CHAPTER 4

PRELIMINARY KINEMATIC EVIDENCE FOR RIGHT-LATERAL SLIP ALONG A SYSTEM OF STEEPLY-DIPPING FAULTS IN THE HANGING WALL OF THE BRUIN BAY FAULT, INISKIN PENINSULA, LOWER COOK INLET, ALASKA

Paul M. Betka[1] and Robert J. Gillis[1]

INTRODUCTION

An ongoing program by the Alaska Division of Geological & Geophysical Surveys aims to understand the Mesozoic and Cenozoic geologic evolution of the northwestern margin of the Cook Inlet forearc basin. As part of that program, this study is directed at understanding the kinematic evolution, relative timing, and tectonic significance of a system of steeply dipping faults that occur in the hanging wall of the Bruin Bay fault, near the Iniskin Peninsula, Cook Inlet, Alaska (fig. 4-1).

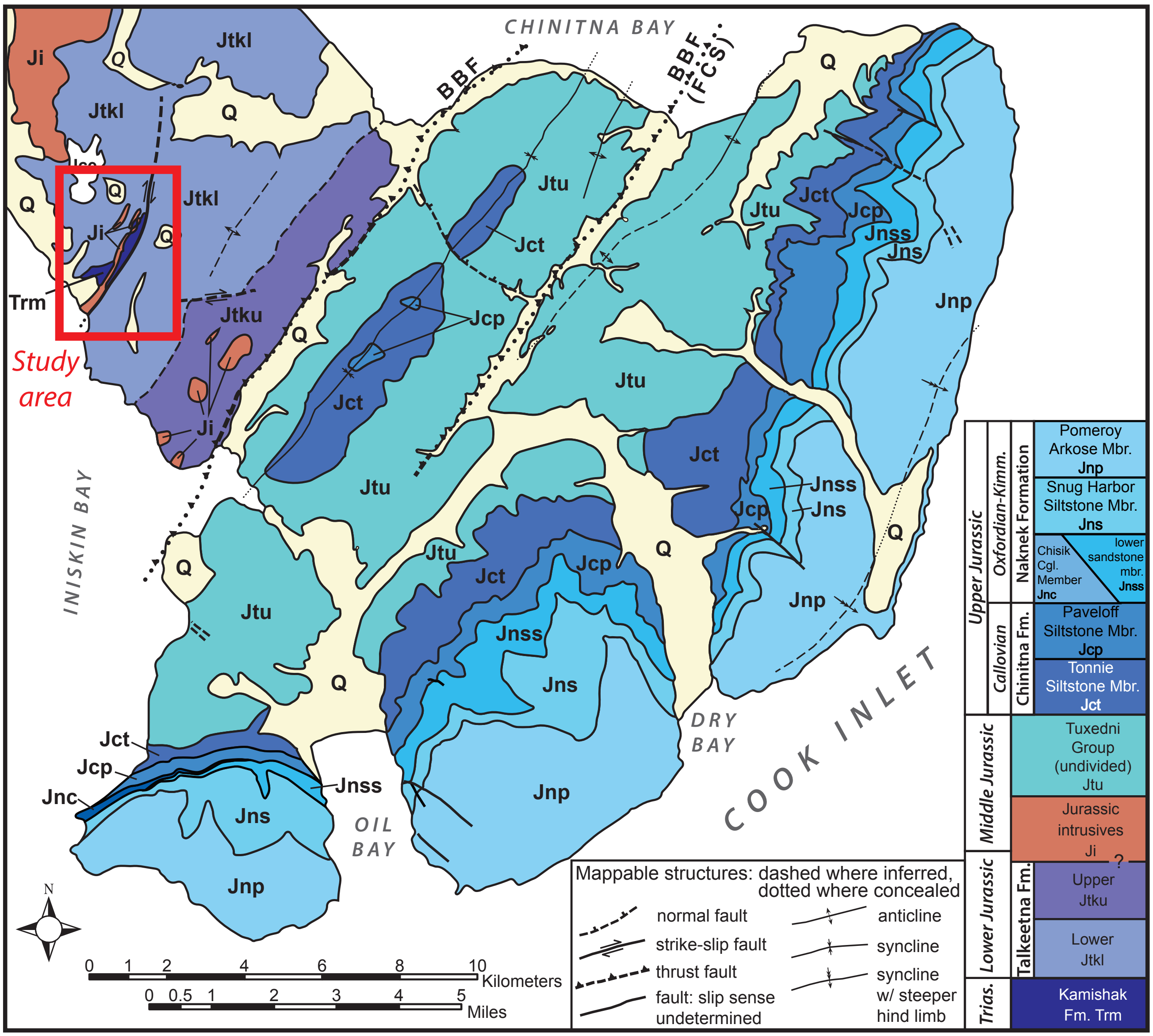

Figure 4-1. Simplified preliminary inch-to-mile geologic map of the Iniskin Peninsula constructed from data collected during the 2013 DGGS mapping campaign. The study area and fault zone discussed are shown within the red box.

[1]Alaska Division of Geological & Geophysical Surveys, 3354 College Rd., Fairbanks, Alaska 99709-3707; paul.betka@alaska.gov; robert.gillis@alaska.gov

The Bruin Bay fault strikes northeastward more than 450 km from the upper Alaska Peninsula to near the northwest terminus of Cook Inlet. In lower Cook Inlet, it defines the tectonic boundary between Mesozoic and Cenozoic sediments of the Cook Inlet forearc basin to the southeast and the crystalline batholith and volcanic edifice of the Jurassic Talkeetna arc toward the northwest. Hanging wall and footwall exposures indicate a significant component of top-southeast reverse motion along a northwest-dipping (40–50° where measured) fault plane. Detterman and Hartsock (1966) first mapped a system of steeply-dipping northeast-striking faults that are present in the hanging wall of the Bruin Bay fault and locally define the contacts between Jurassic volcanic and volcaniclastic deposits of the Talkeetna Formation and Triassic (age uncertain) marbles and metasedimentary rocks of the Kamishak Formation. Detterman and Reed (1980) postulate that the steeply-dipping faults are part of the Bruin Bay fault system and they suggest a genetic relationship among all of the faults in the hanging wall with the Bruin Bay fault. Both Detterman and Hartsock (1966) and Detterman and Reed (1980) interpret the system to be left slip, perhaps accommodating 19–65 km of sinistral displacement on the basis of poorly understood, non-unique stratigraphic piercing points. However, the sense of slip and relative timing gleaned from map patterns of the hanging-wall faults is unclear and their tectonic significance remains ambiguous.

