The Black Mountain Tectonic Zone—A Reactivated Northeast-Trending Crustal Shear Zone in the Yukon-Tanana Upland of East-Central Alaska

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Abstract

The Black Mountain tectonic zone in the Yukon-Tanana terrane of east-central Alaska is a belt of diverse northeast-trending geologic features that can been traced across Black Mountain in the southeast corner of the Big Delta 1°×3° degree quadrangle. Geologic mapping in the larger scale B1 quadrangle of the Big Delta quadrangle, in which Black Mountain is the principal physiographic feature, has revealed a continuous zone of normal and left-lateral strike-slip high-angle faults and shear zones, some of which have late Tertiary to Quaternary displacement histories. The tectonic zone includes complexly intruded wall rocks and intermingled apophyses of the contiguous mid-Cretaceous Goodpaster and Mount Harper granodioritic plutons, mafic to intermediate composite dike swarms, precious metal mineralization, early Tertiary volcanic activity and Quaternary fault scarps. These structures define a zone as much as 6 to 13 kilometers (km) wide and more than 40 km long that can be traced diagonally across the B1 quadrangle into the adjacent Eagle 1°×3° quadrangle to the east. Recurrent activity along the tectonic zone, from at least mid-Cretaceous to Quaternary, suggests the presence of a buried, fundamental tectonic feature beneath the zone that has influenced the tectonic development of this part of the Yukon-Tanana terrane. The tectonic zone, centered on Black Mountain, lies directly above a profound northeast-trending aeromagnetic anomaly between the Denali and Tintina fault systems. The anomaly separates moderate to strongly magnetic terrane on the northwest from a huge, weakly magnetic terrane on the southeast. The tectonic zone is parallel to the similarly oriented left-lateral, strike-slip Shaw Creek fault zone 85 km to the west.

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Introduction

The Black Mountain tectonic zone, recently recognized and mapped in the Big Delta B–1 quadrangle, east-central Alaska, lies within the Yukon-Tanana Upland (YTU) (fig. D1; see also fig. 1 of the Editors' Preface and Overview). The YTU is restricted to the terrane between the Tintina and Denali dextral-slip fault zones and extends from central Alaska eastward into Yukon, Canada. The YTU is underlain mainly by complexly deformed greenschist to amphibolite-grade metamorphic rocks at least as old as Middle Devonian. The supracrustal metasedimentary and metavolcanic Paleozoic units were intruded during the Devonian by plutonic rocks of intermediate composition, which are now preserved as augen and biotite orthogneiss. After the tectonic assembly of the Paleozoic units during the regional early Mesozoic deformation, Jurassic, Cretaceous, and Tertiary plutonism flooded the area with mainly granodioritic batholiths (Dusel-Bacon and others, 2002).

The YTU between Fairbanks and Tok is cut by four prominent northeast-trending lineaments (Wilson and others, 1985). One such lineament is the Shaw Creek fault (fig. D1), a major left-lateral strike-slip fault that cuts across the Salcha River gneiss dome (Foster and others, 1979; Werdon and others, 2004). Two other lineaments to the east, the Sixtymile and Tok, are recognized by the alignment of physiographic features, mainly stream drainages and topographic highlands. The Mount Harper lineament, about 100 kilometers (km) east of the Shaw Creek fault and confined mainly to the Eagle 1°×3° quadrangle, directly east of the map area (see fig. D2), consists of mapped segments of faults, stratigraphic breaks, and physiographic alignments (Foster, 1976). The Mount Harper lineament appears to separate domains that have characteristic geochronologic signatures; Jurassic plutons do not occur west of this lineament (Foster, 1976).

The YTU between Fairbanks and Tok also is bisected by a major linear magnetic anomaly located between the Shaw Creek and Mount Harper lineaments (Saltus and Day, 2006). A steep, pronounced, northeast-trending magnetic gradient,

