CHAPTER 3

PRELIMINARY INVESTIGATION OF FRACTURE POPULATIONS IN MESOZOIC STRATA OF THE COOK INLET FOREARC BASIN: INISKIN PENINSULA AND LAKE CLARK NATIONAL PARK, ALASKA

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INTRODUCTION

Recent investigations by the Alaska Division of Geological & Geophysical Surveys reveal numerous fracture sets exposed in the Mesozoic strata of the Cook Inlet forearc basin on the Iniskin Peninsula, lower Cook Inlet (Betka and Gillis, 2014; Gillis and others, 2013). These fractures are contained in a vast section of potential reservoir rocks and oil source rocks in one of the largest petroleum-producing provinces in Alaska (Magoon and Anders, 1992). Known production areas in Cook Inlet are structurally controlled, fault-cored anticlines (Haeussler and others, 2000; Bruhn and Haeussler, 2006) or en echelon, transpressional anticlines (LePain and others, 2013; Hauessler and Saltus, 2011). Additionally, faults, joints, and fault related fractures control the migration of hydrocarbons through the Mesozoic section (Detterman and Hartsock, 1966; AOGCC, 2015). This ongoing study investigates the possibility of fracture-controlled fluid migration pathways and fractured reservoir resource potential in the Cook Inlet petroleum system.

Middle and Upper Jurassic forearc strata represent important elements of the Cook Inlet petroleum system, including the source of oil in the basin and underexplored potential reservoirs (Magoon and Anders, 1992; Stanley and others, 2011). The Iniskin Peninsula (fig. 3-1) preserves exposures of Middle and Upper Jurassic strata that provide insight into the Cook Inlet subsurface (LePain and others, 2013; Helmold and others, 2013). Here, the Bruin Bay fault system and a northeast-trending, fault-cored anticline–syncline pair deform Mesozoic strata. Detterman and Hartsock (1966) and Detterman and Reed (1980) recognized abundant fracture populations on the Iniskin Peninsula and hypothesized that the fractures were genetically related to the Bruin Bay fault and to regional folds. This ongoing study focuses on understanding the relationship of fractures to these regional structures and considers the field locale as an analog for offshore reservoirs in Cook Inlet. This report contains preliminary field observations for fracture populations from two outcrops that expose fractured strata of the Pomeroy Arkose Member of the Naknek Formation and the Cynthia Falls Sandstone of the Tuxedni Group (fig. 3-1).

FIELD OBSERVATIONS

Three sets of fractures (termed A, B, and C) occur in the Pomeroy Arkose Member of the Naknek Formation, an arkosic sandstone that is well exposed on the Iniskin Peninsula (figs. 3-1 and 3-2A). The fractures dip steeply and form well-defined sets (fig. 3-3A). The mean attitudes of sets A, B, and C are 317°/85°, 204°/83°, and 262°/80°, respectively. Sets A and B form a conjugate geometry (67° angle between mean planes; fig. 3-3A). In some locations, fracture sets A and B terminate against set C (fig. 3-2A), suggesting that set C is older than sets A and B. Fractures in all of the sets have aperture sizes spanning three orders of magnitude (0.05–100 mm) and are commonly cemented with calcite (figs. 3-2C, D, and F). A fourth set of west–northwest-striking open fractures are not mineralized and are interpreted as unloading joints (figs. 3-2A and B). Regionally, fracture set A strikes subparallel to northwest-striking fracture zones that contain minor right-lateral slip surfaces (fig. 3-2B).

Along strike ~50 km toward the northeast (fig. 3-1), the Cynthia Falls Sandstone of the Tuxedni Group also contains three fracture sets that have orientations similar to those in the Pomeroy; thus we use the same naming scheme for the fracture sets. Here the mean orientations of sets A, B, and C are 123°/87°, 204°/83°, and 242°/74°, respectively (fig. 3-3B). Sets A and B in the Cynthia Falls Sandstone cross-cut one another, suggesting contemporaneous deformation (figs. 3-2C and D). Because the fracture sets in the Cynthia Falls have attitudes similar to those of fractures in the Pomeroy (figs. 3-3A and B), we infer that they have a genetically similar origin.

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SUMMARY AND ONGOING WORK

Similarity in fracture orientations in the two widely separated field locations (figs. 3-3C and D) suggests that the three sets are a regional feature. Average strikes of the fracture sets from both field locations are 313°/86° (set A), 204°/83° (set B), and 249°/76° (set C) (figs. 3-3C and D). The cross-cutting and apparent conjugate geometry of fracture sets A and B (angular discordance of 67°) suggest that they formed contemporaneously and are genetically related. Fracture set C is less prominent than sets A and B, and is likely older. Upcoming geochronologic results from felsic and mafic dikes that intrude fractures from sets A and C will help to constrain the ages of deformation.

