

CHAPTER 2

THE SUPERPOSITION OF STRIKE-SLIP AND REVERSE-SLIP FAULTS IN THE BRUIN BAY FAULT SYSTEM, URSUS HEAD, LOWER COOK INLET

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The Bruin Bay fault system defines a tectonic boundary between Mesozoic–Cenozoic sediments of the Cook Inlet forearc basin and the Mesozoic–Cenozoic Talkeetna–Aleutian arc for most of its exposed length (Detterman and Reed, 1980). It is discontinuously exposed for ~450 km along strike from the upper Alaska Peninsula near Becharof Lake northeastward to upper Cook Inlet. Denudation of the Talkeetna arc in the hanging wall of the fault system sourced Upper Jurassic strata of the Cook Inlet forearc basin that are potential hydrocarbon source and reservoir rocks (LePain and others, 2013; Wartes and others, 2013; compare with Trop and others, 2005). Moreover, the structures that formed in Upper Jurassic strata in the footwall of the fault system impose important geometric and relative timing constraints on the development of the Cook Inlet hydrocarbon system. Here, we report field observations from a well-exposed outcrop of the Bruin Bay fault system near the Iniskin Peninsula at Ursus Head, lower Cook Inlet (fig. 2-1; see also Gillis and others, 2013) to elucidate relative timing relationships between systems of thrust and strike-slip faults that occur regionally in the footwall of the Bruin Bay fault (for example, Detterman and Hartssock, 1966).