In this paper, we present field observations and preliminary results from an ongoing kinematic analysis of a well-exposed northeast-striking fault strand in the hanging wall of the Bruin Bay fault where it crops out for ~3.2 km between the head of Iniskin Bay and the headwaters of Roscoe Creek (fig. 4-1). Here, the fault dips steeply northwest and defines the southeastern contact between Jurassic volcanic and volcaniclastic rocks of the Talkeetna Formation in the footwall and rock units including Triassic(?) marble, Jurassic(?) hypabyssal felsic intrusive rocks, and the Talkeetna Formation in the hanging wall. This ongoing study is designed to test whether the Bruin Bay fault is genetically related to the steeply dipping faults in its hanging wall or if each set of faults reflects a separate phase of deformation. Initial fieldwork for this project was completed during July and early August 2013.

FIELD OBSERVATIONS

In the study area (figs. 4-1, 4-2), the northwestern contact between Triassic(?) marble and the Talkeetna Formation is well exposed and moderately deformed. It is tentatively interpreted to reflect a non-conformable contact. The contact is intruded by a felsic dike that is mostly parallel to the contact, but locally cross-cuts it (fig. 4-2). Both the dike and the contact are cut by several minor strike-slip fault planes. Across-strike toward the southeast, the Triassic marble contains a well-defined gneissic banding that is upright and probably reflects recrystallization of original compositional layering (bedding?). The areal width of the marble is ~320 m (fig. 4-3A). Brittle deformation in the marble intensifies toward the southeast, where a decameters-wide fault zone that contains cataclasite defines the southeastern contact between the marble and Talkeetna Formation. The contact dips steeply toward the northwest and is subparallel to gneissic banding in the marble (fig. 4-3A). Along-strike of the fault toward the northeast from the location of figure 4-3A, the fault truncates the northwestern contact

