

## CHAPTER 1

# INTRODUCTION TO PETROLEUM-RELATED GEOLOGIC STUDIES IN LOWER COOK INLET DURING 2015, INISKIN–TUXEDNI REGION, SOUTH-CENTRAL ALASKA

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## INTRODUCTION

Lower Cook Inlet of south-central Alaska has long been recognized to host oil and gas, with hydrocarbon seeps noted on the Iniskin Peninsula as early as the mid-nineteenth century (Martin, 1905) (fig. 1-1). Drilling near these seeps commenced in 1900; continued exploration through 1960 also examined nearby structural culminations (Detterman and Hartsock, 1966). Although no commercial discoveries were made despite oil and gas shows in these wells (Blasko, 1976), the Iniskin–Tuxedni bays region remains important, permitting examination of the basin margin’s Mesozoic stratigraphy and structure along an ~80 km outcrop belt (figs. 1-2 and 1-3). These exposures include Middle Jurassic strata that are age-equivalent to probable source rocks for oil produced from fields in upper Cook Inlet (see LePain and others, 2013). Furthermore, this onshore area is important to understanding the potential for commercial accumulations of hydrocarbons in Mesozoic strata of Cook Inlet. Notably, a recent resource estimate indicates significant oil and gas volumes remain likely to be discovered in Cook Inlet (Stanley and others, 2011), and industry-led exploration on the Iniskin Peninsula resumed in 2013 (Nelson, 2014).

Within this context, the Alaska Division of Geological & Geophysical Surveys (DGGs), in collaboration with the Alaska Division of Oil and Gas and U.S. Geological Survey, initiated a lower Cook Inlet research program in 2009. This work aims to further delineate the geology of this economically important region and is ongoing in continued recognition of the critical energy needs of south-central Alaska and the fact that the Cook Inlet forearc basin is underexplored despite a nearly 60 year oil and gas production history. The DGGs-led field investigations in the Iniskin–Tuxedni area build on the seminal study of Detterman and Hartsock (1966) and focus on modern sedimentologic, stratigraphic, and structural analyses, as well as new 1:63,360-scale geologic mapping (see below), to better characterize petroleum potential.

This volume constitutes the fourth annual publication of a collection of short papers regarding our work in lower Cook Inlet (Gillis, 2013, 2014; Wartes, 2015b). Additional standalone papers have also been released recently, including a noteworthy overview of Cook Inlet geology by LePain and others (2013) that incorporates original data from DGGs-led studies conducted throughout Cook Inlet since 2006.

## GEOLOGIC MAPPING CAMPAIGNS

Detailed geologic mapping is an integral component of the Iniskin–Tuxedni bays field investigations. Two major mapping campaigns—funded in part by federal STATEMAP grants—were completed during the 2013 (Gillis and others, 2014; Herriott and Wartes, 2014) and 2015 field seasons (for example, Gillis, 2016 [this volume]; Wartes and others, 2016 [this volume]). During 2015 the field crew mapped the geology between Chinitna Bay and the Johnson River (fig. 1-1), including magmatic arc rocks northwest of the Bruin Bay fault system (see fig. 1-2) and extending to the Cook Inlet coast. This map area lies immediately northeast of the Iniskin Peninsula, which was mapped in 2013 (see references above). An important aspect of our lower Cook Inlet work is the recognition of along-strike changes in the stratigraphy and structure and the implications of these changes for depositional systems and deformation along the basin margin through time and space; geologic mapping serves as the cornerstone for documenting these trends in the geology and provides the framework for detailed analyses of the sedimentology, stratigraphy, and structural geology of the Iniskin–Tuxedni area. This information yields insights into basin evolution and petroleum systems.

## VOLUME OVERVIEW

Nine topical chapters (2–10) follow this introduction, and address studies carried out during the 2015 field season. Six of these chapters (2–7) report on sedimentologic and stratigraphic investigations and are organized in ascending stratigraphic order (see fig. 1-3 for reference). The final three chapters (8–10) examine the deformational history of the Iniskin–Tuxedni region. Brief context for each chapter is presented below.

