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Mesozoic Sedimentation and Deformation Along the Talkeetna Thrust Fault, South-Central Alaska—New Insights and Their Regional Tectonic Significance

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Abstract

Recent work in the Talkeetna Mountains of south-central Alaska involving sedimentologic and structural investigations along the trace of the Talkeetna thrust fault reveals the following relations: (1) the Kahiltna assemblage in the footwall of the Talkeetna thrust fault represents proximal submarine-fan deposits that were derived from strata exposed in the adjacent hanging wall of the fault; and (2) the structure along the exposed trace of the fault is that of minor thrust slices in the juxtaposed upper and lower plates, is nonpenetrative, and is restricted to within 20 to 50 m of the thrust fault. Lower-plate rocks containing rounded pebble to boulder clasts and delicate bivalve macrofossils adjacent to the fault are undeformed. The proximal sedimentary relation between the footwall and hanging-wall rocks, coupled with the absence of well-developed penetrative-deformation fabrics, suggests that the Talkeetna thrust fault is not a major nappelike structure with tens of kilometers of tectonic transport, as originally interpreted, and so this individual fault zone does not mark a major tectonic terrane boundary in the accretionary tectonic landscape of south-central Alaska.

Introduction

The tectonic evolution of south-central Alaska is largely known from reconnaissance geologic mapping in the Talkeetna Mountains quadrangle (Csejtey and others, 1978) and adjacent Healy quadrangle (Csejtey and others, 1992). These studies showed that the regional geologic framework of the region between the Alaska Range on the north and the Border Ranges of the Chugach terrane on the south represents a composite of two allochthonous terranes and associated basins that were sutured to the North American craton during mid-Cretaceous and Late Cretaceous time. The four major tectonostratigraphic units involved in this collisional event are, from north to south, the North American, Kahiltna, Wrangellia, and Peninsular terranes (fig. 1). The narrow, elongate Peninsular and Wrangellia terranes evolved separately during the Paleozoic at latitudes far south of their present position and were not in their present positions during Early Cretaceous time (Packer and Stone, 1974; Jones and others, 1977). The two terranes were apparently sutured together as early as late Paleozoic, because they share a common geologic history throughout the Mesozoic (Csejtey and others, 1982; Gardner and others, 1988); they have since acted as a structurally cohesive unit and, as such, were termed the "Talkeetna superterrane" by Csejtey and others (1982) and the Wrangellia composite terrane by Plafker and Berg (1994). The Kahiltna assemblage consists of strata deposited in sedimentary basins between the Wrangellia composite terrane and the North American craton (fig. 1). Exposed within the Kahiltna assemblage are what have been called miniterranes, composed of geologically dissimilar fault-bounded blocks, interpreted to have been tectonically intermixed with the Kahiltna assemblage during the collisional event that joined the Wrangellia composite terrane to the continental margin (Csejtey and others, 1982, p. 3747). The miniterranes, the best known of which is the Chulitna terrane (fig. 1), have been interpreted to represent klippen directly tied to a major nappelike structure emplaced along the Talkeetna thrust fault (Csejtey and others, 1978, 1982, 1992). Thus, the Talkeetna thrust fault was interpreted to represent a major terrane boundary that marks the northwest edge of the Wrangellia composite terrane.

Recent geologic mapping along a northwest-trending transect across the Talkeetna Mountains allowed us to examine the Talkeetna thrust fault where it is well exposed. This chapter describes the structural characteristics of the Talkeetna thrust fault and the stratigraphy and sedimentology of footwall strata of the overthrust Late Jurassic and Early Cretaceous Kahiltna assemblage, and discusses the tectonic implications of these observations.

Talkeetna Thrust Fault

The Talkeetna thrust fault, as previously described by Csejtey and others (1982), dips moderately to steeply southeast and everywhere marks the boundary between Triassic and Permian metavolcanic and metasedimentary strata of the