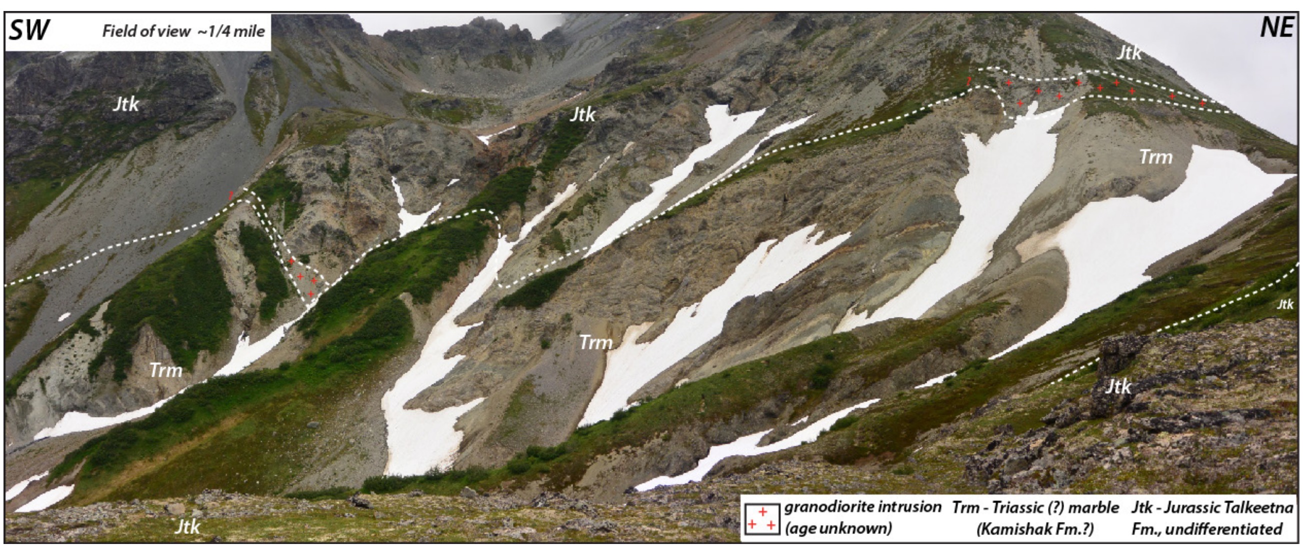

Figure 4-2. Panoramic view looking northwest showing the outcrop extent of Triassic(?) marble (Trm) in the map area. Along the northwestern boundary, the marble is in contact with Jurassic volcanic breccias of the Talkeetna Formation (Jtk). The contact is weakly deformed and intruded by a medium-grained granodiorite dike (red "+" symbols). The eastern contact (out of field of view at base of photo) is defined by a northeast- to north–northeast-striking fault zone (see fig. 4-3). Viewpoint for this photograph is shown in figure 4-3.