- **Chapter 2:** LePain and others (2016a [this volume]) document nonmarine facies in the Horn Mountain Tuff Member of the Lower Jurassic Talkeetna Formation and present a depositional environment interpretation for a 45-m-thick

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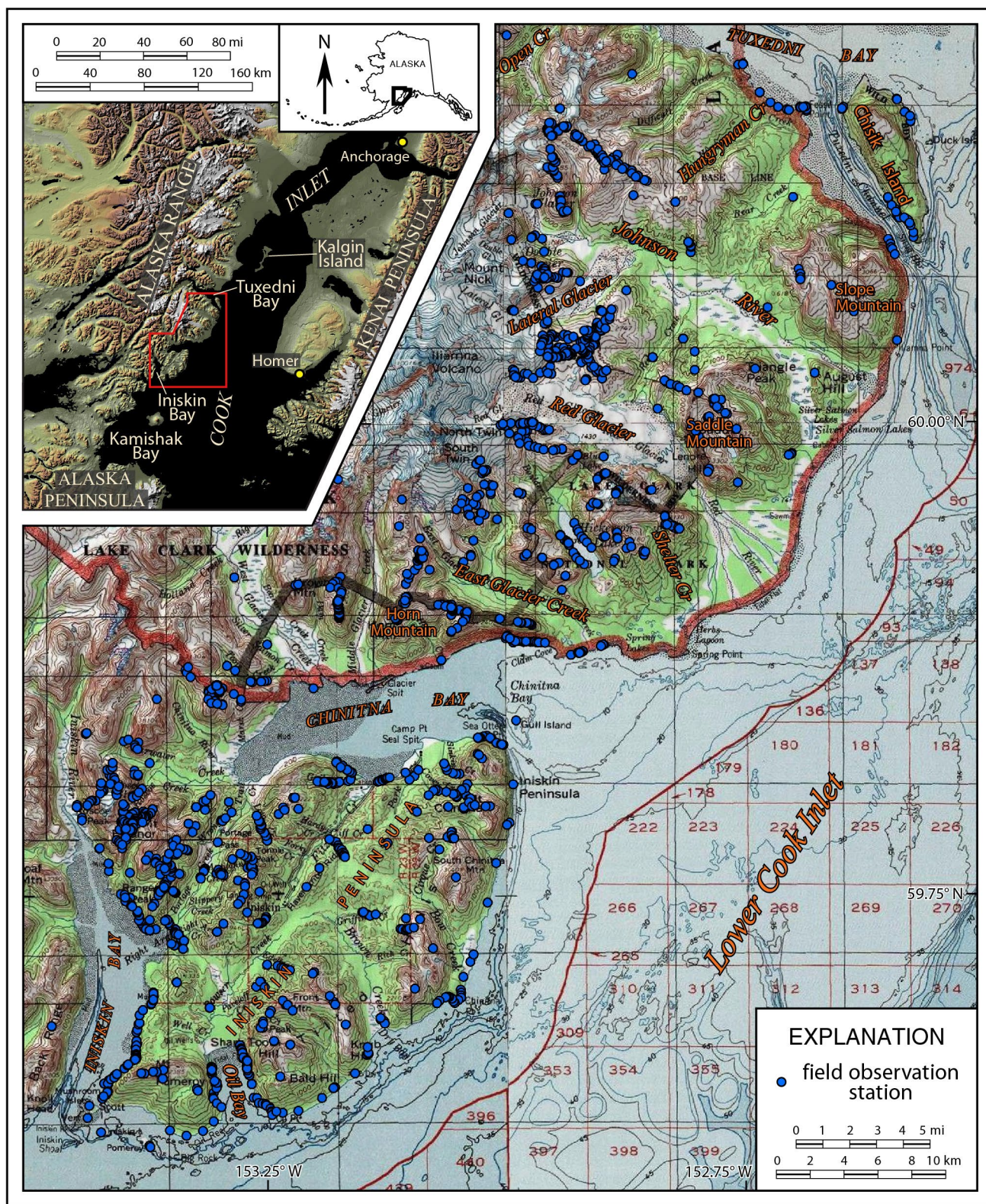


