The Trans–Rocky Mountain Fault System—A Fundamental Precambrian Strike-Slip System

Circular 1334

U.S. Department of the Interior
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Abstract

Recognition of a major Precambrian continental-scale, two-stage conjugate strike-slip fault system—here designated as the Trans–Rocky Mountain fault system—provides new insights into the architecture of the North American continent. The fault system consists chiefly of steep linear to curvilinear, en echelon, braided and branching ductile-brittle shears and faults, and local coeval en echelon folds of northwest strike, that cut indiscriminately across both Proterozoic and Archean cratonic elements. The fault system formed during late stages of two distinct tectonic episodes: Neoarchean and Paleoproterozoic orogenies at about 2.70 and 1.70 billion years (Ga). In the Archean Superior province, the fault system formed (about 2.70–2.65 Ga) during a late stage of the main deformation that involved oblique shortening (dextral transpression) across the region and progressed from crystal-plastic to ductile-brittle deformation. In Paleoproterozoic terranes, the fault system formed about 1.70 Ga, shortly following amalgamation of Paleoproterozoic and Archean terranes and the main Paleoproterozoic plastic-fabric-producing events in the protocontinent, chiefly during sinistral transpression. The postulated driving force for the fault system is subcontinental mantle deformation, the bottom-driven deformation of previous investigators. This model, based on seismic anisotropy, invokes mechanical coupling and subsequent shear between the lithosphere and the asthenosphere such that a major driving force for plate motion is deep-mantle flow.

Introduction

Transcurrent faults, chiefly northwest striking, are fundamental basement structures in the interior of the North American continent (Sims and others, 2008). These faults were developed during Neoarchean and Paleoproterozoic orogenesis. The faults are of particular significance because (1) they were significant structures in the early tectonic evolution of the continent, and (2) they localized much subsequent tectono-magmatic activity, particularly in the Western United States. The Rocky Mountain region provides a natural laboratory for study of the fault system because of abundant exposures of exhumed basement rocks and structural features as well as neofaults formed during reactivation.

The basic concept of transcurrent faulting in the Rocky Mountains and implications for basement control were conceived during early tectonic analyses in the region (Thom, 1923; Chamberlin, 1940, 1945; Sales, 1968; Stone, 1969). The tectonic models of Sales (1968) and Stone (1969), based chiefly on geologic field studies, were prescient in that they related the faults to a regional shear couple associated with northeast-southwest shortening. Chamberlin (1940, p. 698) proposed a geometric analogy with structures associated with the San Andreas fault system in California. Baars and others (1995) also recognized the geometric similarity of the Trans–Rocky Mountain fault system to the San Andreas fault system. The work of Stone (1969), in particular, established wrench faulting qualitatively as the causal mechanism for the transcurrent fault system in the Rocky Mountain region.

This paper is an outgrowth of preparation of regional geologic maps of the Precambrian basement in the Western United States (for Wyoming and Colorado, Sims and others, 2001; for Montana, Sims and others, 2002, 2004; for Idaho, Sims and others, 2005) followed by preparation of a Precambrian structure map of the continental United States (Sims and others, 2008). The basement mapping relied heavily on interpretation of regional aeromagnetic-anomaly maps (North American Magnetic Anomaly Group, 2002). The purpose of this paper is to describe general aspects of the fault system, including its characteristics and regional extent, with emphasis on the Rocky Mountains, and to provide a background needed for more rigorous future kinematic and geochronologic studies. I propose that the deformation resulted from subcontinental mantle deformation, in a manner discussed by Tikoff and others (2002, 2004) as bottom-driven deformation.