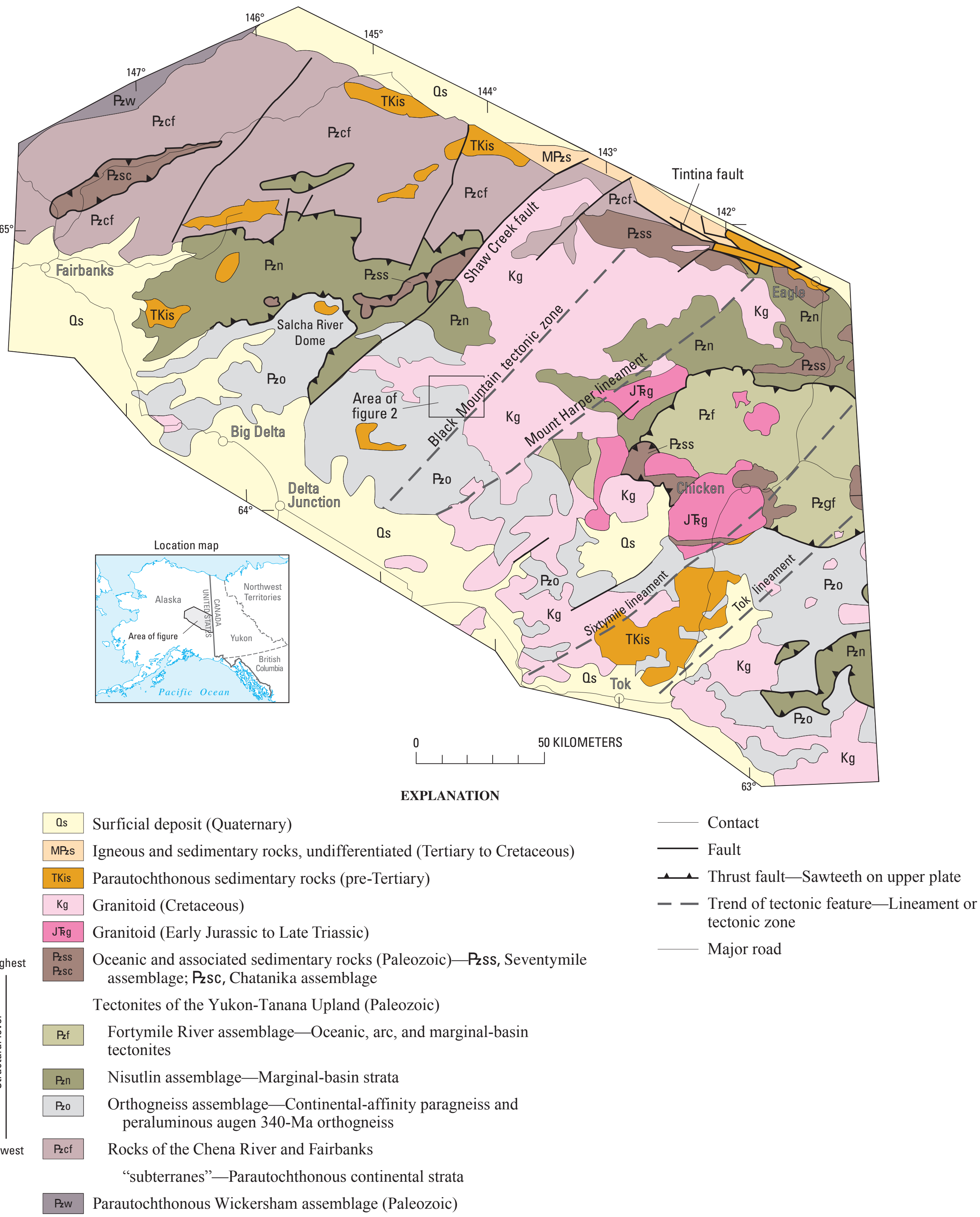
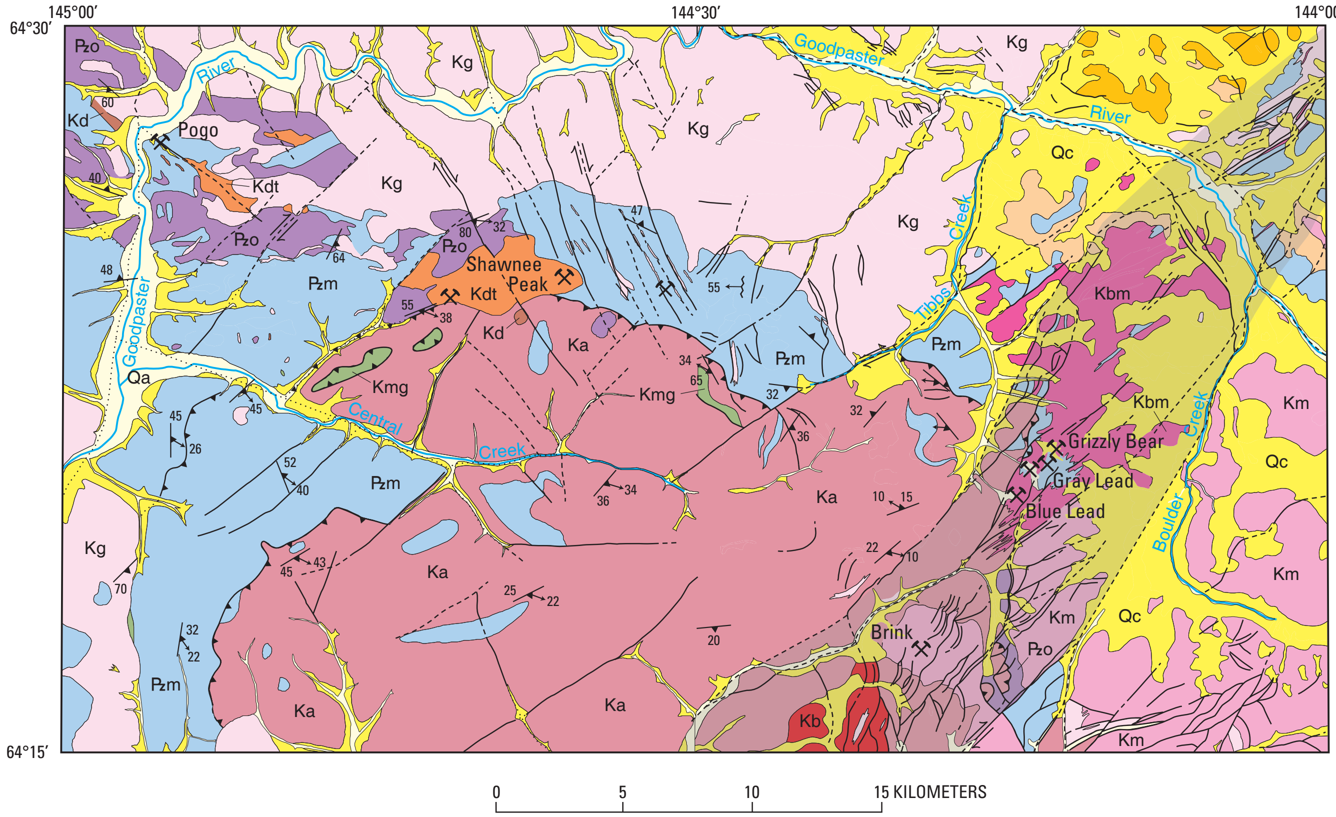


