group. Several large structures act as hydrocarbon traps and the possibility exists for stratigraphic traps although this potential has not been fully exploited. As part of this study a significant number of Tertiary sandstones from the basin have been already collected and analyzed (Helmold and others, 2013). Recent field programs have shifted attention to the Mesozoic stratigraphic section to ascertain whether it contains potential hydrocarbon reservoirs. During the 2013 Cook Inlet field season, two days were spent on the Iniskin Peninsula examining outcrops of the Middle Jurassic Gaikema Sandstone along the south shore of Chinitna Bay (fig. 7-1). A stratigraphic section approximately 34 m in thickness was measured and a detailed description was initiated (Stanley and others, 2015), but due to deteriorating weather it was not possible to complete the description. During the 2014 field season two additional days were spent completing work on the Gaikema section. Analyses of thin sections from six of the samples collected in 2013 are available for incorporation in this report (table 7-1). Data from samples collected during the 2014 field season will be included in future reports.

Table 7-1. Samples of Gaikema Sandstone collected during the 2013 Cook Inlet field season that are included in this report.

Sample Number	General Location	Specific Location	Latitude	Longitude	Unit
13A017-006.0A	Iniskin Peninsula	South shore Chinitna Bay	N 59.81702	W 153.16617	Gaikema
13A017-006.15A	Iniskin Peninsula	South shore Chinitna Bay	N 59.81702	W 153.16617	Gaikema
13A017-006.8A	Iniskin Peninsula	South shore Chinitna Bay	N 59.81702	W 153.16617	Gaikema
13A017-008.2A	Iniskin Peninsula	South shore Chinitna Bay	N 59.81702	W 153.16617	Gaikema
13A017-008.3A	Iniskin Peninsula	South shore Chinitna Bay	N 59.81702	W 153.16617	Gaikema
13A017-012.7A	Iniskin Peninsula	South shore Chinitna Bay	N 59.81702	W 153.16617	Gaikema

FRAMEWORK MINERALOGY AND PROVENANCE

Petrographic analyses indicate that Gaikema sandstones on the Iniskin Peninsula are largely feldspatholithic with an average modal composition of $Qt_{33}F_{34}L_{33}$, $Qm_{11}F_{33}Lt_{56}$, $Qm_{25}P_{73}K_{2}$, $Qp_{41}Lvm_{52}Lsm_{7}$ (figs. 7-2 and 7-3) and a plagioclase/feldspar (P/F) ratio of 0.97 (see table 7-2 for explanation of grain parameters). The average grain size is 0.09 mm (upper very-fine) with an average Folk sorting of 0.52 (moderate). The rock framework consists predominantly of plagioclase (range 30–50 percent, average 21 percent) and volcanic rock fragments (VRFs; range 26–43 percent, average 15 percent). Additional components include monocrystalline quartz (average 10 percent), polycrystalline quartz (average 9 percent), chert (average 11 percent), sedimentary rock fragments (SRFs, average 3 percent), and heavy minerals (average 3 percent). Accessory grains include plutonic rock fragments (PRFs), K-feldspar, and micas. One sample (13A13-12.7A) is distinctive in that it consists almost exclusively of euhedral to subhedral plagioclase crystals, with virtually no detrital quartz or other lithic grains. It remains to be determined if this variability in detrital mineralogy is related to differences in depositional environment.

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 that comprise the Lower Jurassic Talkeetna Formation that underlies the Tuxedni Group (Bull, 2014; Bull, 2015). The source terrane was probably a region of uplifted Talkeetna Formation west of the Bruin Bay fault (Detterman and Hartsock, 1966).