Figure 1-1. Location map for lower Cook Inlet—broadly defined as the forearc region that lies between Kalgin Island and Kamishak Bay (Fisher and Magoon, 1978; LePain and others, 2013)—and the Iniskin–Tuxedni bays study area. Geologic observations were made at ~2,000 field localities by Alaska Department of Natural Resources and U.S. Geological Survey geologists as part of the lower Cook Inlet program during six field seasons in this area. This volume reports on 2015 field studies chiefly focused on the region between Chinitna and Tuxedni bays. Detailed (1:63,360-scale) geologic mapping between Chinitna Bay and the Johnson River was also completed during 2015, building on DGGs-led mapping of the Iniskin Peninsula in 2013. Geographic place names referred to in this chapter are labeled in orange text with black outline. Topographic base map from portions of U.S. Geological Survey Iliamna, Seldovia, Lake Clark, and Kenai 1:250,000-scale quadrangles; shaded-relief image modified after U.S. Geological Survey Elevation Data Set Shaded Relief of Alaska poster (available for download at <http://eros.usgs.gov/alaska-0>). Abbreviation: Cr = Creek.



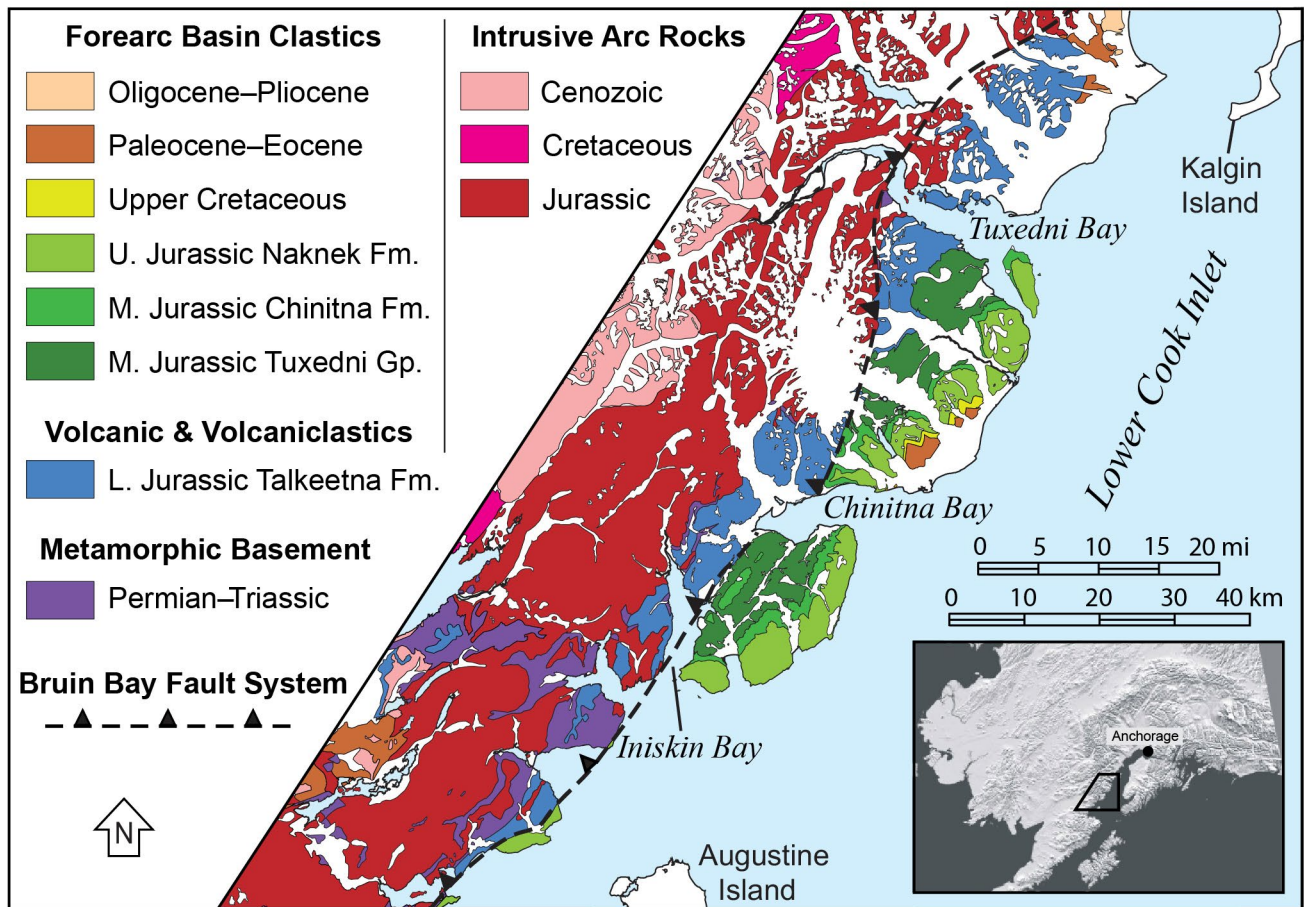


Figure 1-2. Simplified geologic map of lower Cook Inlet. The Bruin Bay fault system in this region is generally regarded as the northwestern margin of the forearc basin, with Middle Jurassic and younger forearc basin strata lying to the southeast and Lower Jurassic and younger arc rocks dominantly to the northwest (see LePain and others, 2013). Figure from Wartes (2015a); geologic mapping modified from regional compilation by Wilson and others (2009; see also Wilson and others, 2012). Abbreviations: Fm. = Formation; Gp. = Group; L. = Lower; M. = Middle; U. = Upper.

interval near Horn Mountain (fig. 1-1). This work provides a better understanding of depositional systems in the Talkeetna Formation as well as additional details regarding local paleogeographic constraints for this early manifestation of the magmatic arc.

- **Chapter 3:** LePain and others (2016b [this volume]) continue an investigation of the Middle Jurassic Red Glacier Formation (see also Stanley and others, 2013; LePain and Stanley, 2015), a stratigraphic unit that is correlative to source rocks for Cook Inlet's oil (see references above). This paper presents a sedimentologic analysis for the lower several hundred meters of the formation south of Hungryman Creek (fig. 1-1). The authors' interpreted depositional setting for this locality contrasts sharply with the Lateral Glacier (fig. 1-1) locality of LePain and Stanley (2015), suggesting along-basin-margin changes in paleo-water depth and depositional setting recorded by this economically significant formation.