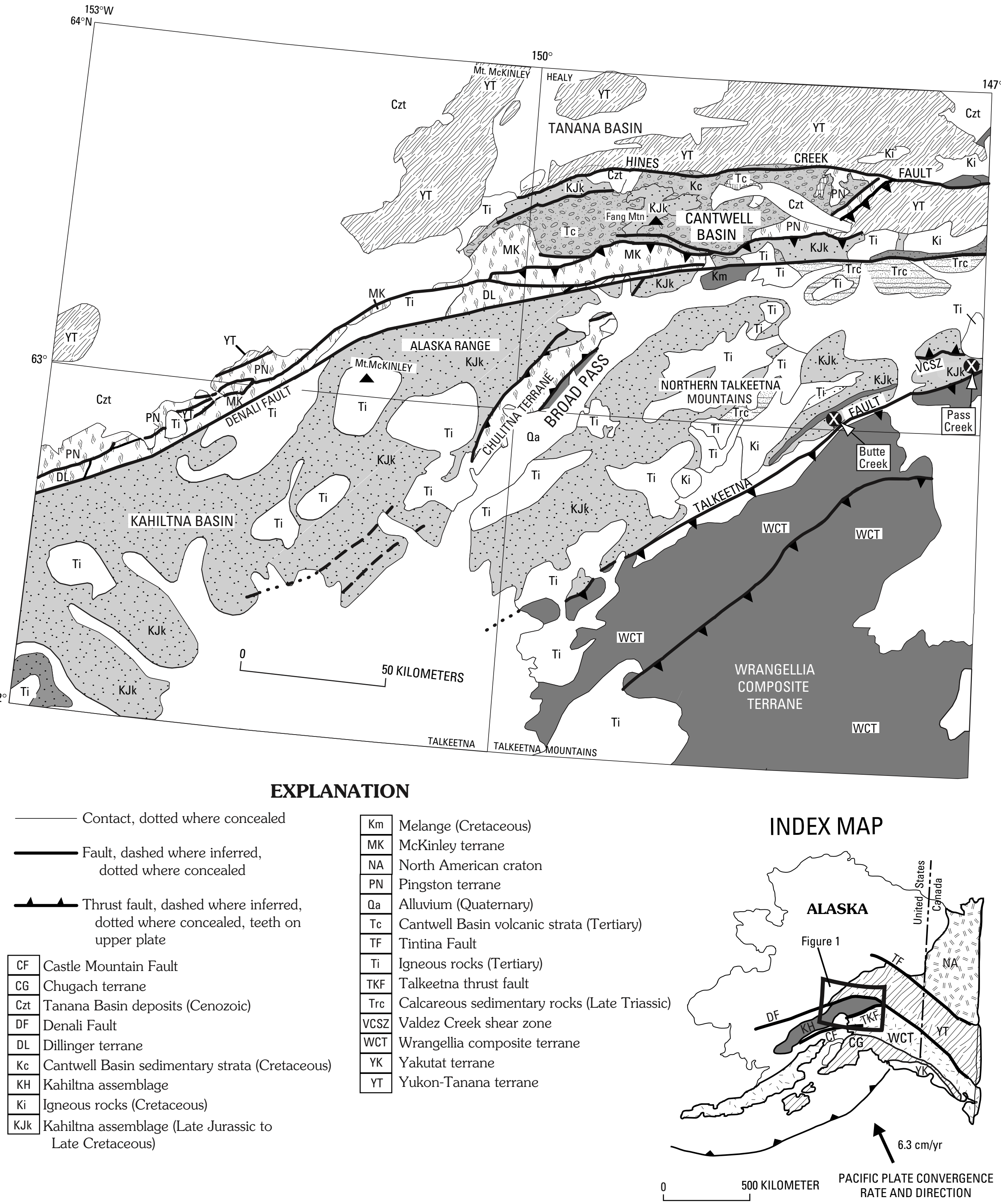


Figure 1. Generalized lithotectonic map of south-central Alaska, showing locations of Butte Creek and Pass Creek study areas.

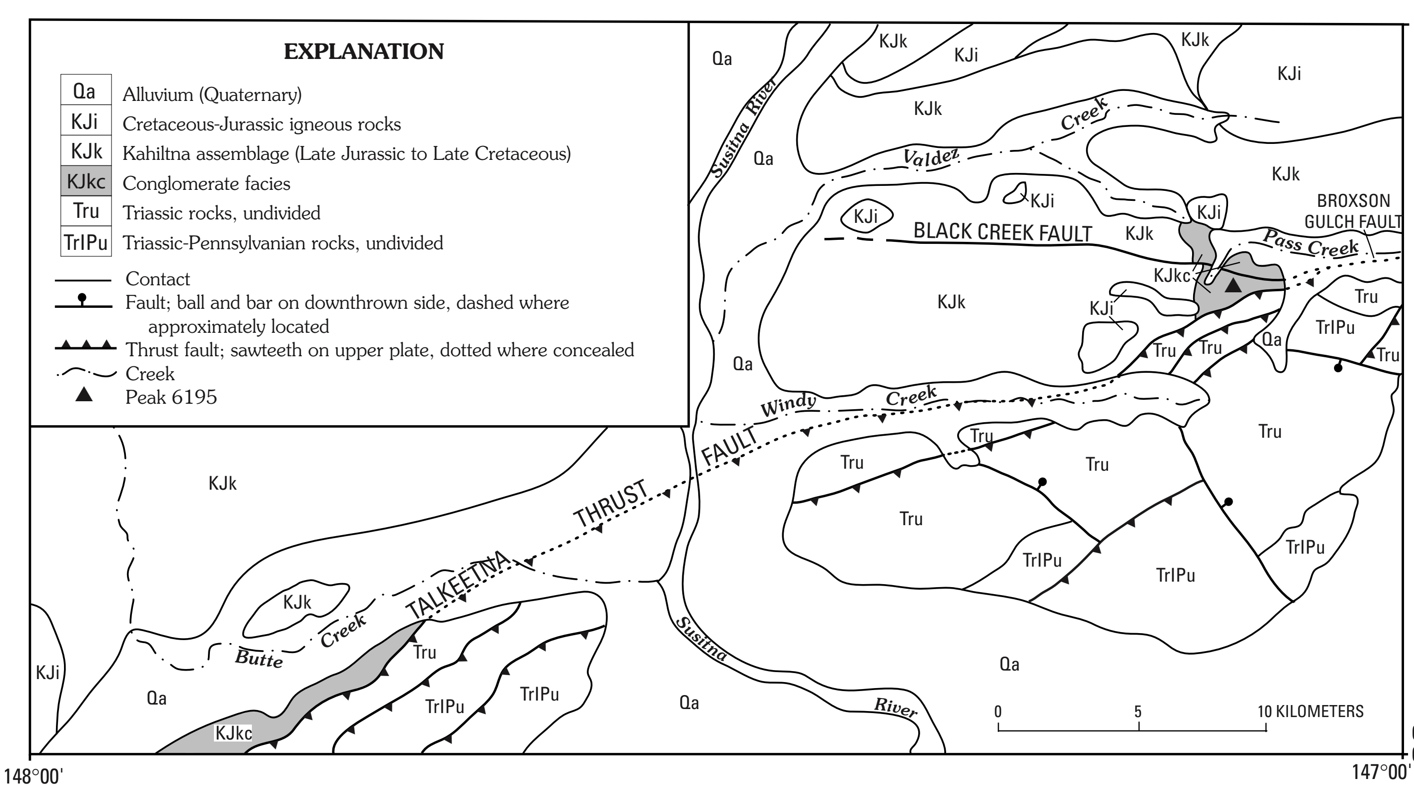


Figure 2. Geologic map of the Butte Creek and Pass Creek study areas, south-central Alaska (modified from Csejtey and others, 1992).