[1]Alaska Division of Oil & Gas, 550 W. 7th Avenue, Suite 800, Anchorage, AK 99501-3560; ken.helmold@alaska.gov
[2] U.S. Geological Survey, 345 Middlefield Road, Mail Stop 969, Menlo Park CA 94025-3561

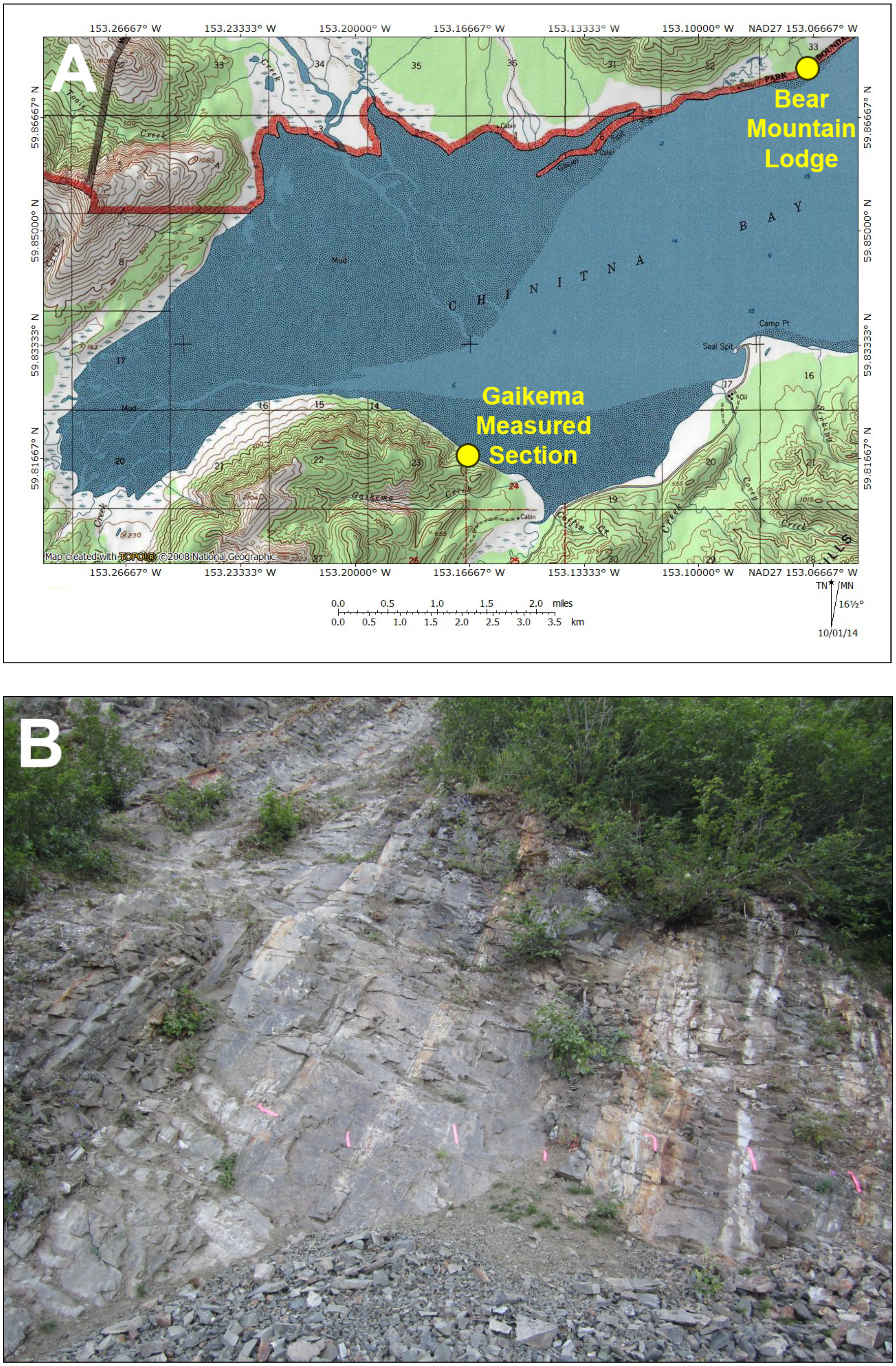

Figure 7-1. **A.** Topographic map showing location of measured section of Gaikema sandstone along the northern shore of Chinitna Bay on the Iniskin Peninsula. **B.** Measured section of Gaikema sandstone consists largely of very-fine- to fine-grained sandstone and siltstone. Distance between flags represents a stratigraphic thickness of 1 m.