Figure D1. Simplified geologic map showing tectonic assemblage of the Yukon-Tanana tectonostratigraphic terrane of east-central Alaska. Shows approximate outline of map area (fig. D2), and location of major northeast-trending lineaments of Wilson and others (1985). Modified from Hansen and Dusel-Bacon (1998).



EXPLANATION

Qa	Alluvium (Quaternary)
Qc	Colluvium (Quaternary)
Tr	Rhyolite (Paleocene)
Tg	Gravel (Paleocene)
Kg	Granite, undifferentiated (Late Cretaceous)
Km	Rocks of the Mount Harper batholith (Late Cretaceous)
Kbm	Rocks of the Black Mountain intrusion (Late Cretaceous)
Kb	Rocks of the Brink intrusion (Late Cretaceous)
Kdt	Diorite and tonalite (Late Cretaceous)
Ka	Augen gneiss (Devonian)
Kd	Diorite gneiss (Paleozoic)
Kmg	Mafic and ultramafic gneiss (Paleozoic)
Pzo	Orthogneiss (Paleozoic)
Pzm	Metasedimentary rock, undivided (Paleozoic)
	Black Mountain tectonic zone—Shown by gray tint

Fault—Dashed where approximately located, dotted where inferred. Arrows show sense of relative horizontal movment, where known

Thrust fault—Teeth on upper plate. Dashed where approximately located, dotted where inferred

20 Strike and dip of foliation

22 Trend and plunge of mineral lineation

55 Trend and plunge of minor fold

Gold deposit or occurence

Location map

Figure D2. Simplified geologic map of the Big Delta B–1 and B–2 quadrangles, east-central Alaska, showing location of gold mines and prospects and the surficial expression of the Black Mountain tectonic zone (shaded area).