Talkeetna superterrane (Wrangellia composite terrane) on the south and sedimentary strata of the Kahiltna assemblage on the north (fig. 1). The thrust was most recently interpreted to terminate against the younger, north-dipping Broxson thrust fault on the east (fig. 2; Nokleberg and others, 1994). On the west, much of the thrust zone is either intruded by younger plutons and (or) covered by their volcanic counterparts (Csejtey and others, 1978). Complex structural relations are interpreted to exist along this terrane-bounding thrust fault. Csejtey and others (1982) described the thrust zone as a series of southeast-dipping thrust slices that consistently bring older rocks of the Wrangellia terrane over the Kahiltna assemblage. Folds associated with the thrust fault are tight to isoclinal and verge northwest. About 40 to 80 km northwest of the mapped trace of the Talkeetna thrust fault are exposures of Triassic and older rocks interpreted to be crustal blocks (miniterranes) derived from the Wrangellia terrane by displacements along the Talkeetna thrust system. The allochthonous miniterrane interpretation requires that a 6-km-thick nappelike structure consisting of an imbricate stack of thrust slices with north-westward-directed tectonic transport of as much as 80 km be emplaced above strata of the Kahiltna Basin (Csejtey and others, 1982, figs. 5–7). Displacement along the Talkeetna thrust fault and deformation of the Wrangellia terrane and the adjacent Kahiltna assemblage was interpreted as a mid-Cretaceous and Late Cretaceous event that accreted the Wrangellia composite terrane to Alaska.

Geologic Observations of the Talkeetna Thrust Fault and the Kahiltna Assemblage

The Talkeetna thrust fault and associated footwall rocks are largely covered by Tertiary and Quaternary valley-fill sedimentary deposits along most of its length. The thrust fault is best exposed directly south of Butte Creek in the Healy and Talkeetna Mountains quadrangles, and in the Clearwater Mountains to the east at the headwaters of Pass Creek (fig. 1).

Butte Creek Area

Structural Geology

The Talkeetna thrust fault is exposed in the rugged mountains directly south of Butte Creek in the southeastern part of the Healy and adjacent Talkeetna Mountains quadrangles (Smith and others, 1988), where it can be traced for about 8 km (fig. 2). Hanging-wall rocks consist of Triassic mafic metavolcanic flows, gabbroic sills, and interlayered Triassic fine-grained clastic and carbonate rocks. The footwall rocks consist of Jurassic and Cretaceous sedimentary strata consisting of about 75 m of interbedded shale, siltstone, sandstone, and marl that overlie more than 500