Ongoing work includes quantifying the fracture intensity (number of fractures per unit length) of the dominant fracture sets and determining the relationships among fracture intensity, geologic formation, and facies. Preliminary observations suggest a relationship between grain size and fracture intensity (figs. 3-2E and F). Fracture intensity in both the Pomeroy and the Cynthia Falls appears to increase with decreasing grain size. Finer-grained units consistently have higher apparent fracture intensity than coarser-grained units (for example, figs. 3-2E and F). Additionally, we will examine a possible relationship between fracture intensity and proximity to regional structures such as the Bruin Bay fault. Upcoming results will help to characterize the unconventional reservoir potential and possible fluid migration pathways in Cook Inlet's hydrocarbon system.

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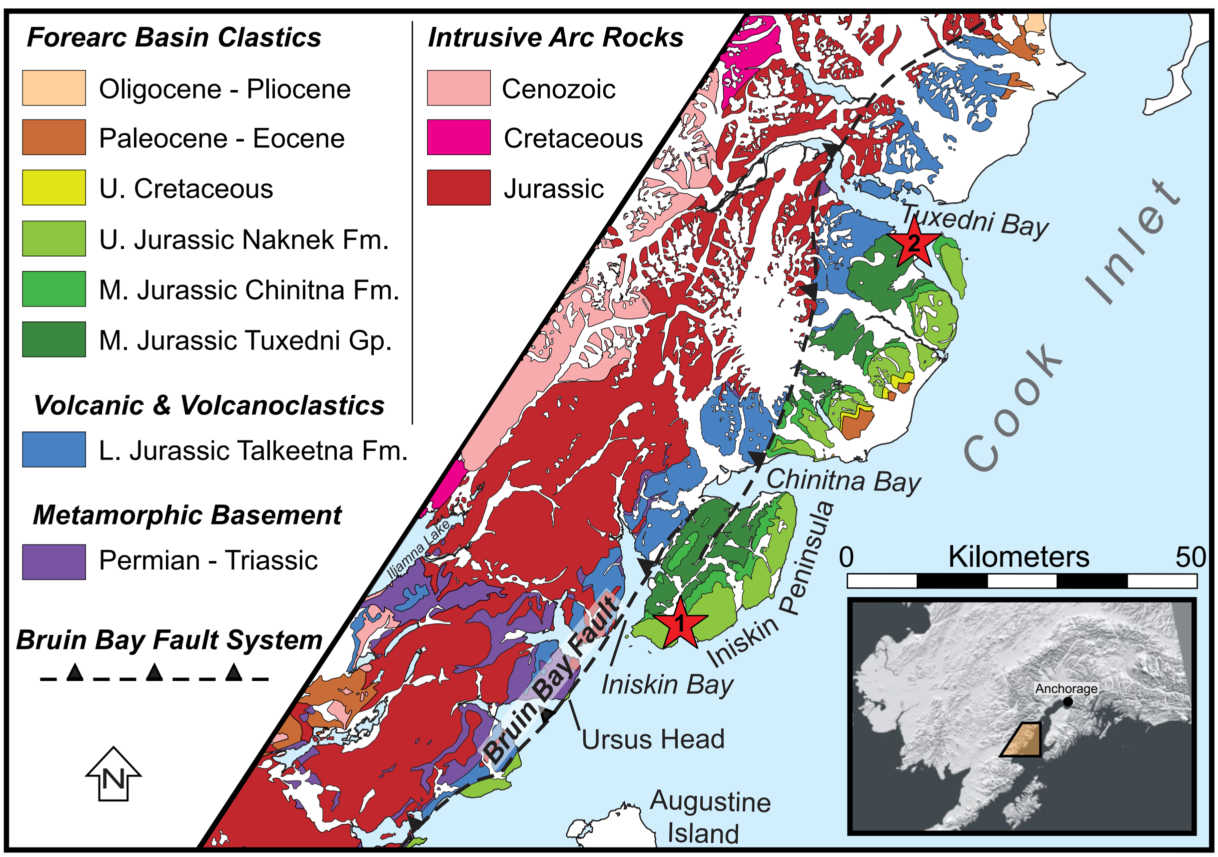

Figure 3-1. Simplified geologic map of the Iniskin Peninsula region, lower Cook Inlet, Alaska, showing the trace of the Bruin Bay fault and distribution of Mesozoic–Cenozoic sedimentary rocks of the Cook Inlet forearc basin, volcanic and plutonic rocks of the Talkeetna–Aleutian arc, and Permian–Triassic metamorphic basement. Large red stars show location of the two study areas discussed in text: 1–Pomeroy Arkose Member of the Naknek Formation, and 2–Cynthia Falls Sandstone of the Tuxedni Group.