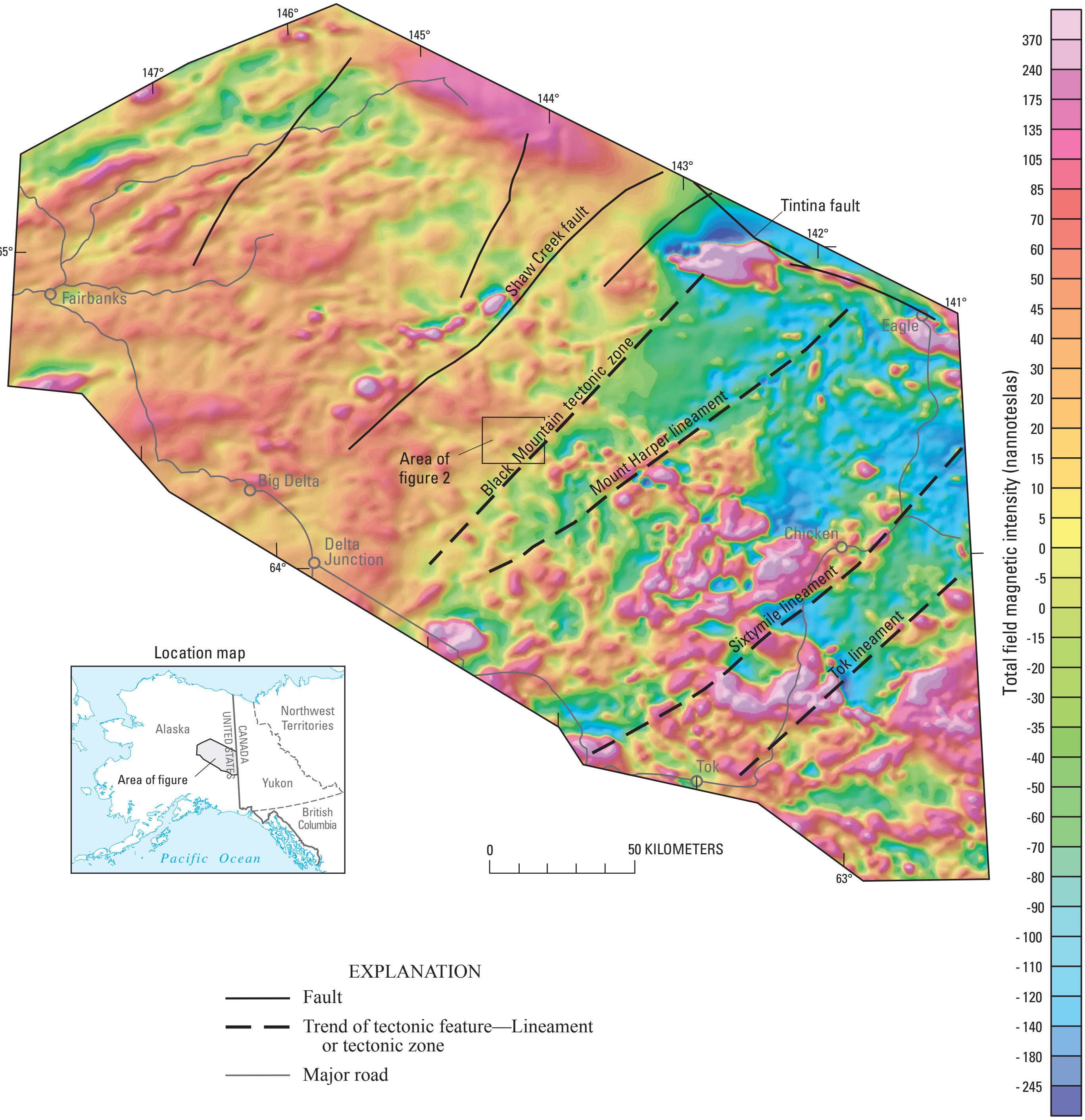


Figure D3. Regional aeromagnetic map of the Yukon-Tanana Upland of east-central Alaska showing location of the Black Mountain tectonic zone.