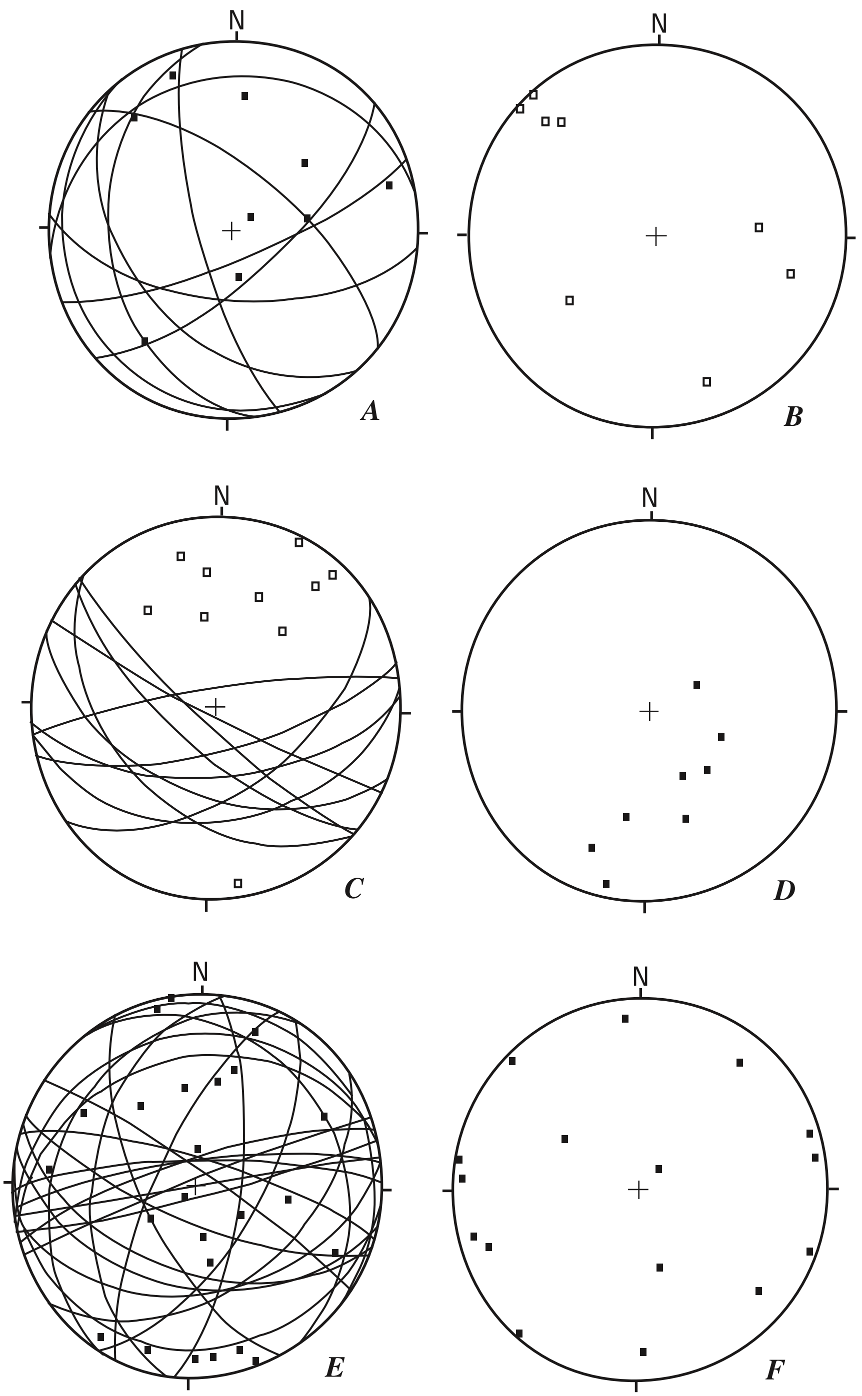


Figure 3. Lower-hemisphere, equal-area stereographic projections showing orientation of fabric elements in Butte Creek and Pass Creek study areas (figs. 1, 2). *A*, Orientation of secondary fractures (planes and poles to those planes; *n*=9) in footwall rocks adjacent to the Talkeetna thrust fault at Butte Creek. *B,* Orientation of slickenlines on fractures (*n*=8) in footwall rocks at Butte Creek. *C*, Orientation of secondary fractures (planes and poles to those planes; *n*=10) in footwall rocks associated with the Talkeetna thrust fault at Pass Creek. *D*, Orientation of slickenlines associated with fractures (*n*=8) at the Talkeetna thrust fault at Pass Creek. *E*, Orientation of fractures (planes and poles to those planes; *n*=24) associated with the Black Creek Fault/Broxson Gulch thrust fault zone. *F*, Orientation of slickenlines on fractures (*n*=17) in the Black Creek Fault/Broxson Gulch thrust fault zone.

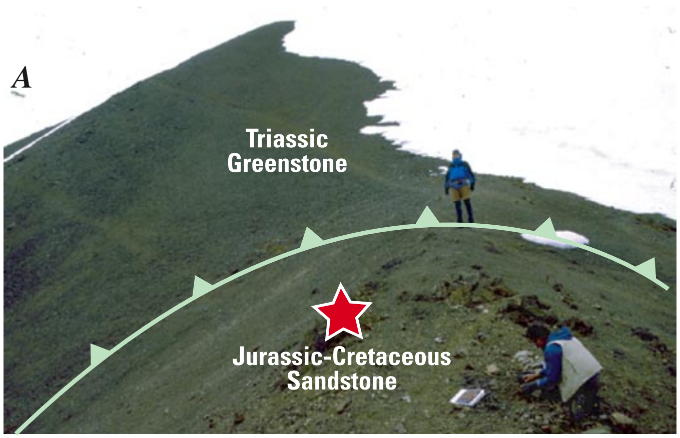
m of pebble to boulder conglomerate. The thrust fault dips gently to moderately south-southwest in this area. Secondary fractures in footwall rocks containing slickenlines on their surfaces are variously oriented; most fractures dip moderately southwest (fig. 3*A*). The fractures are associated with a poorly developed cleavage that consistently strikes east-northeast and dips steeply southeast. Slickenlines are predominantly subhorizontal, and their azimuth and associated Reidel shears indicate tectonic transport to the northwest (fig. 3*B*). Bedding in the fine-grained clastic strata directly beneath the hanging wall is weakly to moderately folded about axes that plunge gently southwest. A 1- to 3-m-thick bed of marl about 20 m below the main fault contains abundant undeformed pelecypods of Cretaceous age (fig. 4). Folding, fracturing with slickenlines, and cleavage are confined to beds within 50 m of the thrust fault; the underlying conglomerate is essentially undeformed (fig. 5). At this locality the overall structural characteristics of the rocks 0 to 20 m directly below the thrust fault show an absence of intense, penetrative deformation.

Kahiltna Assemblage

The Kahiltna assemblage in the Butte Creek area directly below the Talkeetna thrust fault consists of three dominant lithofacies: (1) pebble to boulder conglomerate, (2) horizontally stratified sandstone, and (3) laminated siltstone (fig. 6).

The conglomerate lithofacies forms discontinuous lens-shaped packages of conglomerate and finer grained rocks that are 20 to 50 m long and as much as 25 m thick. Internally, this lithofacies consists of normally graded, moderately sorted conglomerate in 0.5- to 1.5-m-thick beds that fine upward into siltstone (for example, 200–216 m, fig. 6). The conglomerate is clast supported and contains subrounded pebbles and cobbles. The conglomerate lithofacies is commonly interbedded with laminated

A



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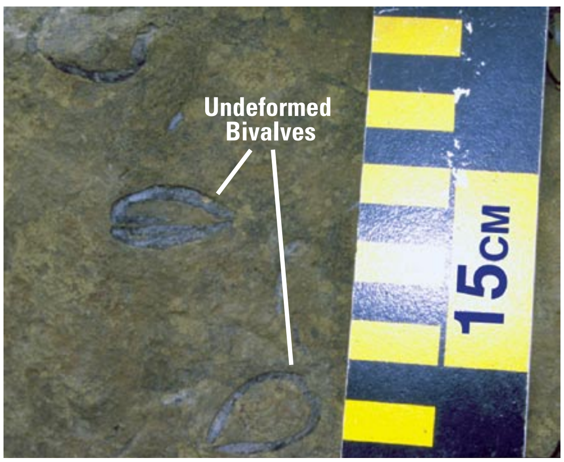

Figure 4. Talkeetna thrust fault in Butte Creek study area, south-central Alaska (figs. 1, 2). *A*, Trace of fault, showing Triassic greenstone structurally overlying Jurassic-Cretaceous sandstone. *B*, Marl of the Kahiltna assemblage and enclosed, undeformed pelecypod bivalves.