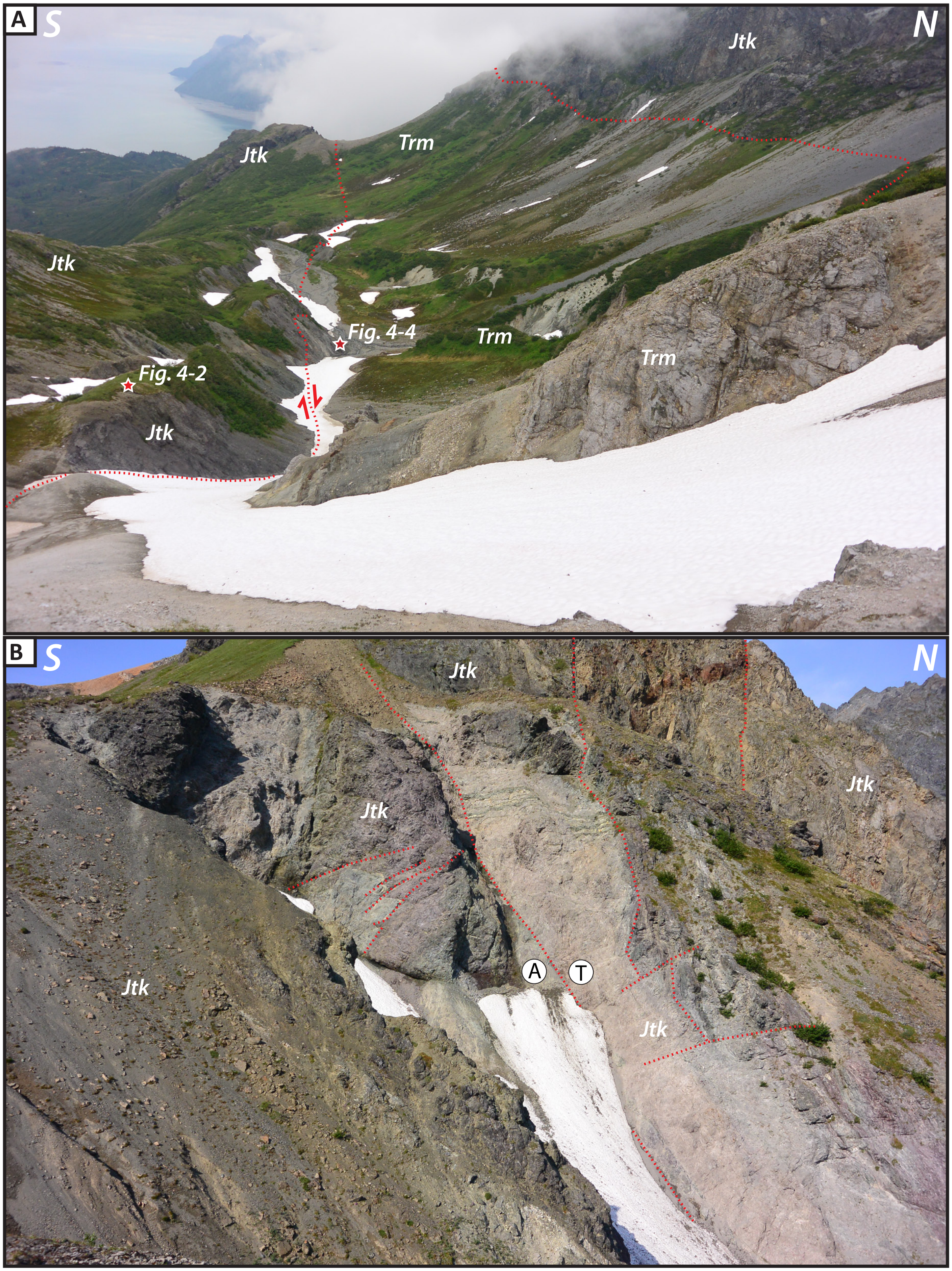

Figure 4-3. A. View looking west–southwest showing map trace of the southwestern contact of the Triassic marble (Trm) with the Talkeetna Formation (Jtk); outcrop width of the Triassic marble is ~320 m. The southwestern contact is tectonized and defined by a decameter wide right-lateral strike-slip fault zone. Compositional layering in the marble (foreground) defines a gneissic banding that is upright and interpreted to reflect original bedding. Locations of figures 4-2 and 4-4 are marked with red stars. B. Trace of fault zone in A where it cuts across a gully above the headwaters of Roscoe Creek. Several fault planes are highlighted by red dashed lines and define a decameters-wide fault zone. Sense of slip on fault is inferred based on kinematic data collected elsewhere along the fault trace (for example, figs. 4-4, 4-5). T, toward; A, away.

between the marble and Talkeetna Formation, thus cutting out the marble and juxtaposing Talkeetna Formation along both sides of the fault. This relationship is best confirmed where the fault is exposed in a steeply sloped gulley above the headwaters of Roscoe Creek (fig. 4-3B). Here, the marble is absent and the Talkeetna Formation is present on either side of a fault plane that dips steeply toward the northwest. A decameters-wide damage zone is defined by several subsidiary faults (fig. 4-3B). Unfortunately, this outcrop is inaccessible due to steep terrain and loose rock, ruling out measurements from this segment of the fault.