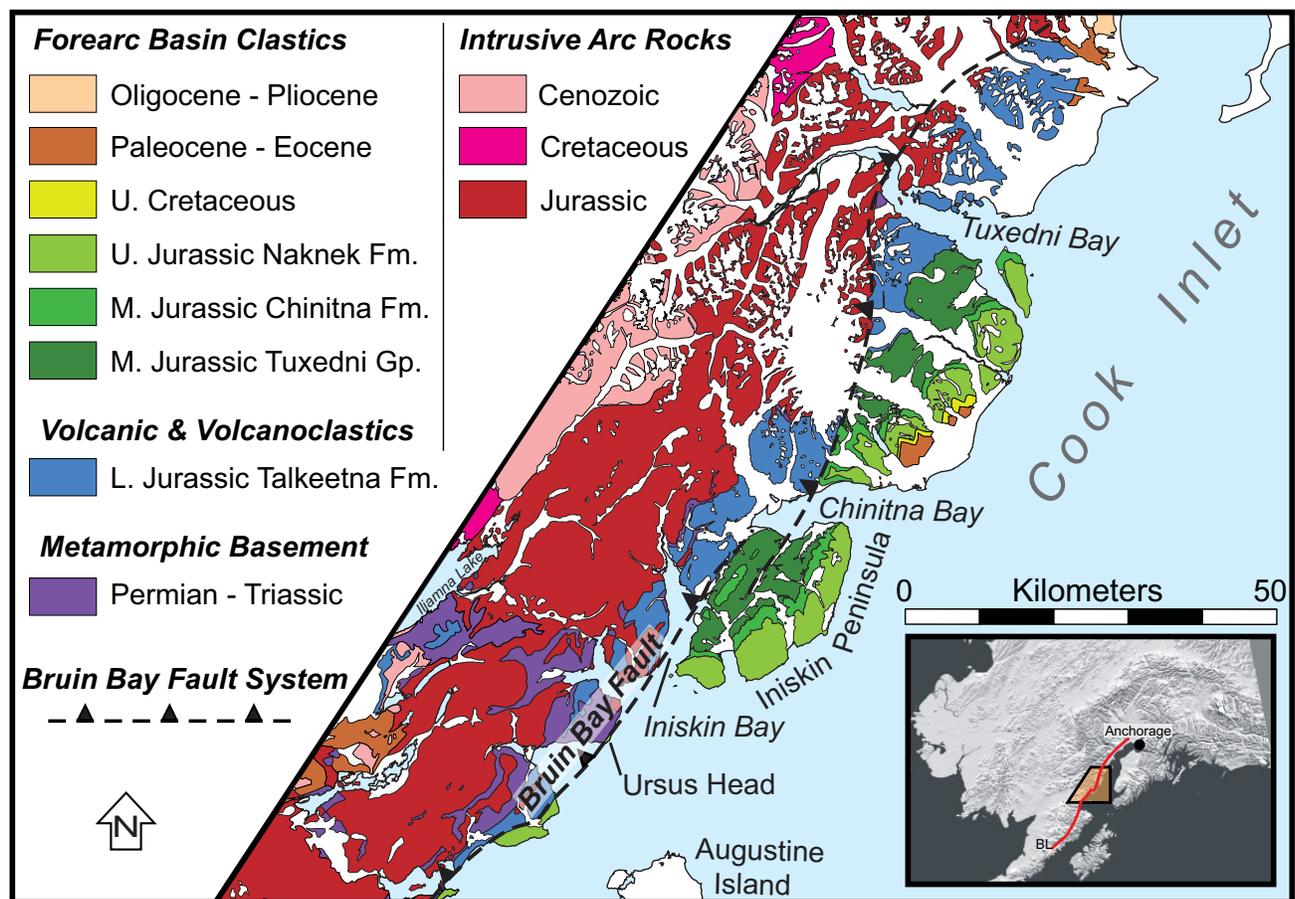


Figure 2-1. Simplified geologic map of the Iniskin Peninsula region, lower Cook Inlet, Alaska, showing the trace of the Bruin Bay fault and distribution of Mesozoic–Cenozoic sedimentary rocks of the Cook Inlet forearc basin, volcanic and plutonic rocks of the Talkeetna–Aleutian arc, and Permian–Triassic metamorphic basement, including the Kamishak Formation referenced in text. Location of the study area at Ursus Head is shown. Inset shows location of geologic map and regional trace of the Bruin Bay fault. BL = Becharof Lake. Map after Wilson and others, 2012.

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Ursus Head (fig. 2-1) is a prominent ~2-km-wide, south-facing sea cliff (fig. 2-2A) southwest of Iniskin Bay and the Iniskin Peninsula. Here, the Bruin Bay fault (BBF, fig. 2-2B) is exposed where it juxtaposes Triassic volcanic rocks and limestone (Kamishak Formation) above Jurassic sandstone (Naknek Formation; fig. 2-2). In the footwall, Jurassic strata of the Naknek Formation are folded into an overturned-to-the-southeast, tight syncline (fig. 2-2B). In the hanging wall, the Kamishak Formation consists of silicic and intermediate composition volcanic rocks and overlying thinly-bedded limestone. Several low-angle thrust faults that commonly form thrust flats subparallel to bedding imbricate and thicken the limestone. Felsic and mafic dikes³ oriented approximately orthogonal to bedding provide excellent marker units and suggest a top-southeast thrust sense of displacement along the thrusts (fig. 2-2B). Minor folds of bedding in the limestone are commonly breached by small, northwest-dipping thrusts with several centimeters of top-southeast displacement. The minor thrusts confirm the top-southeast sense of slip that is inferred by the separation of the dikes (fig. 2-3A). At the contact between the limestone and underlying volcanic rocks, bedding within the basal ~20 m of the limestone is folded by a train of detachment folds that are detached along the contact and are exposed continuously across the outcrop (pink shading in fig. 2-2B). The detachment fold horizon is imbricated and forms four thrust “horses” (locations I–IV in figs. 2-2B and 2-3B). The low-angle thrusts that imbricate the limestone root into the detachment that formed at the contact with the underlying volcanic rocks, probably reflecting the contrast in competency between the two lithologies.