representing a 20-nanotesla (nT) step in mean magnetic anomaly values (as measured at a flight height of 300 meters, m) with higher values to the northwest, extends from the Denali fault to the Tintina fault and bisects the YTU (Saltus and Day, 2006) (fig. D3). In addition to the difference in mean values, there are distinct differences in the statistical character of the magnetic field on each side of the gradient, indicating that it is a fundamental boundary between magnetic source domains. Preliminary modeling of the magnetic boundary suggests that it represents a steeply east-dipping zone between contrasting crustal blocks that extend throughout the middle and lower crust (Saltus and Day, 2006). A gravity gradient coincides with a portion of the magnetic gradient in the Big Delta B–1 quadrangle (Saltus and Day, 2006; fig. D3). This gravity gradient is the eastern boundary of a 30-milligal (mGal) residual gravity high that occupies much of the western and central portions of the Big Delta B–1 quadrangle. The adjacent lower gravity values to the east correlate, at least in part, with mapped postmetamorphic granitic rocks. Preliminary modeling of the gravity boundary suggests it also dips to the east as inferred for the magnetic feature (Saltus and Day, 2006). If a density contrast of 200 kilograms per cubic meter (kg/m^3) is assumed between the granitic intrusion (lower density) and the adjacent metamorphic rocks, the preliminary models suggest that the density contrast persists to depths of at least 8 km.

Geologic investigations in the Black Mountain area reveal a northeast-trending structural corridor, recognized as the Black Mountain tectonic zone by O'Neill and others (2005) (figs. D2 and D3), that coincides with the prominent magnetic and gravity anomalies described by Saltus and Day (2006). The tectonic zone and its associated faults and shear zones controlled the emplacement of Cretaceous (113–110 million years before present, Ma) granitoids and related felsic dikes, sills, elongate plugs, and quartz vein systems that carry gold deposits and occurrences. This high-angle tectonic zone formed a conduit along which subsequent basaltic to dioritic (109 Ma) dikes and dike swarms were emplaced and controlled the location and emplacement of a sulfide-bearing subvolcanic quartz-feldspar porphyry stock (99–95 Ma), and controlled the development of a Paleocene (57 Ma) rhyolite flow-dome complex. Reactivation and deformation along the Black Mountain tectonic zone has offset perched Tertiary erosion surfaces, and most recently, cut Quaternary alluvial deposits, indicating that tectonic activity along the zone is long-lived, complex, and ongoing (Day and others, 2007).

Black Mountain Tectonic Zone

Four distinct tectonic events are recorded in the bedrock of the Big Delta B–1 quadrangle that can be correlated to major regional magmatic-tectonic events that affected the YTU—Devonian (D_1) arc-related plutonism, Jurassic to Early Cretaceous (D_2) dynamothermal convergent tectonism, Early Cretaceous (D_3) ductile-brittle deformation and plutonism, and Paleocene to present (D_4) uplift and high-angle, northeast- and northwest-striking faulting related to strike-slip displacement on the Tintina-Denali fault systems. The third and fourth major tectonic events (D_3 and D_4) were concurrent with deformation observed in the 6.5- to 13-km-wide, northeast-trending Black Mountain tectonic zone.