- **Chapter 4:** Helmold and others (2016 [this volume]), in a companion study to chapter 3, present preliminary observations and interpretations of petrology and reservoir quality for sandstones in the Red Glacier Formation at the Hungryman Creek (fig. 1-1) locality. Despite the age and volcanogenic composition of these strata, the authors note that comparable facies in the subsurface may serve as tight-gas reservoirs. Furthermore, interfingering of lithologically similar sandstones with oil-prone source rocks could yield continuous oil accumulations in the subsurface.
- **Chapter 5:** Herriott and others (2016a [this volume]) analyze the stratigraphic architecture of the Middle Jurassic Paveloff Siltstone Member (Chinitna Formation) in the Johnson River area, between Slope and Saddle mountains (fig. 1-1). This paper documents sand-prone, channelized depositional systems that likely exported coarse detritus to downdip settings, where such deposits may host oil accumulations in the subsurface of Cook Inlet. Similar sand-rich facies in the Paveloff are oil stained in outcrop at Chinitna Bay (Wartes and Herriott, 2015).

- **Chapter 6:** Herriott and others (2016b [this volume]) continue to examine the stratigraphy of deep-water deposits in the Upper Jurassic Snug Harbor Siltstone and Pomeroy Arkose Members (Naknek Formation) (see also Wartes and others, 2013a; Herriott and Wartes, 2014; Herriott and others, 2015a). This chapter documents a newly discovered paleo-canyon at Chisik Island (fig. 1-1), with implications for bypass and accumulation of sand in deep-water settings as well as the sequence stratigraphic framework of the Naknek Formation (see also Herriott and others, 2015b). Similar deep-water depositional systems known throughout the world are important reservoirs for oil and gas.
- **Chapter 7:** Gillis (2016 [this volume]) documents porosity-hosted residual oil in sandstone of the Shelter Creek area (fig. 1-1). This outcrop lies in a Campanian to Maastrichtian(?) interval that is likely equivalent to Upper Cretaceous strata that are oil stained in outcrop elsewhere in Cook Inlet (for example, LePain and others, 2012; Wartes and others,