Figure 5. Conglomerate of the Kahiltna assemblage (undeformed volcanic-rock and limestone clasts) at Butte Creek (figs. 1, 2). Pen is 14 cm long.

siltstone and shale sequences that are tens of meters thick (230–297 m, fig. 5). The normal grading, overall grain size, and moderate sorting of rocks in the conglomerate lithofacies all suggest deposition from gravelly to sandy turbidity currents. Clast grading probably resulted from decreasing current velocity, which allowed progressively smaller clasts to settle (for example, Hein, 1982). Imbrication of clasts is rare in these conglomerate beds. Also present in the Butte Creek section are nongraded, laterally discontinuous lenses of boulder conglomerate (308–334 m, fig. 6) that contain poorly sorted, subangular clasts ranging in size from 0.1 to more than 7 m across. Because of the wide range of clast sizes (especially the very large clasts), the angularity of the clasts, and the absence of grading, we interpret these deposits as submarine rockfalls and (or) avalanche and debris flows that formed in the proximal part of a submarine-fan system, adjacent to submarine canyons (for example, Lowe, 1982; Stow and others, 1996).

The sandstone lithofacies is fine to coarse grained and is commonly part of upward-fining packages. Beds range in thickness from 10 to 50 cm and typically display sharp bases. Horizontal stratification is the most common sedimentary structure observed in the sandstone beds (360–429 m, fig. 6). According to Bouma's (1962) classification for turbidite deposits, the sandstone beds are described as Ta (massive, graded sandstone), Tab (Ta unit overlain by horizontally laminated sandstone), and Tabd (Tab unit overlain by laminated siltstone and mudstone). Well-preserved pelecypods (*Buchia*) and ammonites were collected 525 m above the base of the section in the sandstone lithofacies.

The siltstone lithofacies is laminated (0–54, 230–297, 476–522 m, fig. 5). We interpret this lithofacies to indicate pelagic sedimentation and (or) very fine grained, low-density turbidity-current deposition (Bouma, 1962).

Clast composition changes upsection in conglomerate beds of the Butte Creek section. In the lower part of the section, clasts consist mainly of black argillite (53 volume percent), gray limestone (22 volume percent), and siltstone (11 volume percent) (fig. 7*A*); in the middle of the section, clasts consist mainly of gray limestone (86 volume percent) and black argillite (9 volume percent) (fig. 7*B*); and in the uppermost part of the section, clasts consist mainly of greenstone (60 volume percent) and chert (17 volume percent) chert clasts (fig. 7*C*). We interpret the upsection clast-compositional trend from argillite through limestone to volcanic rock (greenstone) dominated as representing the progressive unroofing of the nearby Wrangellia terrane (northern part of the Wrangellia composite terrane). The Wrangellia terrane consists of more than 3,000 m of middle and (or) Late Triassic volcanic rocks (Nikolai Greenstone), overlain by 1,100 m of Upper Triassic carbonate strata (Chitistone and Nizina Limestones) and capped by 600 m of Upper and Lower Triassic to Jurassic argillite (McCarthy Formation). These rocks are exposed in the hanging wall of the Talkeetna thrust fault (Csejtey and others, 1978, fig. 1).