Table 7-2. 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)

RESERVOIR QUALITY

The combination of abundant plagioclase and VRFs results in a labile framework mineralogy that is highly susceptible to diagenetic alteration. Authigenic chlorite and/or mixed-layer chlorite/smectite is the dominant cement in the majority of samples. Laumontite is a significant cement in a few samples, where it occurs as a replacement of detrital plagioclase grains and as intergranular cement that occludes primary porosity. Due to the high VRF content, heulandite is anticipated to be a common cement in Gaikema sandstones, although it has not been observed in the few samples analyzed to date. The combination of authigenic clay and zeolite occludes virtually all primary porosity, resulting in overall poor reservoir quality with porosities typically less than 8 percent and permeabilities less than 1 millidarcy (md) (figs. 7-3 and 7-4). The two samples with the lowest permeabilities (<0.1 md) contain significant laumontite cement. Based on this limited dataset, it appears laumontite has a greater impact on permeability than porosity. Because of the extensive cementation, Gaikema sandstones on the Iniskin Peninsula probably have minimal potential as conventional reservoirs. However, due to the extensive authigenic clay cement, the Gaikema in this area could have potential for tight-gas reservoirs. The superposition of tight Gaikema sandstones and potential source rocks of the underlying Red Glacier Formation (LePain and Stanley, 2015)