FAULT KINEMATIC METHODS

To determine the overall sense of slip along the fault, we collected a fault-slip dataset from numerous discrete fault surfaces that occur in the fault zone that defines the southeastern contact between the Talkeetna and Kamishak Formations. A population of fault-slip data was collected by measuring the attitudes of fault surfaces and associated slip lineations. The sense of shear on individual faults was determined using kinematic indicators including Riedel shears, steps on fault surfaces, preferred orientations of associated tensile or sigmoidal veins, and other common methods (for example, Petit, 1987). Shear-sense indicators were weighted by quality. To interpret the population of fault-slip data and test for multiple overprinting deformations along the fault zone, we followed the graphical methods of Marrett and Allmendinger (1990). Measurements were collected along the fault where it crops out in a low saddle between the headwaters of Roscoe Creek and Iniskin Bay (fig. 4-3A). Here the fault zone is defined by a cataclasite in the Triassic marble that has a minimum thickness of 2 m (fig. 4-4A). Discrete slip surfaces in the cataclasite are abundant and commonly contain well-preserved slip lineations (for example, fig. 4-4B).

FAULT KINEMATIC RESULTS

Preliminary results from 17 discrete fault planes are presented in figure 4-5. All of the 17 faults analyzed strike northeast and contain moderately to shallowly plunging slip lineations (<40° plunge). The sense of shear is dominantly right-lateral with a subordinate dip-slip component (fig. 4-5A). Shortening and extension axes, which were calculated for each fault plane, form well-defined clusters. Shortening axes plunge shallowly west and east, and extension axes plunge shallowly north and south (fig. 4-5B). Principal kinematic axes (directional maxima for shortening and extension axes) were calculated by the linked-Bingham method and used to construct a fault-plane solution that reflects an average fault-plane orientation and sense of slip from the population of faults. Results indicate an average sense of slip along the fault zone that is dominantly dextral strike-slip along a subvertical, northeast-striking surface (fig. 4-5B). Clustering of extension and shortening axes from the population of faults suggests that all of the faults formed during the same deformation, and thus do not reflect multiple overprinting slip events.

SUMMARY

Preliminary kinematic results from this study indicate that at least one of the steeply dipping faults in the hanging wall of the Bruin Bay fault formed in a tectonic setting favorable to right-lateral strike-slip motion along steeply dipping surfaces, and that locally the juxtaposition of Triassic(?) marble against the Jurassic Talkeetna Formation occurred along a strike-slip fault. These results suggest that deformation along steeply dipping northeast-striking faults in the hanging wall of the Bruin Bay fault may be kinematically distinct from the Bruin Bay fault, which itself is thought to reflect mostly reverse-slip motion, possibly implying different tectonic origins for either fault. We postulate that brittle deformation associated with the Bruin Bay fault system could reflect a multiphase kinematic history that ultimately resulted in heterogeneous fault kinematics in the study area. Ongoing work during 2014 will include collecting similar kinematic datasets from Bruin Bay fault as well as other faults in the region.

ACKNOWLEDGMENTS

We thank Rebekah Tsigonis for field assistance and camp support; Rick Stanley (U.S. Geological Survey) and Ken Helmold (Alaska Division of Oil & Gas) for constructive conversations in the field; Mike Fell (Pathfinder Aviation) for helicopter support; Merril and Marti (Bear Mountain Lodge) for their hospitality; Jack Barber (Alaska Air Taxi); Bald Mountain Air; and David LePain for careful review of this report. The Iniskin Peninsula area mapping project was funded by a substantial contribution from the U.S. Geological Survey STATEMAP Program (award no. G13AC00157).