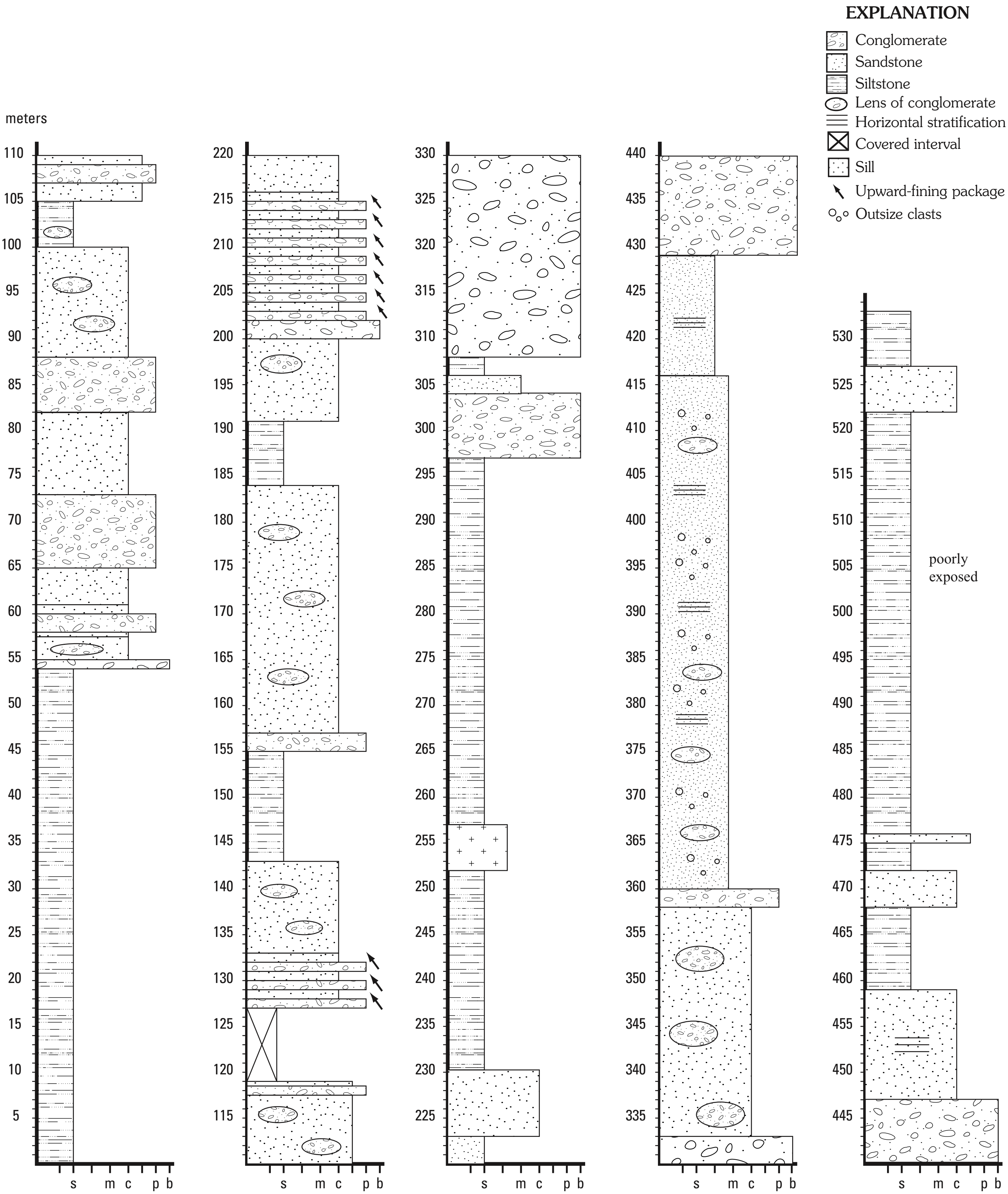

Figure 6. Measured stratigraphic section at Butte Creek (figs. 1, 2) Rock types: b, boulders; c, coarse-grained sandstone; m, medium-grained sandstone; p, pebbles; s, siltstone.

Pass Creek Area

Structural Geology

The Talkeetna thrust fault is not exposed between the Butte Creek area and the Pass Creek area in the Clearwater Mountains to the east, a distance of nearly 45 km (fig. 1). In the Pass Creek area, the trace of the thrust is exposed over a distance of about 8 km between Windy Creek and Pass Creek (fig. 2). The thrust trends east-northeast in this area and, on the northeast, joins the buried trace of the Broxson Gulch thrust fault of Nokleberg and others (1994); the nature of this join is unknown because it is concealed beneath surficial deposits of Pass Creek. Nokleberg and others (1994) interpreted the Broxson Gulch thrust fault to truncate the Talkeetna thrust fault at Pass Creek but did not locate the trace of the Broxson Gulch thrust fault beyond the point of truncation. Silberling and others (1981) mapped the Talkeetna and Broxson Gulch thrust faults as continuous structures within the same thrust zone. A high-angle fault mapped across the southern Clearwater Mountains by Smith (1981) and Adams and others (1991) merges with the Talkeetna thrust fault at Pass Creek. Named the Black Creek Fault by Adams and others (1991), their high-angle fault was later interpreted by Csejtey and others (1992) as a southward-directed reverse fault that truncates the Talkeetna thrust fault.

The Broxson Gulch thrust fault is interpreted to have a long and complex history of movement. To paraphrase Nokleberg and others (1994), the first movement involved thrusting along a south-dipping fault that placed the Wrangellia terrane onto the Kahiltna assemblage in the Maclaran Glacier area (Maclaran terrane of Nokleberg and others). A second period of movement involved strike-slip displacement, followed by a third period of displacement wherein the original south-dipping thrust fault was overturned to a north-dipping structure that then placed rocks of the Wrangellia terrane over Tertiary and Quaternary deposits.

At peak 6195 (fig. 2), directly south of Pass Creek, are two faults with completely different displacement histories. The Talkeetna thrust fault is clearly an east-northeast-trending fault that places older Triassic metasedimentary and metavolcanic rocks on coarse conglomerate of the Kahiltna assemblage (Silberling and others, 1981; Smith, 1981; Adams and others, 1991). The fault dips moderately south; associated fractures in the upper and lower plates dip moderately to steeply southward (fig. 3*C*). Slickenlines consistently plunge downdip (fig. 3*D*), and associated kinematic indicators show tectonic transport nearly due northward. Deformation of upper- and lower-plate rocks is restricted to brecciation at the fault contact, decreasing outward into minor folding and fracturing within 20 m of the fault trace. Minor northward-directed bedding-plane slippage is present locally at greater distances beneath the thrust fault. Evidence of stretching or flattening of conglomerate clasts is absent in the underlying Kahiltna assemblage.

At peak 6195 (fig. 2), the Broxson Gulch fault (Black Creek Fault of Adams and others (1991) and the unnamed fault of Smith (1981) form a zone of shearing and brecciation, as much as 200 m wide. The Kahiltna assemblage is present on both sides of the fault zone. Fractures with slickensided surfaces within this zone range in attitude from subhorizontal to steeply inclined in this east-trending fault zone (fig. 3*E*). The fault zone is marked by major topographic breaks and strongly brecciated and broken, limonite-stained rock where it crosses glacial arêtes at peak 6195. Similar topographic breaks persist for 15 km westward, where the fault zone cuts through strongly glaciated terrane before it apparently dies out in the western Clearwater Mountains.