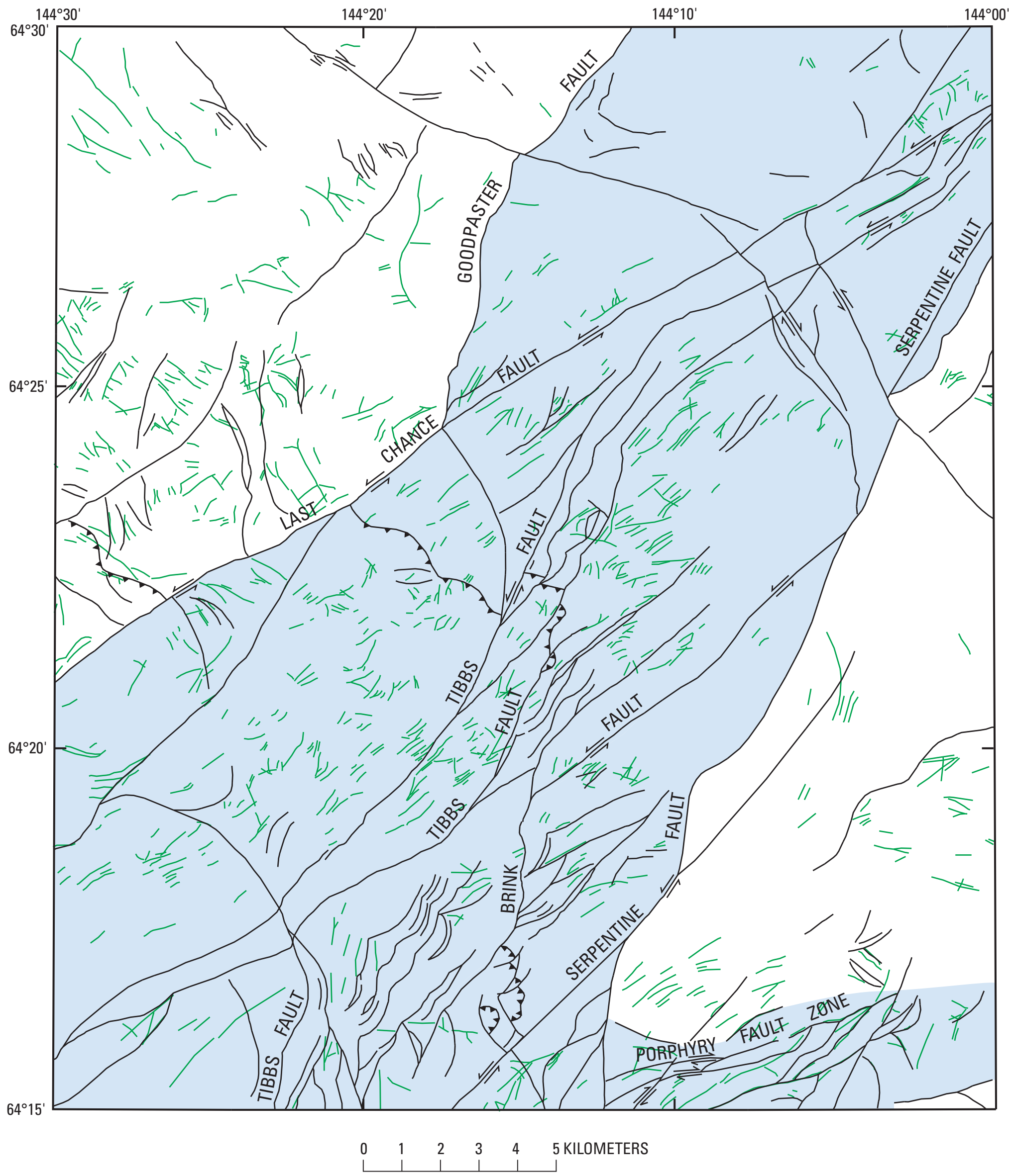
The tectonic zone in the Big Delta B–1 quadrangle consists of five major left-lateral strike-slip faults spaced 1.6 to 4.8 km apart; they are, from west to east: the Last Chance-Goodpaster, Tibbs, Brink, and Serpentine faults, and the east-northeast-striking Porphyry fault zone (fig. D4). All faults strike northeast and have conspicuous left-stepping fault segments that accommodated extension along their traces.

Last Chance-Goodpaster Fault System

The Last Chance fault system marks the western boundary of the tectonic zone (fig. D2). The fault follows the northeast-trending Last Chance Creek on the southwest to Tibbs Creek, where a splay of the fault, the Goodpaster fault segment, steps left and trends north, following the creek to its intersection with the Goodpaster River. The eastern extent of the Last Chance fault system trends northeast to the map boundary, whereas the main strand of the fault trends north from Tibbs Creek to the northeastern corner of the map area. The Last Chance fault is a strike-slip structure and shows more than 4.8 km of sinistral displacement. On the northeast, the fault is marked by wide zones of shearing, by thin vertical screens of strongly deformed Paleozoic strata, and by dioritic to felsic dikes and dike swarms emplaced about 108 Ma. The area between the Goodpaster segment of the fault and the Last Chance fault on the north is unique; it is a graben underlain mainly by a Paleocene rhyolite flow-dome complex and is restricted to this part of the map area. The rhyolitic rocks were later partly covered and concealed by locally derived boulder gravel deposits of mid-Tertiary age. The Last Chance fault bounds the main body of the Black Mountain intrusive complex, a mixed granitic to granodioritic plutonic system, 109 to 107 Ma, confined to the core of the tectonic zone. No rocks related to the Black Mountain intrusive complex and no northeast-trending faults of significant size and magnitude are present northwest of this fault system (Day and others, 2003, 2007). The Last Chance fault separates markedly different rock types in the north part of the map area where Tertiary volcanic rocks and their extrusive centers on the east are juxtaposed against the Cretaceous Goodpaster batholith.