Geologic Framework

The Rocky Mountains are spectacular ranges in the western part of the continental United States (fig. 1) that characteristically have Precambrian cores (Reed and others, 1987). The Precambrian rocks form a continuous basement that is covered in intervening basins by sedimentary rocks of Mesoproterozoic, Neoproterozoic, Paleozoic, and Late Cretaceous–Tertiary age, and volcanic rocks of Tertiary and Quaternary age. These basement rocks are intruded at places by late Mesozoic and Tertiary granitic intrusions. The basement rocks were deformed by regional tectonic events in Archean and Paleoproterozoic times. The basement and overlying rocks have been deformed subsequently in the Western United States, principally by a late Paleozoic orogeny equated with development of the Ancestral Rocky Mountains (Tweto, 1975; Hamilton, 1981, 1988; Perry and others, 1992; Ye and others, 1996), Cretaceous–Eocene (Laramide) orogeny (Tweto, 1975, 1980a), and differential uplift during the Neogene (Taylor, 1975; Tweto, 1980b), followed by extensive normal faulting (basin-and-range structure) along the western and southern parts of the Rocky Mountain region (fig. 1; Tweto, 1979). The Sevier orogen (Armstrong, 1968), or Cordilleran thrust belt (Powers, 1983), which temporally and spatially overlaps with the Laramide orogen, encroached from a western hinterland (Dickinson, 2001) and disturbed the western margin of the Northern Rocky Mountain Province (Kulik and Schmidt, 1988).

The Precambrian basement terranes in the region consist of the Archean Wyoming province (Houston and others, 1993) and three accretionary Paleoproterozoic ocean-arc terranes (fig. 1). The oldest of these, the Trans–Montana orogen (Sims and others, 2002, 2004), coincides approximately with the previously designated Great Falls tectonic zone of O'Neill and Lopez (1985). It was sutured to the northwest margin of the craton at ca. 1.85 Ga as indicated by the age of oceanic arc rocks exposed in the Little Belt Mountains in Montana (fig. 1) (Mueller and others, 2002). The Trans–Hudson orogen (Peterman and Sims, 1993)—not shown in figure 1—was attached to the eastern margin (circa 1.8 Ga) of the Wyoming province craton; and finally the Colorado province (Bickford and others, 1986; Sims and Stein, 2003) was added to the southern margin during the interval 1.78 to 1.70 Ga. Following stabilization of the protocontinent, rocks within the Colorado province (fig. 1) were deformed by intraplate tectonism, designated the Berthoud orogeny (circa 1.7–1.4 Ga; Sims and Stein, 2003), which is expressed by northeast-striking ductile shear zones accompanied by regional thermal metamorphism (Selverstone and others, 1997, 2000) and younger, mainly alkali-calcic plutonism (1.5–1.35 Ga; Anderson and Cullers, 1999; Sims and others, 2001). The Berthoud orogeny was followed abruptly by renewed continent-scale strike-slip faulting in Paleoproterozoic terranes (Sims and Stein, 2003).

Trans–Rocky Mountain Fault System

The Trans–Rocky Mountain fault system is a systematic array of strike-slip shears and faults (fig. 1) of Precambrian ancestry. The system consists chiefly of northwest-striking strike-slip faults, commonly with horizontal displacements of a few to several tens of kilometers (km) (for example, Lewis and Clark line, Wallace and others, 1990; Clearwater shear zone, Sims and others, 2005; J.M. O'Neill, 2007, written commun.), and conjugate north-striking (transfer) faults. Repeated rejuvenation of the faults mainly involved reactivation of discrete preexisting structures, but also involved the development of neoformed offshoots of the preexisting faults, as demonstrated by Bump (2003) for the Laramide orogeny in the Rocky Mountain region.

Magnetic Expression

Individual structures within the Trans–Rocky Mountain fault system are commonly expressed on magnetic-anomaly maps (North American Magnetic Anomaly Group, 2002) by linear negative anomalies, as shown in figure 2, an area typical of the Rocky Mountain region. The shear zones and faults are conspicuous where they transect basement rocks with strong positive magnetism, such as Archean and Proterozoic calc-alkaline granitic plutons, but are less well defined in metamorphosed volcanic and sedimentary country rocks with neutral magnetism. The negative expression mainly results from the destruction of magnetite caused by ductile-brittle shearing and attendant alteration by circulating fluids during retrograde metamorphism (Finn and Sims, 2005). The magnetic expression of the faults indicates that they are deep seated, fundamental fracture zones that transect the basement rocks.

Interpretation of magnetic features is highly subjective, but existing geologic mapping in several areas in the region, such as that shown in figure 3, provides reliable ground truth for most areas. Aeromagnetic-anomaly data provide a means to extrapolate known geology into covered regions.