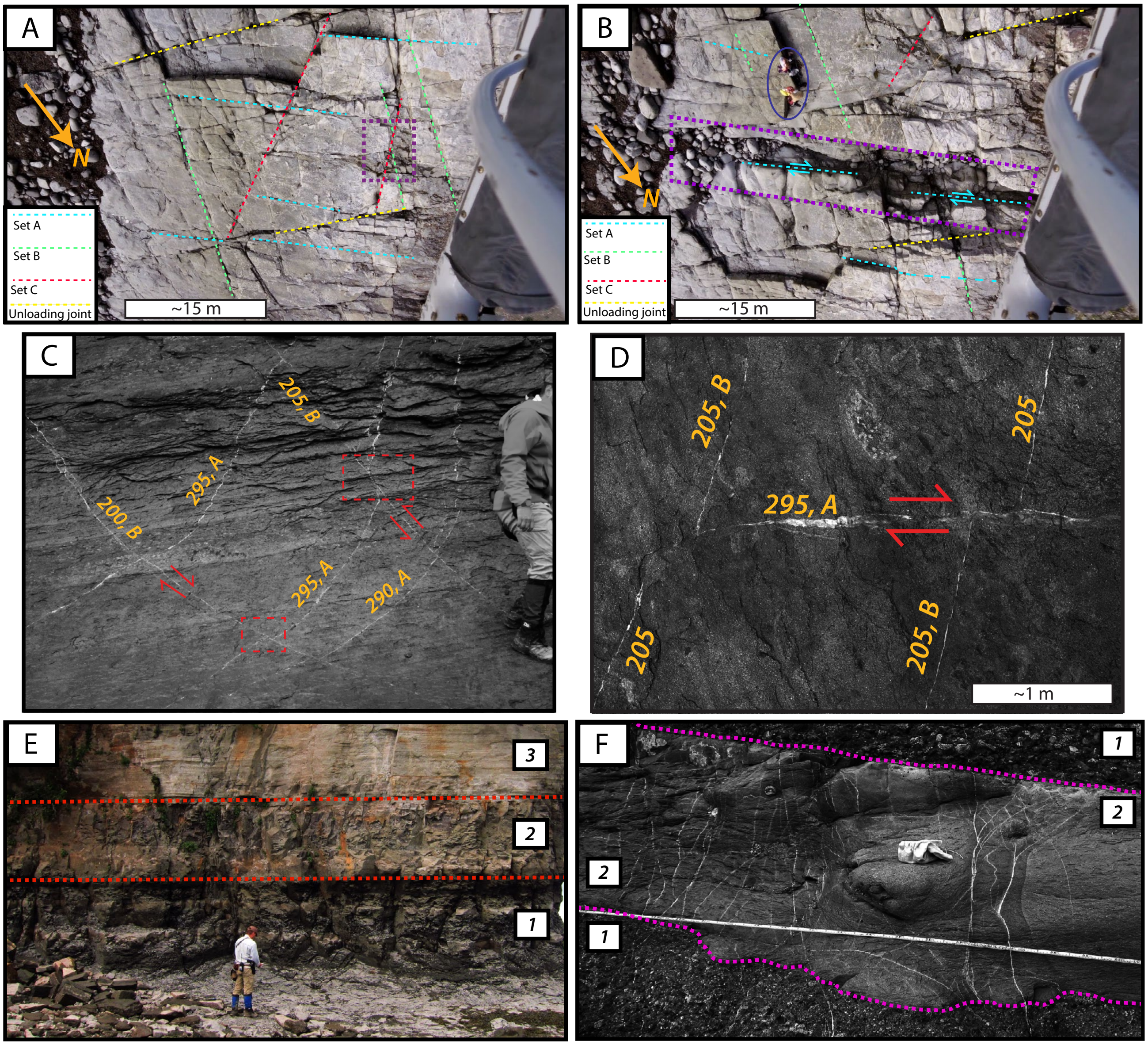

Figure 3-2. **A, B.** Aerial photographs taken from helicopter of the Pomeroy member exposed on the Iniskin Peninsula. **A.** Outcrop orientation relationships between sets A, B, and C. Purple rectangle outlines apparent truncation of fracture set B by fracture set C. In photo **B,** purple rectangle highlights the location of a northwest-striking fracture zone that contains right-lateral slip surfaces. Blue oval indicates geologists for scale. **C, D.** Outcrop of the Cynthia Falls Sandstone of the Tuxedni Group. Fracture strikes and apparent offsets are labeled. In photo **C**, red rectangles highlight piercing points; fracture set B crosscuts fracture set A. In photo **D,** fracture set A crosscuts fracture set B in another location at the same outcrop as in photo C. **E.** Red dotted lines trace bed boundaries, with beds 1–3 comprising a coarsening-upward succession. Bed 3 is coarse- to medium-grained sandstone and has the lowest apparent fracture intensity of the succession. Bed 2 is medium- to fine-grained sandstone and exhibits an increase in fracture intensity relative to bed 3. Bed 1 is fine- to very-fine-grained sandstone and hosts the greatest fracture intensity in this three-bed succession. **F.** Outcrop in the Pomeroy (measuring tape for scale; field of view is 2 m; grayscale to highlight fractures). Fine-grained lenticular sand bed (2) has a higher apparent fracture intensity than the overlying and underlying conglomerate beds (1).