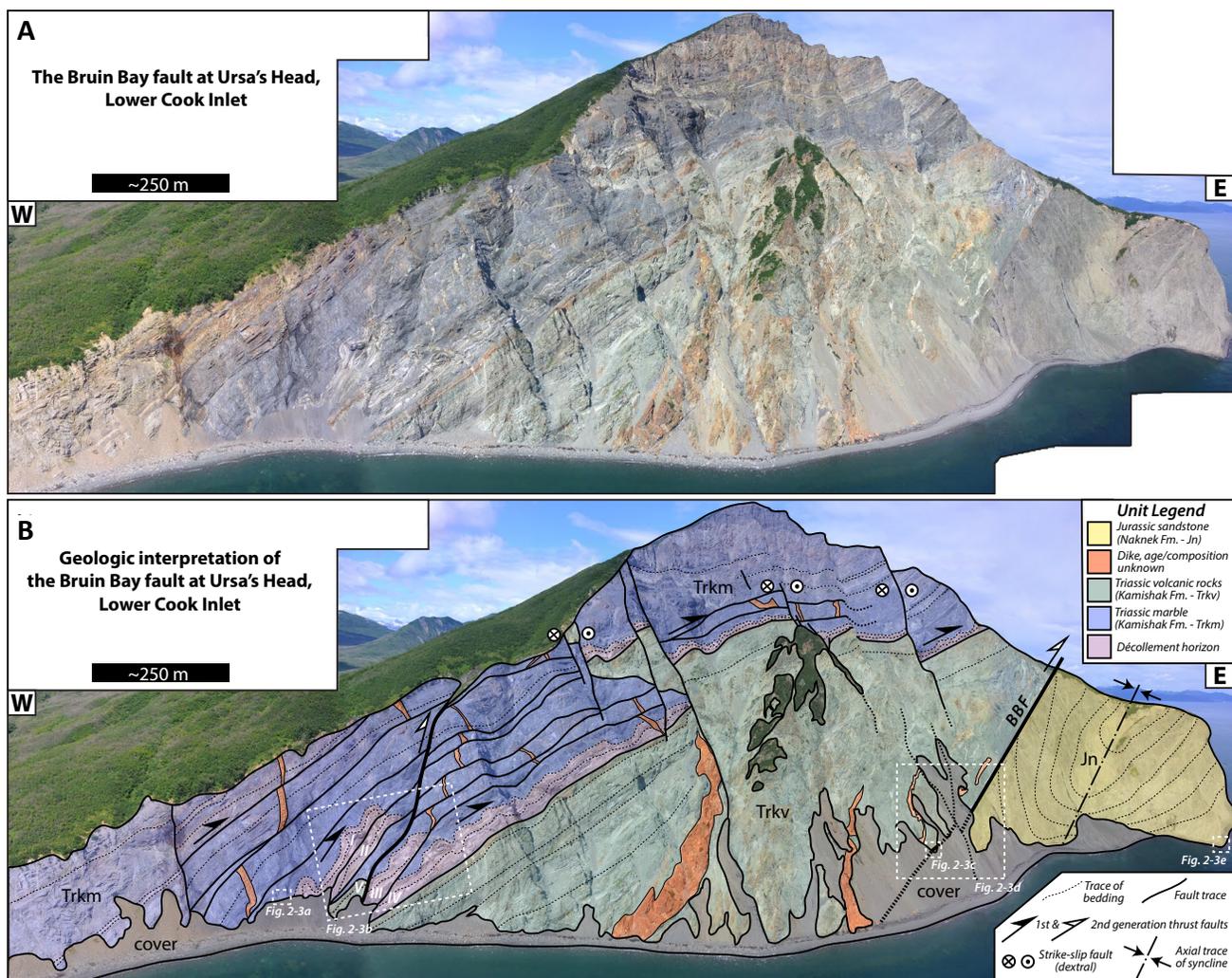


Figure 2-2. Photomosaic (A) and geologic interpretation (B) of the Bruin Bay fault system at Ursus Head, lower Cook Inlet, where Triassic limestone and volcanic rocks of the Kamishak Formation are thrust above Jurassic sandstones of the Naknek Formation. In photo B, unit colors highlight lithology and the detachment horizon discussed in text. Thin dashed lines show trace of bedding, solid lines show fault traces, and heavy solid lines show second-generation reverse faults (dashed where approximately located or inferred). Locations of figures 2-3A–E are shown. Thrust horses I–V are shown in figure 2-3B. BBF = Bruin Bay fault.

³Unpublished zircon U-Pb ages are 221 Ma and 225 Ma for two samples.

The Bruin Bay fault crops out in a gully at the top of a talus cone (fig. 2-3C; location in fig. 2-2B), where it dips steeply northwest. Here, the fault zone is ~2 m thick and defined by at least two overlapping thrust surfaces. Fault zone cleavage is subvertical and confirms a top-southeast reverse sense of displacement. In the footwall, bedding in the Naknek Formation is upright and truncated by the fault (fig. 2-3C). At least one other steeply-dipping reverse fault occurs in the hanging wall of the Bruin Bay fault at Ursus Head (fig. 2-2B). The reverse fault is interpreted to truncate the detachment horizon and uplifts volcanic rocks from below the detachment above the limestone (location V, figs. 2-2B and 2-3B). On the basis of similarities in dip and structural style, we infer that the Bruin Bay fault is probably kinematically related to the reverse fault in its hanging wall and thus postdates the low-angle thrusts and the detachment horizon.