CENO-ZOIC	Paleogene		West Foreland Formation (Twf)
MESOZOIC	Upper Cretaceous		Maastrichtian strata (Kms)
	Upper Jurassic	Naknek Formation (Jn)	Pomeroy Arkose Member (Jnp)
			Snug Harbor Siltstone Mbr. (Jns)
			Chisik Cgl. Mbr. (Jnc) / lower sandstone mbr. (Jnss)
	Middle Jurassic	Chinitna Fm. (Jc)	Paveloff Siltstone Member (Jcp)
			Tonnie Siltstone Member (Jct)
		Tuxedni Group (Jt)	Bowser Formation (Jtb)
			Twist Creek Siltstone (Jtt)
			Cynthia Falls Sandstone (Jtc)
			Fitz Creek Siltstone (Jtf)
			Gaikema Sandstone (Jtg)
			Red Glacier Formation (Jtr)
	Lower Jurassic	Talkeetna Formation (Jtk)	Horn Mountain Tuff Member (Jtkh)
			Portage Creek Agglomerate Mbr. (Jtkp)
			Marsh Creek Breccia Mbr. (Jtkm)

Figure 1-3. Stratigraphic column for the Iniskin–Tuxedni region. Stratigraphy modified from Detterman and Hartsock (1966) and Gillis (2016 [this volume]). Kms from Gillis (2016 [this volume]); all other map unit labels from Detterman and Hartsock (1966) and Wilson and others (2012). Abbreviations: Cgl. = Conglomerate; Fm. = Formation; Mbr. = Member; mbr. = member (informal).

2013b; Herriott and others, 2013) and yield oil shows in wells. The relatively quartz-rich nature of Upper Cretaceous deposits in Cook Inlet and their documented association with porosity-hosted oil suggest the potential for the interval to contain conventional accumulations of oil. This chapter also presents new constraints for timing of deformation in the basin, which is critical to evaluating petroleum migration and trap formation.

- **Chapter 8:** Wartes and others (2016 [this volume]) introduce new geologic mapping of the east-trending ridge between East Glacier Creek and the north shore of Chinitna Bay (fig. 1-1). Their mapping extends across the trace of the Bruin Bay fault system and is immediately north of a kilometer-scale, right-stepping bend, step-over, or offset along this regionally significant structure. The paper proposes several permissible models that may account for the large-scale structural relations across Chinitna Bay that have implications for known fracture-associated occurrences of oil and gas on the Iniskin Peninsula.
- **Chapter 9:** Rosenthal and others (2016 [this volume]) continue a regional fractures study (see also Gillis and others, 2013a; Rosenthal and others, 2015) and present results from two field localities in the Oil Bay area (fig. 1-1). These authors report higher fracture intensities at their Paveloff Siltstone Member (Chinitna Formation) locality than at their Pomeroy Arkose Member (Naknek Formation) locality, inferring that grain size is the primary control of fracture intensity. This work relates to unconventional reservoir prospectivity in the basin and development of effective well stimulation programs for potential reservoirs.
- **Chapter 10:** Betka and Gillis (2016 [this volume]) continue an investigation of the Bruin Bay fault system (see also Gillis and others, 2013b; Betka and Gillis 2014a, 2014b, 2015). New observations from fault exposures near Red Glacier, Johnson River, and Open Creek (fig. 1-1) suggest left transpression along this extent of the fault system. Fault kinematics from the three field localities record a transition from left-reverse-slip in the south to left-strike-slip in the north, probably reflecting the Bruin Bay fault system's change in strike north of the Johnson River. This work aims to constrain the nature and timing of deformation along the basin's northwest margin, which are essential elements to a comprehensive understanding of Cook Inlet petroleum systems.

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Nina Harun compiled station data plotted on figure 1-1 and Marwan Wartes rendered a version of figure 1-2. Paula Davis and Joni Robinson deftly guided this volume through the publication process with timely attention to detail. Steve Masterman carefully reviewed proofs for each of the volume's chapters. David LePain provided instructive comments for this introduction and reviewed all chapters in this volume except those he authored.

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