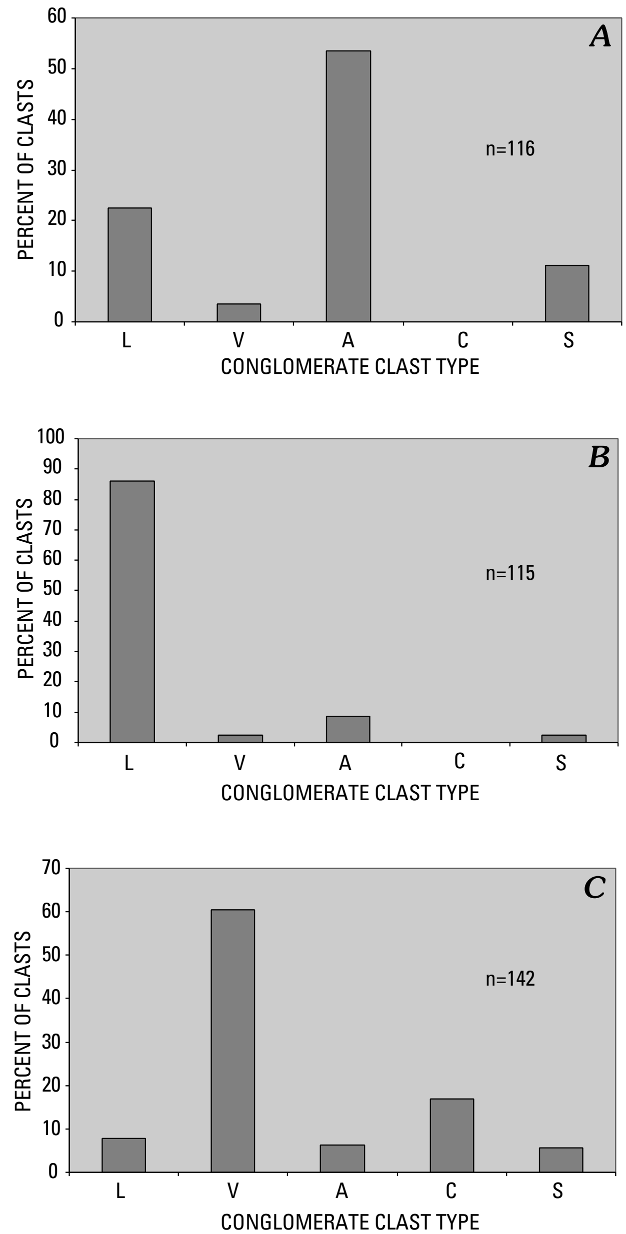

Figure 7. Clast-count data from stratigraphic section at Butte Creek (figs. 1, 2, 6). *A*, 59 m. *B*, 320 m. *C*, 470 m. Clast types: A, argillite; C, chert;, L, limestone; S, siltstone; V, volcanic rocks.