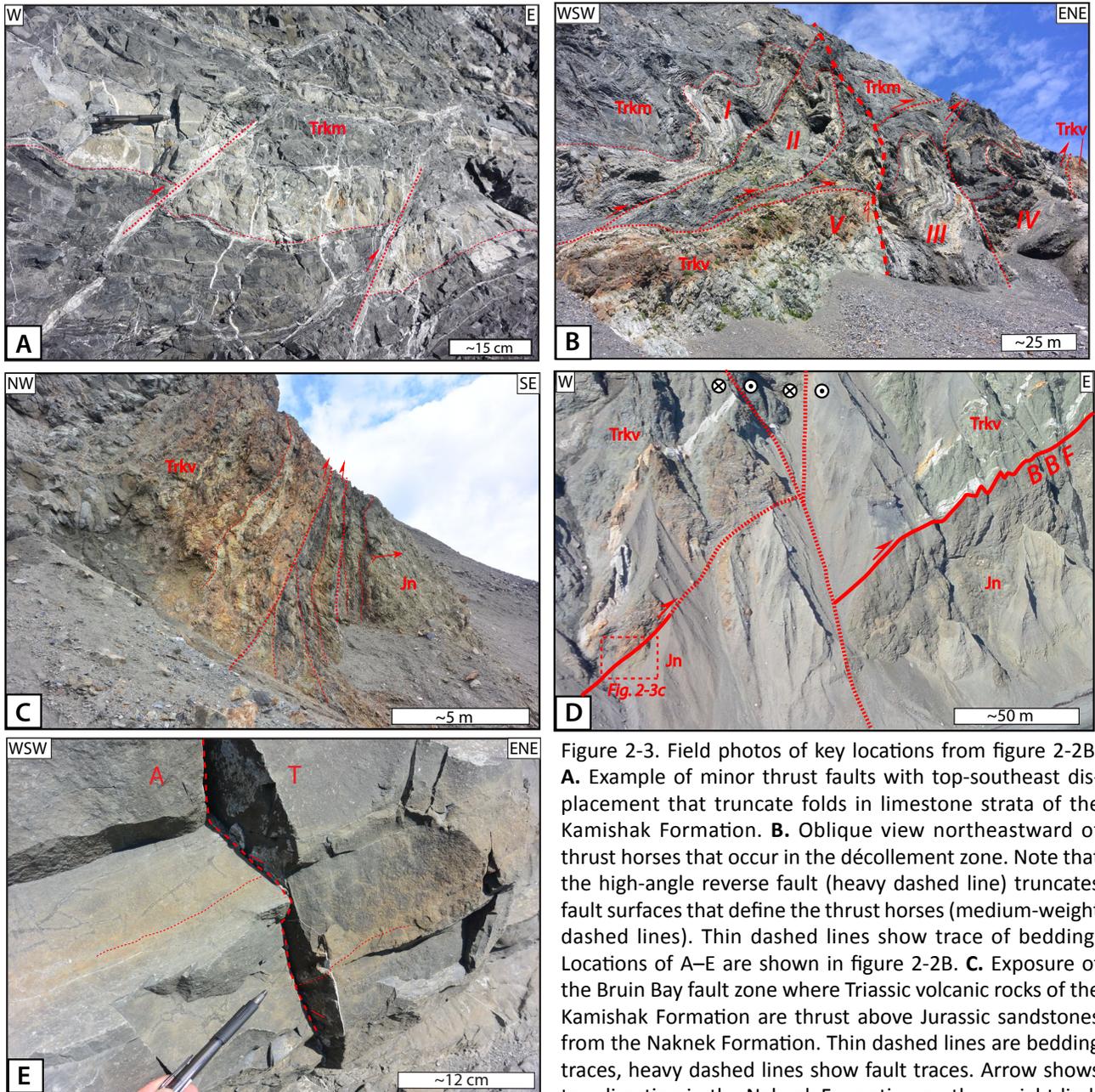


Figure 2-3. Field photos of key locations from figure 2-2B. **A.** Example of minor thrust faults with top-southeast displacement that truncate folds in limestone strata of the Kamishak Formation. **B.** Oblique view northeastward of thrust horses that occur in the décollement zone. Note that the high-angle reverse fault (heavy dashed line) truncates fault surfaces that define the thrust horses (medium-weight dashed lines). Thin dashed lines show trace of bedding. Locations of A–E are shown in figure 2-2B. **C.** Exposure of the Bruin Bay fault zone where Triassic volcanic rocks of the Kamishak Formation are thrust above Jurassic sandstones from the Naknek Formation. Thin dashed lines are bedding traces, heavy dashed lines show fault traces. Arrow shows top-direction in the Naknek Formation on the upright limb of the footwall syncline (see fig. 2-2B). **D.** Aerial view of the Bruin Bay fault offset by an inferred, steeply dipping fault; sense of slip is inferred to be right-lateral. The location of figure 2-3C is shown; see text for details. **E.** Example of minor strike-slip fault surfaces that crosscut the footwall syncline in the Naknek Formation. Thin dashed red line shows base of a medium-grained sand bed that is offset several centimeters by a subvertical fault surface (thicker dashed red line). Short, solid red lines of fault surface show orientation of the slickenline, which plunges shallowly (04°) north. Sense of slip is right-lateral. A = away; T = toward.

Bruin Bay fault offset by an inferred, steeply dipping fault; sense of slip is inferred to be right-lateral. The location of figure 2-3C is shown; see text for details. **E.** Example of minor strike-slip fault surfaces that crosscut the footwall syncline in the Naknek Formation. Thin dashed red line shows base of a medium-grained sand bed that is offset several centimeters by a subvertical fault surface (thicker dashed red line). Short, solid red lines of fault surface show orientation of the slickenline, which plunges shallowly (04°) north. Sense of slip is right-lateral. A = away; T = toward.