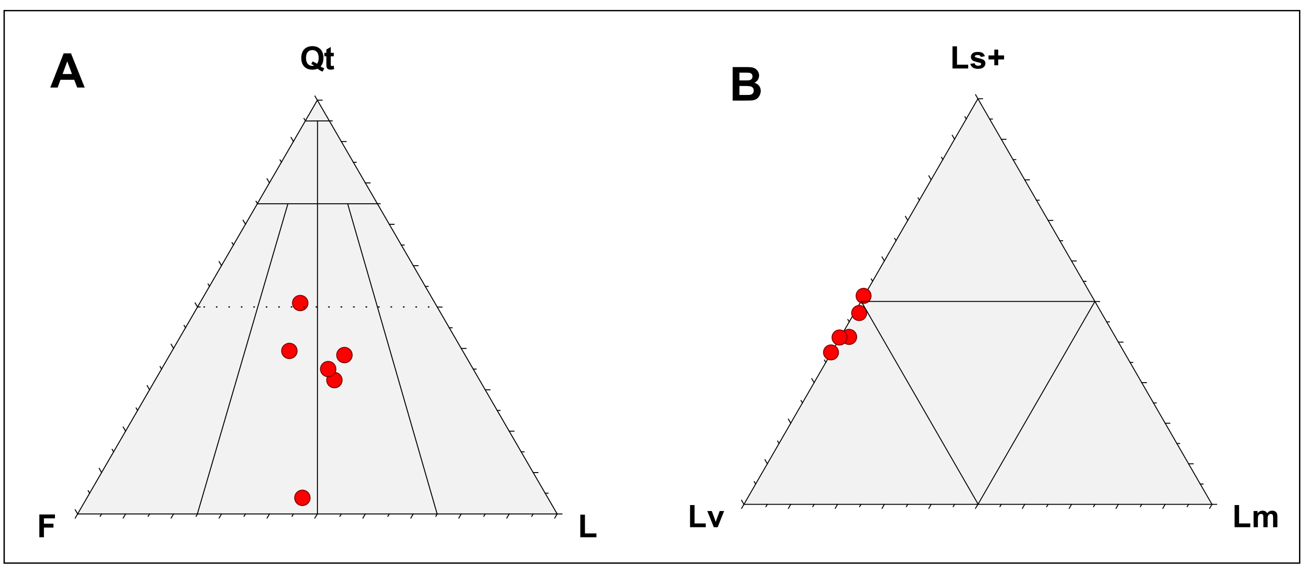

Figure 7-2. **A.** QtFL ternary diagram of total quartz (Qt), feldspar (F), and lithic grains (L), showing the feldspatholithic nature (<50% total quartz) of the Gaikema sandstones. **B.** Ls+LvLm ternary diagram of sedimentary lithic grains including chert (Ls^+), volcanic lithic grains (Lv), and metamorphic lithic grains (Lm), showing that the lithic population consists almost exclusively of VRFs and chert.