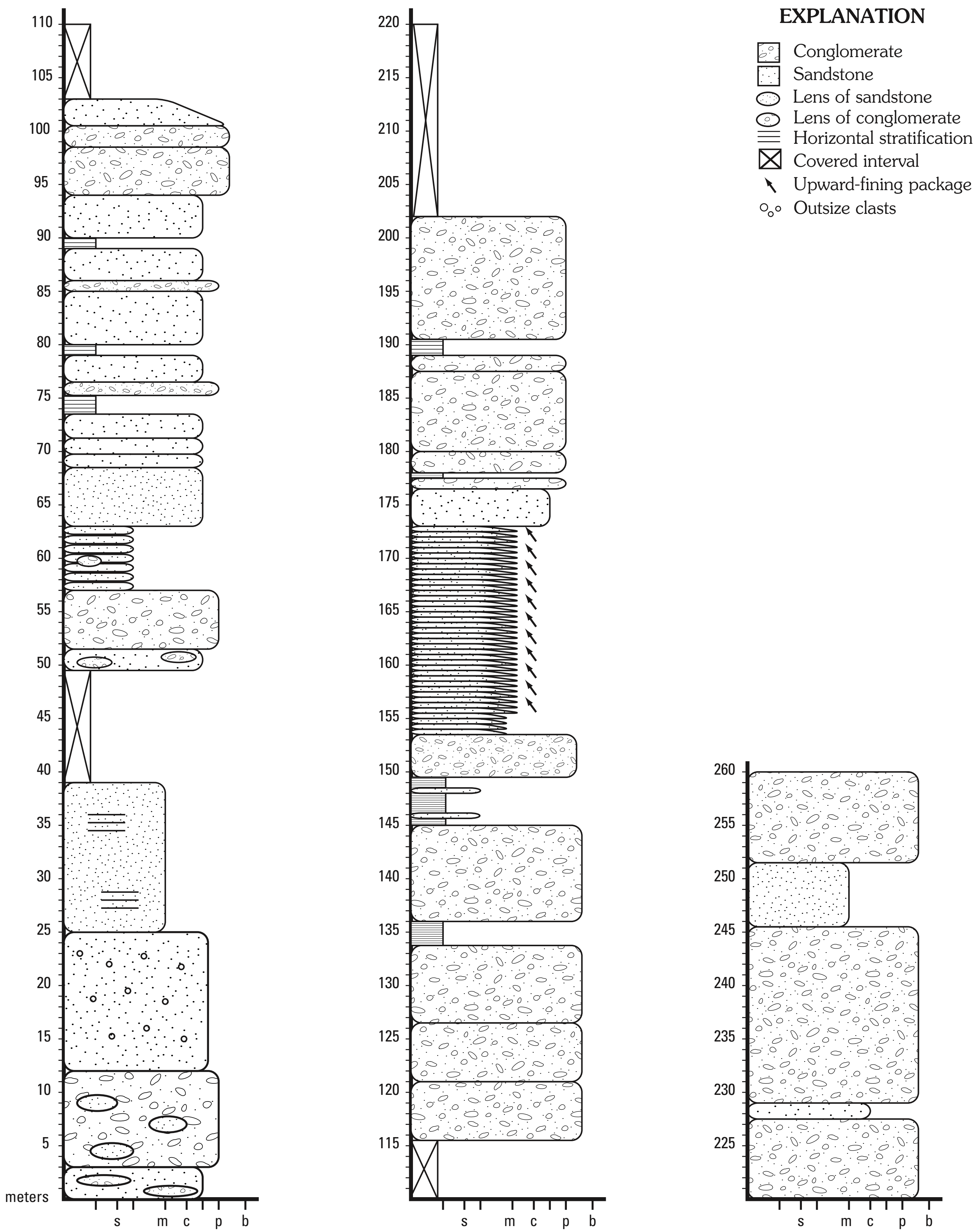

Figure 8. Measured stratigraphic section at Pass Creek (figs. 1, 2). Rock types: b, boulders; c, coarse-grained sandstone; m, medium-grained sandstone; p, pebbles; s, siltstone.

No large displacement was determined for the Broxson Gulch fault. At peak 6195 (fig. 2), conglomerate of the Kahiltna assemblage on the south is juxtaposed variously on the north with conglomerate and finer grained Kahiltna strata. Kinematic indicators—tension gashes, cleavage, and Reidel shears associated with slickensides—are best developed on subvertical surfaces that show strike-slip displacement (fig. 3*F*). Strike-slip displacement is dextral. Moderately north- and south-dipping high-angle faults within the fault zone show normal displacement (fig. 3*F*).

Kahiltna Assemblage

The Kahiltna assemblage in the Pass Creek area of the Clearwater Mountains (fig. 1) is exposed in the footwall of the Talkeetna thrust fault. In the Pass Creek area, the Kahiltna assemblage is similar to that described in the Butte Creek area and consists of the same three dominant lithofacies—pebble to boulder conglomerate, horizontally stratified sandstone, and laminated siltstone. The main difference between the two areas is the greater abundance of the pebble to boulder conglomerate lithofacies in the Pass Creek area (fig. 8). Conglomerate beds in the Pass Creek area do not exhibit the upsection clast-compositional trend characteristic of the Butte Creek area (fig. 7); instead, the conglomerate beds throughout the studied section are dominated by greenstone clasts. As at Butte Creek, the Pass Creek section is interpreted as proximal submarine-fan deposits that were derived from the Wrangellia terrane exposed in the hanging wall of the Talkeetna thrust fault.

Discussion and Conclusion

First, structural and stratigraphic relations at Butte Creek and Pass Creek lead us to conclude that major contractional displacements have not occurred along the Talkeetna thrust fault. The absence of major penetrative deformation associated with the thrust fault in these two areas indicates that displacement along the fault is relatively minor and did not involve shortening measured in tens of kilometers, as suggested by previous workers. The overthrust Kahiltna assemblage represents proximal, synorogenic submarine-fan facies derived from the Wrangellia terrane that is exposed in the hanging wall of the Talkeetna thrust fault. The proximal, coarse conglomeratic Jurassic and Cretaceous Kahiltna assemblage was deposited directly adjacent to the Wrangellia terrane and is still adjacent to that source terrane, even though their present contact is a thrust fault. The composition of conglomerate clasts in the Kahiltna assemblage near Butte and Pass Creeks can be readily matched with lithologies of the Wrangellia terrane in the hanging wall of the Talkeetna thrust fault. In addition, excellent exposures of the Kahiltna assemblage in the footwall of the Talkeetna thrust fault in the Butte and Pass Creek areas show little deformation. We conclude that the Talkeetna thrust fault has undergone relatively minor displacement and does not represent a major tectonic terrane boundary.

Second, displacements on this relatively small thrust fault could not accommodate the tens of kilometers of tectonic transport required to emplace exotic miniterranes 40 to 80 km northwest of the fault trace. The actual join of the Wrangellia composite terrane with the North American craton must be zone located northwest of the Talkeetna thrust fault. Additional fieldwork in summer 2002 has shown that the exotic miniterranes in the northern Talkeetna Mountains south of Broad Pass (fig. 1) are, in fact, parautochthonous basement rocks of Wrangellia affinity that unconformably underlie the Kahiltna assemblage. On the basis of these more recent observations, the miniterranes exposed in the northern Talkeetna Mountains represent uplifted basement rocks of Wrangellia; the actual suture zone between Wrangellia and the North American craton is northwest of the Talkeetna Mountains and, we would suggest, likely underlies Broad Pass.

Third, the Broxson thrust fault of Nokleberg and others (1994) is a younger feature partly superimposed on the Talkeetna thrust fault. Tertiary and Quaternary dextral strike-slip displacements and southward-directed contractional movement along the Black Creek Fault/Broxson Gulch thrust fault suggest that the fault has a strong kinematic tie to the larger and longer right-lateral strike-slip Denali Fault, with which it merges. The Talkeetna thrust fault of Csejtey and others (1992) and the Broxson Gulch thrust fault of Nokleberg and others (1994) are collinear and superimposed on the east; the Black Creek Fault/Broxson Gulch thrust fault truncates the Talkeetna thrust fault at Pass Creek, where it diverges from the trace of the older feature. Thus, the two faults in the Pass Creek area are not kinematically related.

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