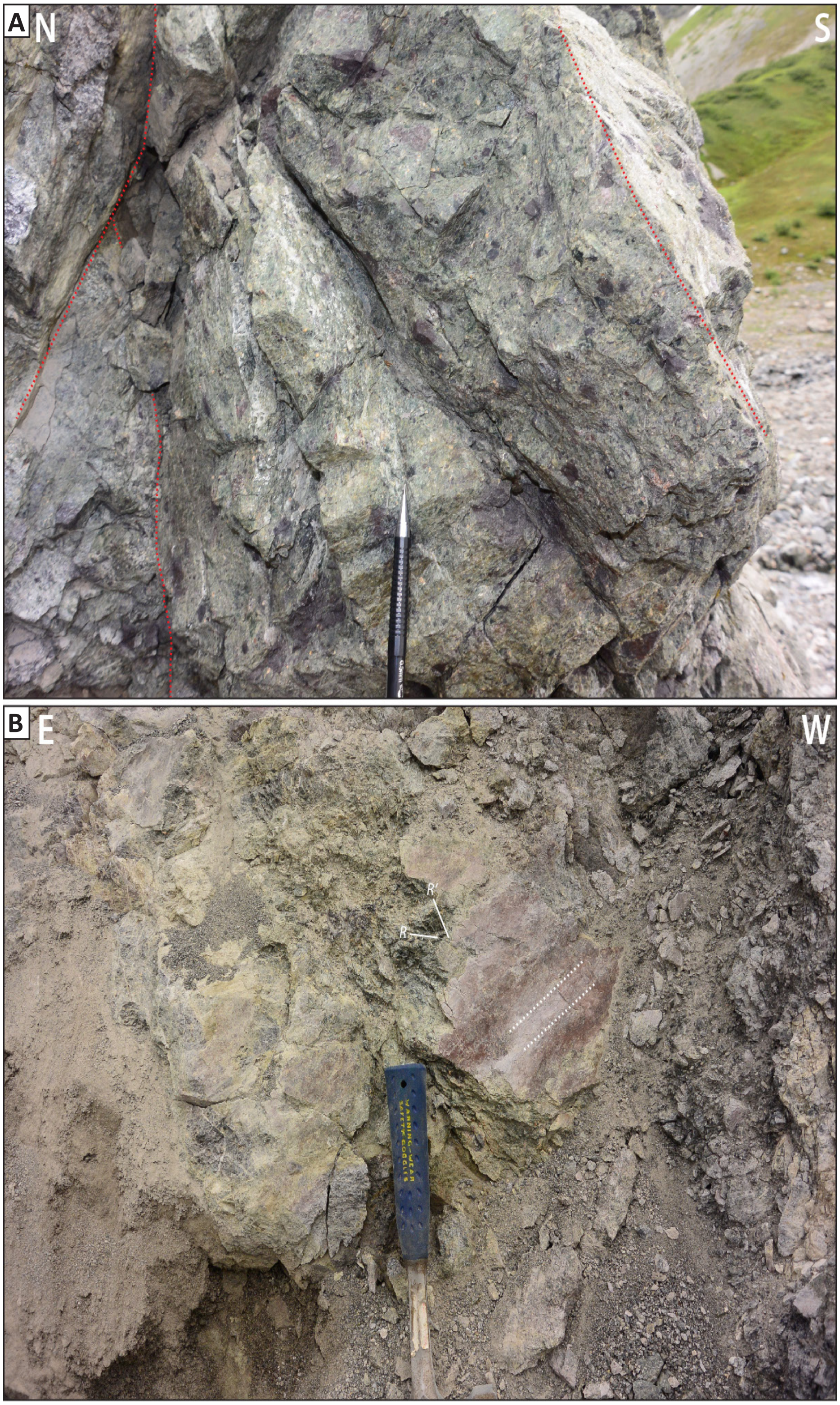

Figure 4-4. A. Fault-zone cataclasite contained within the Triassic marble. Several discrete fault planes that contain slip lineations are highlighted with dashed lines. Location is shown in figure 4-3A. B. A fault surface that contains slip lineations defined by calcite slicken fibers and fault-plane mullions. Slip lineations are highlighted by white dashed lines and plunge moderately (~35°) toward the northeast. Sense of shear on this fault plane is interpreted to be right-lateral on the basis of Riedel shears that intersect the fault surface (R and R').