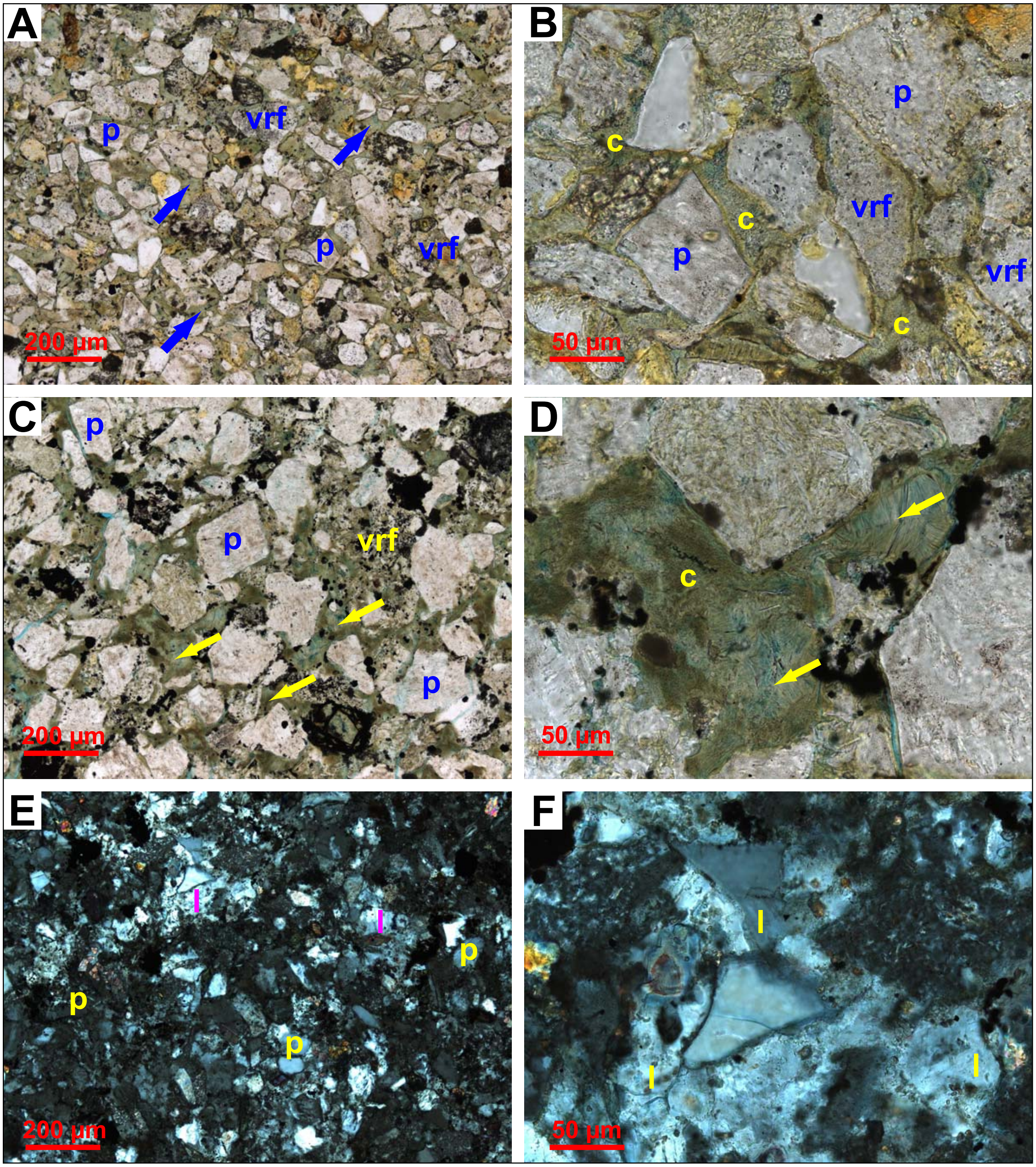

Figure 7-3. Photomicrographs of Gaikema sandstones from the measured section. **A.** Very-fine-grained (upper), well-sorted sandstone consisting largely of plagioclase (p) and volcanic rock fragments (vrf). Primary intergranular porosity is almost completely occluded by authigenic clay (arrows). Sample 13A17-6.0A; plane-polarized light. **B.** Plagioclase (p) and VRFs (vrf) comprise the majority of the rock framework. Intergranular pores are totally occluded by authigenic clay cement (c). Sample 13A17-6.0A; plane-polarized light. **C.** Fine-grained (lower), moderately-sorted sandstone consisting largely of euhedral to subhedral plagioclase crystals (p) and VRFs (vrf), with virtually no detrital quartz. Primary intergranular porosity is almost completely occluded by authigenic clay (arrows). Sample 13A17-12.7A; plane-polarized light. **D.** Authigenic chlorite (c) with well-developed medial sutures (arrows) filling large intergranular pore. Sample 13A17-12.7A; plane-polarized light. **E.** Very-fine-grained (upper), well-sorted sandstone consisting largely of plagioclase (p). Laumontite cement (l) has patchy distribution throughout the rock. Sample 13A17-8.3A; crossed polarizers. **F.** Laumontite cement (l) replacing detrital plagioclase and filling intergranular pores. Sample 13A17-8.3A; crossed polarizers.

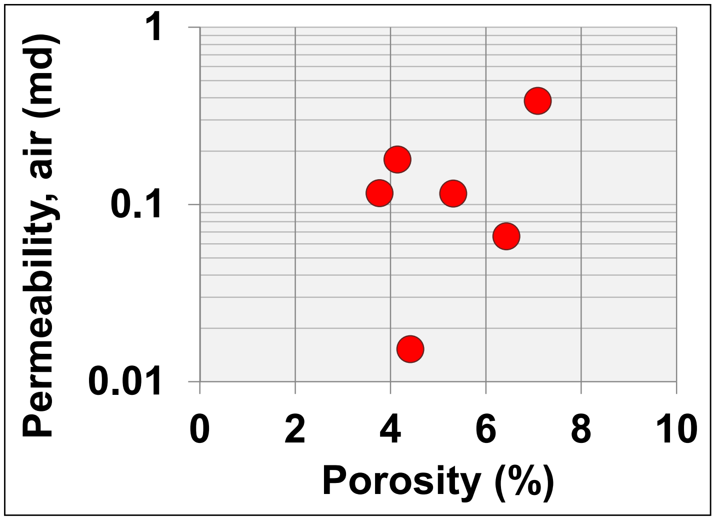

Figure 7-4. Porosity–permeability cross plot shows the relatively poor reservoir quality (φ <8 percent, k <1 md) of Gaikema sandstones from the measured section.

also suggest the alluring possibility of continuous oil accumulations in the Tuxedni Group, perhaps analogous to those in the Late Devonian and Early Mississippian Bakken Formation of North Dakota (Nordeng, 2009). Additional analyses from a larger geographic area are needed before making sweeping conclusions regarding the regional reservoir potential of the Gaikema Sandstone.

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