Tibbs Fault

The Tibbs fault is a complex structure within the tectonic zone. The Tibbs fault includes several interconnected splays along its central part characterized by a 1.6-km-wide zone of oblique-slip faulting and shearing. The Tibbs fault is subparallel to the Last Chance fault and, like the Last Chance fault, is a strike-slip structure; however, the Tibbs fault shows only about 1 km of left-lateral displacement. The Tibbs fault also includes left-stepping segments along its trace, the most profound and tectonically significant of which is in the south part of map area. Here the Tibbs fault is north trending and bounds the east margin of the Brink intrusion; this left-stepping segment of the fault accommodated a zone of extension during deformation and is interpreted to have provided a tectonic opening that influenced the localization and emplacement of the 113-Ma Brink granodiorite and its associated base- and precious-metal mineralization. On the northeast, the Tibbs and Last Chance faults are only about 1 km apart and may converge northeast of the map area where coalescing shear zones, dioritic dike swarms, and tectonic screens of strongly deformed Paleozoic strata are abundant.



EXPLANATION

- Black Mountain tectonic zone
- High-angle strike-slip fault or normal fault—For strike-slip faults, arrows show sense of relative horizontal movement
- Thrust fault—Sawteeth on upper plate
- Lineament—Interpreted from aerial photographs

Figure D4. Structural geologic map of the Big Delta B–1 quadrangle showing major high-angle strike-slip and normal faults, thrust faults, and lineaments in the Black Mountain tectonic zone.

Brink Fault

The Brink fault is subparallel to the Tibbs fault and also has a major left-stepping segment along its trace in the southern part of the map area. The fault is clearly a strike-slip structure where a 50-m-wide gouge zone crosses the central part of Black Mountain, and it marks the southeast boundary of the Black Mountain intrusive complex. On the west side of Black Mountain, the fault turns abruptly south into the valley of the headwaters of the South Fork of Goodpaster River; there the fault is a profound down-to-the-west normal fault that is parallel to the left-stepping segment of the Brink fault on the west. In the area between the north-trending Brink and Tibbs fault segments is a leucocratic phase of the

Mount Harper batholith whose intrusion appears to have been accommodated along a pull-apart extensional zone created between these two faults (figs. D2 and D4). In this area only, the about 111 Ma Mount Harper pluton is sill-like, overlain by a metamorphosed, flat-lying carapace of augen gneiss; the pluton and the overlying gneissic rocks are also cut by a young, northeast-trending swarm of predominantly down-to-the-west normal faults that includes numerous small pull-apart grabens. These extensional faults and their scarps indicate ongoing left-lateral displacement and concomitant extension along and between the Tibbs and Brink fault systems (fig. D2). On the north, the Brink fault merges with the Serpentine fault directly south of the Eisenmenger Fork.

Serpentine Fault

The Serpentine fault in the southern part of the map area is marked by the juxtaposition of Paleozoic metasedimentary rocks against Devonian augen gneiss and underlying Devonian orthogneiss along a wide zone of strongly sheared rocks. The fault projects into the broad valley of Boulder Creek, where it is covered by widespread accumulations of Quaternary deposits. It follows Boulder Creek northward to its confluence with the Eisenmenger Fork, where it branches: the main segment continues northeastward across sheared, altered, and displaced metasedimentary and igneous rocks in the northeastern corner of the map; the northwest-trending segment of the fault, marked by normal faults that offset Quaternary deposits, appears to be a left-stepping tectonic link between the Serpentine fault and the converging Tibbs and Last Chance faults. This left-stepping link and the normal faults that define it outline a down-dropped zone of extension that has resulted in a northwest-trending graben that controls the course of the Eisenmenger Fork. Normal faults along the south side of this graben displace both older and younger Quaternary alluvial fan deposits, indicating that deformation along this graben has occurred in the recent past. Young fault displacements farther northwest along the Fork suggest that the tectonic linkage of the Serpentine fault with the Last Chance fault may actually extend farther northwest and connect with the Goodpaster segment of the Last Chance fault. The tectonic linkage of the Serpentine fault with the three strike-slip faults to the northwest, all within the Black Mountain tectonic zone and all accommodated along left-stepping normal fault segments, implies that the faults are coeval, are a part of the same kinematic movement picture, and have been recurrently active since the mid-Cretaceous.