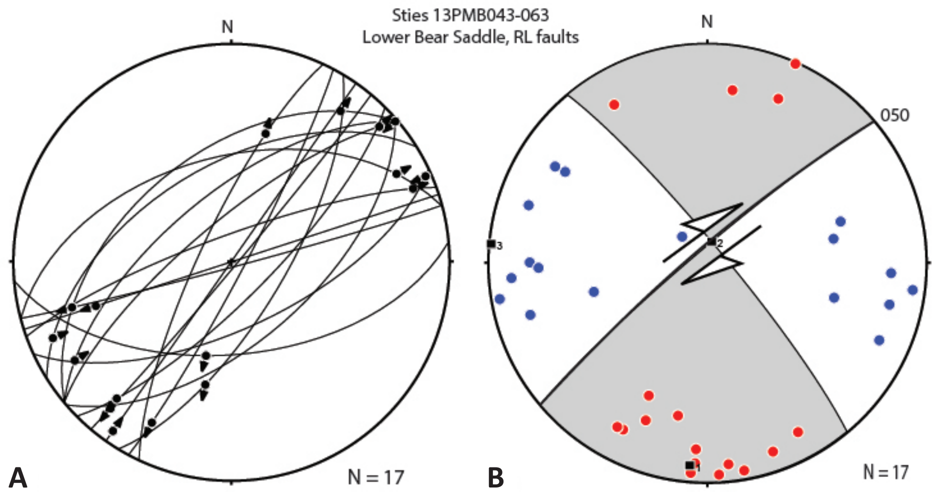

Figure 4-5. Synthesis of fault-slip data from 17 minor fault surfaces collected in the fault zone in the vicinity of figure 4-4. A. Equal-area stereographic projection showing fault-plane strike and dip (great circles), the trend and plunge of slip lineations associated with each fault (black dots), and sense of motion of the hanging wall (arrows on slip lineations). B. Equal-area stereographic projection showing distribution of shortening axes (blue dots) and extension axes (red dots) from each of the faults in A. Average directional maxima of shortening and extension axes (kinematic axes) are plotted (black squares) using the "linked-Bingham" method of the computer software package FaultKin (1–extension, 2–intermediate, and 3–shortening axis; Marrett and Allmendinger, 1990; Allmendinger et al., 2012). The fault-plane solution (nodal planes, gray and white dihedra) was constructed from the kinematic axes and is sympathetic with overall right-lateral shear within a subvertical northeast-striking (050°) strike-slip fault zone. N = number of faults in population. Kinematic analyses of fault slip data are after the methods of Marrett and Allmendinger (1990).

REFERENCES

Allmendinger, R.W., Cardozo, N.C., and Fisher, D., 2012, Structural geology algorithms—Vectors and tensors in structural geology: Cambridge, England, Cambridge University Press, 302 p.

Detterman, R.L., and Hartsock, J.K., 1966, Geology of the Iniskin–Tuxedni region, Alaska: U.S. Geological Survey Professional Paper 512, 78 p., 6 sheets, scale 1:63,360, http://www.dggs.alaska.gov/pubs/id/3873.

Detterman, R.L., and Reed, B.L., 1980, Stratigraphy, structure, and economic geology of the Iliamna Quadrangle, Alaska: U.S. Geological Survey Bulletin 1368-B, p. B1–B86, 1 sheet, scale 1:250,000, http://www.dggs.alaska.gov/pubs/id/3682.

Marrett, R.A., and Allmendinger, R.W., 1990, Kinematic analysis of fault-slip data: Journal of Structural Geology, v. 12, p. 973–986.

Petit, J.P., 1987, Criteria for the sense of movement on fault surfaces in brittle rocks: Journal of Structural Geology, v. 9, no. 5/6, p. 597–608.