Several subvertical, north–northwest-striking faults crosscut contractional structures. These faults are best exposed near the top of the outcrop, where they clearly crosscut the detachment horizon. The apparent sense of displacement is most commonly east-side down (figs. 2-2A–B). A fault of this orientation is inferred to crosscut the Bruin Bay fault where it is covered by talus (figs. 2-2B, 2-3D) because the Bruin Bay fault projects down dip toward the west to a position that is below the exposure of the Bruin Bay fault presented in figure 2-3C (see fig. 2-3D). Thus, we infer that the outcrop in figure 2-3C is in the upthrown block west of the subvertical fault. Minor, subvertical, strike-slip faults with several centimeters of displacement are ubiquitous throughout the outcrop. The strike-slip faults most commonly strike north–northwest and show right-lateral displacements (for example, fig. 2-3E). On the basis of similarities in the attitudes of the minor right-lateral faults and the mesoscale subvertical faults that crosscut the detachment horizon and the Bruin Bay fault, we deduce that the latter set of faults are also right-lateral strike-slip faults. Right-lateral slip is consistent with the apparent east-side-down offset of the northwest-dipping structures and strata that these faults displace.

Crosscutting relationships preserved at Ursus Head record the superposition of three dominant sets of faults. The first faults to form are low-angle thrust faults that imbricate and thicken limestone deposits in the Kamishak Formation. The imbricate thrusts root into a detachment horizon that is defined by a train of detachment folds, and developed along the contact between the limestone and underlying volcanic rocks. The competency contrast between the two lithologies probably influenced the position of the detachment horizon. A second stage of contraction is recorded by two high-angle reverse faults that crosscut the early thrusts and the detachment horizon. At Ursus Head, the Bruin Bay fault is a reverse fault that uplifts and juxtaposes the Kamishak Formation above the Naknek Formation and is inferred to have formed with the second generation of reverse faults and reflect progressive shortening of the thrust wedge. A later stage of deformation is recorded by several subvertical strike-slip faults that strike north–northwest and have right-lateral displacements. The strike-slip faults crosscut both earlier generations of faults, including the Bruin Bay fault, and probably reflect a separate tectonic event. Field relations exposed at Ursus Head provide an important example of the relative timing of structures that formed during the tectonic development of lower Cook Inlet and they can be extrapolated to interpret regional structural evolution of the Cook Inlet hydrocarbon system.

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