The northernmost segment of the Serpentine fault has a more northerly trend and, like the Tibbs fault, may merge with the Last Chance and Tibbs faults northeast of the map area; the area is unique in that it is the most strongly sheared part of the Black Mountain tectonic zone and is characterized by thin, closely spaced vertical screens of metamorphic tectonites and sheared granodioritic plutonic rocks, all intruded by swarms of vertical dikes of all compositions.

Porphyry Fault Zone

The Porphyry fault zone is marked by a 1-km-wide zone of intense shearing, folding, and faulting, and associated dike swarms. The Porphyry fault zone is confined to rocks of the Mount Harper batholith; although there are no piercing points along the trace of the fault to indicate the magnitude of fault displacements, S-C mylonitic fabric (Lister and Snoke, 1984), and small-scale folds within the fault zone. These mesoscopic features are all consistent with dextral offset. The zone appears to have controlled the intrusion of a subvolcanic 99- to 95-Ma quartz-feldspar porphyry stock where it intersects and merges with the Serpentine fault at an acute angle along the south margin of the map area (fig. D3). This fault zone is marked by abundant normal faults and by swarms of subparallel granitic, aplitic, and pegmatitic dikes. This fault zone is also the locus of many sulfide-bearing dikes of quartz-feldspar porphyry and basaltic composition.

Lineaments

Linear features of various origins, mostly fractures and faults and less commonly dike swarms and geologic contacts, were mapped from aerial photographs of the Big Delta B–1 quadrangle. The major faults of the Black Mountain tectonic zone are visible on aerial photographs as are many of the mapped dike swarms; however, the vast majority of lineaments mapped from aerial photographs are fractures with no obvious offset. These fracture sets and other lineaments are ubiquitous and abundant across the quadrangle (fig. D4) (Day and others, 2007).

The northwest corner of the Big Delta B–1 quadrangle shows lineaments with a somewhat random pattern to preferred northwest-trending orientation. The fracture orientations appear to reflect the northwest-trending tectonic grain of small faults and dikes mapped in the adjacent Big Delta B–2 quadrangle (figs. D3 and D4) (Day and others, 2003).

The Last Chance strike-slip fault and associated Goodpaster fault segment separate the fracture pattern in the northwest corner of the quadrangle from a zone of consistently northeast-oriented fractures and recognizable faults east of the fault. The abrupt change in fracture patterns from random to dominantly northeast-striking across the Last Chance-Goodpaster faults coincides with the northwest boundary of the Black Mountain tectonic zone.

Southeast of the Last Chance fault, the predominant fracture orientation is northeast and continues uninterrupted to the southeast to the Serpentine fault. The width of this zone of consistently oriented fracturing, as much as 13 km wide, is inferred to define the scale, breadth, and tectonic continuity of the Black Mountain tectonic zone. The fracture pattern cuts rocks of the Mount Harper batholith southeast of the Serpentine fault; however, east of this fault, especially east of the Boulder Creek in the east-central part of the quadrangle, the fracture patterns define intermixed, contiguous blocks or domains of randomly oriented fractures separated by northeast-trending zones of mixed fractures and faults.

Summary

Geologic investigations in the Black Mountain area reveal a northeast-trending structural corridor, described herein as the Black Mountain tectonic zone, that consists of five major strike-slip faults, spaced 1.6 to 4.8 km apart (fig. D2). The tectonic zone and its associated faults, fractures, and shear zones controlled the emplacement of 110- to 95-Ma Cretaceous granitoids and related felsic dikes, plugs, and quartz vein systems; formed a conduit along which subsequent basaltic to dioritic dikes and dike swarms were emplaced; and controlled the location and emplacement of a 57-Ma Paleocene rhyolite flow-dome complex erupted during the Paleocene. Reactivation and deformation along the Black Mountain tectonic zone have offset perched Tertiary erosion surfaces, and most recently, cut Quaternary alluvial deposits, indicating that tectonic reactivation of the zone is long-lived, complex, and ongoing. The tectonic zone coincides with fundamental geophysical crustal anomalies, suggesting that it is related to deep-seated crustal discontinuities; the tectonic zone is also a magmatic conduit that has a long-lived intrusive history and has localized gold deposits associated with igneous activity.

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