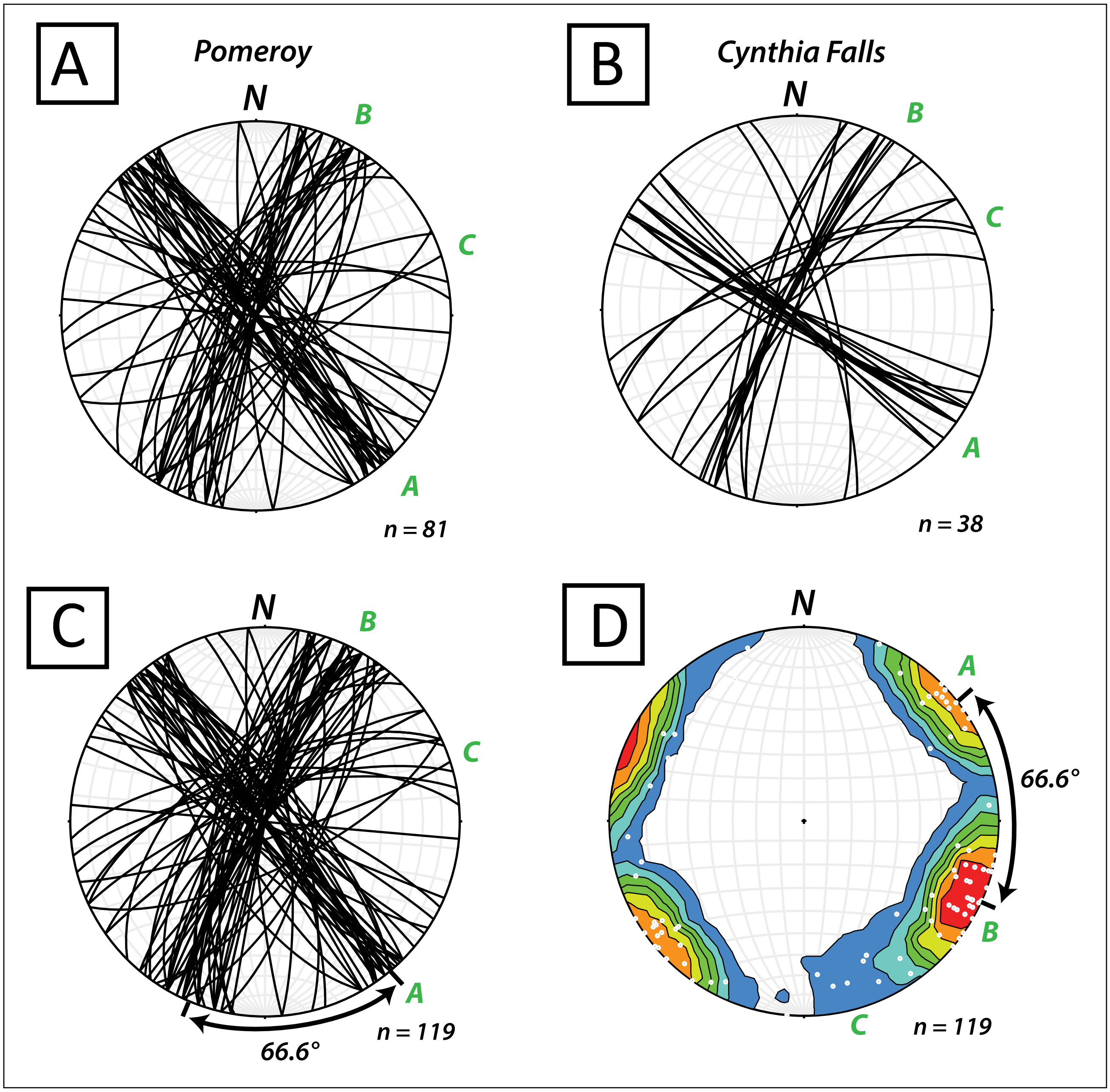

Figure 3-3. Stereograms showing similarity in orientations of three fracture sets (A, B, and C) of both the Cynthia Falls Sandstone of Tuxedni Group and the Pomeroy Arkose Member of Naknek Formation. **A.** Fracture populations of the Pomeroy near Dry Bay. **B.** Fracture populations from the Cynthia Falls in Tuxedni Bay. **C.** Combined fracture populations from stereograms A and B. **D.** Poles to the planes from C. The angle between mean planes from populations A and B is 67°

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