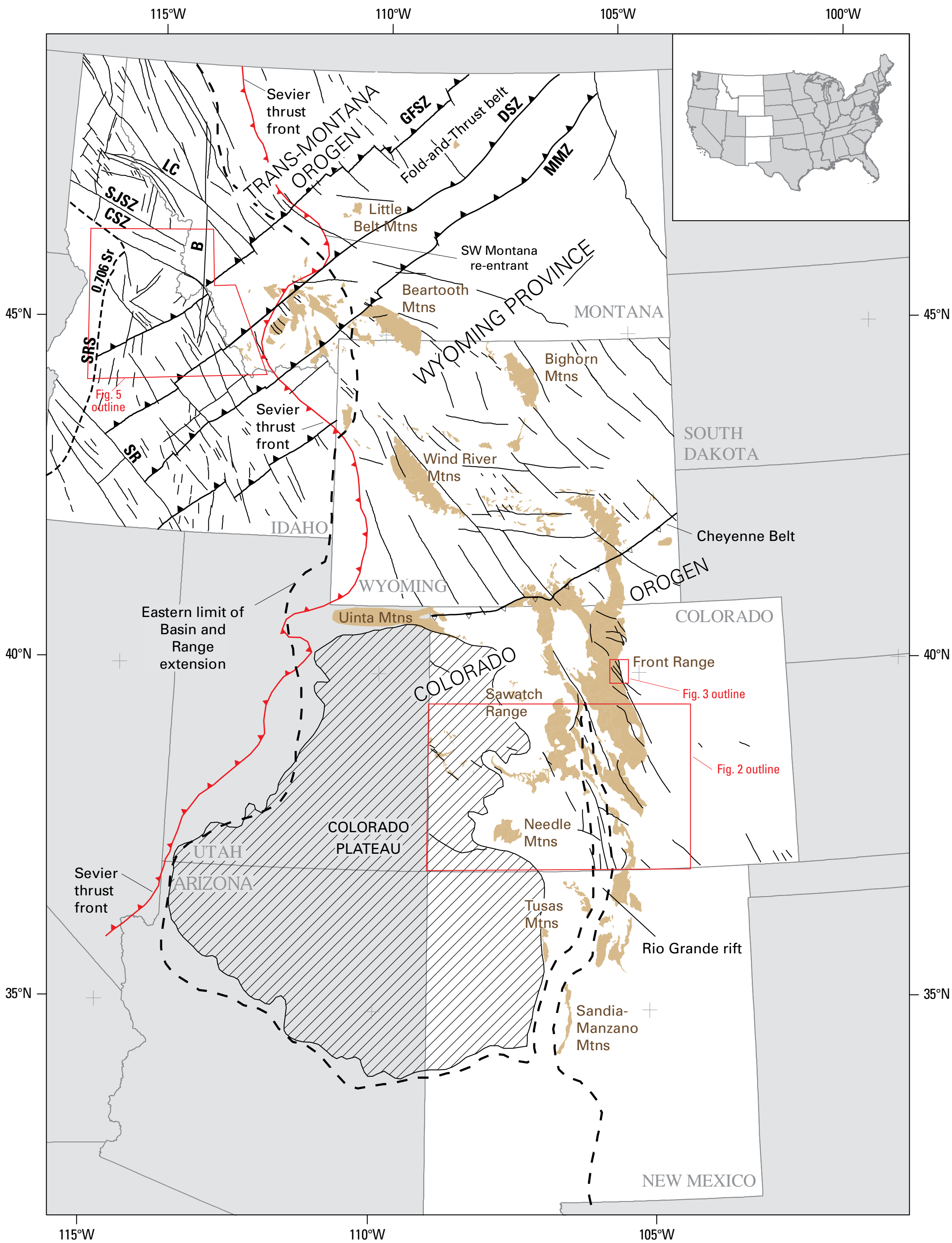

Figure 1. Rocky Mountain region showing relation of Precambrian-cored uplifts to basement faults of the Trans–Rocky Mountain fault system. Small inset map shows location of Rocky Mountain region. B, Bitterroot mylonite zone; CSZ, Clearwater shear zone; DSZ, Dillon shear zone (suture); GFSZ, Great Falls shear zone; MMZ, Madison mylonite zone; SRS, Salmon River suture zone; SJSZ, St. Joe shear zone; LC, Lewis and Clark line; SR, Snake River tectonic zone. 0.706 Sr line (red) essentially follows the Salmon River suture. Map compiled by author.

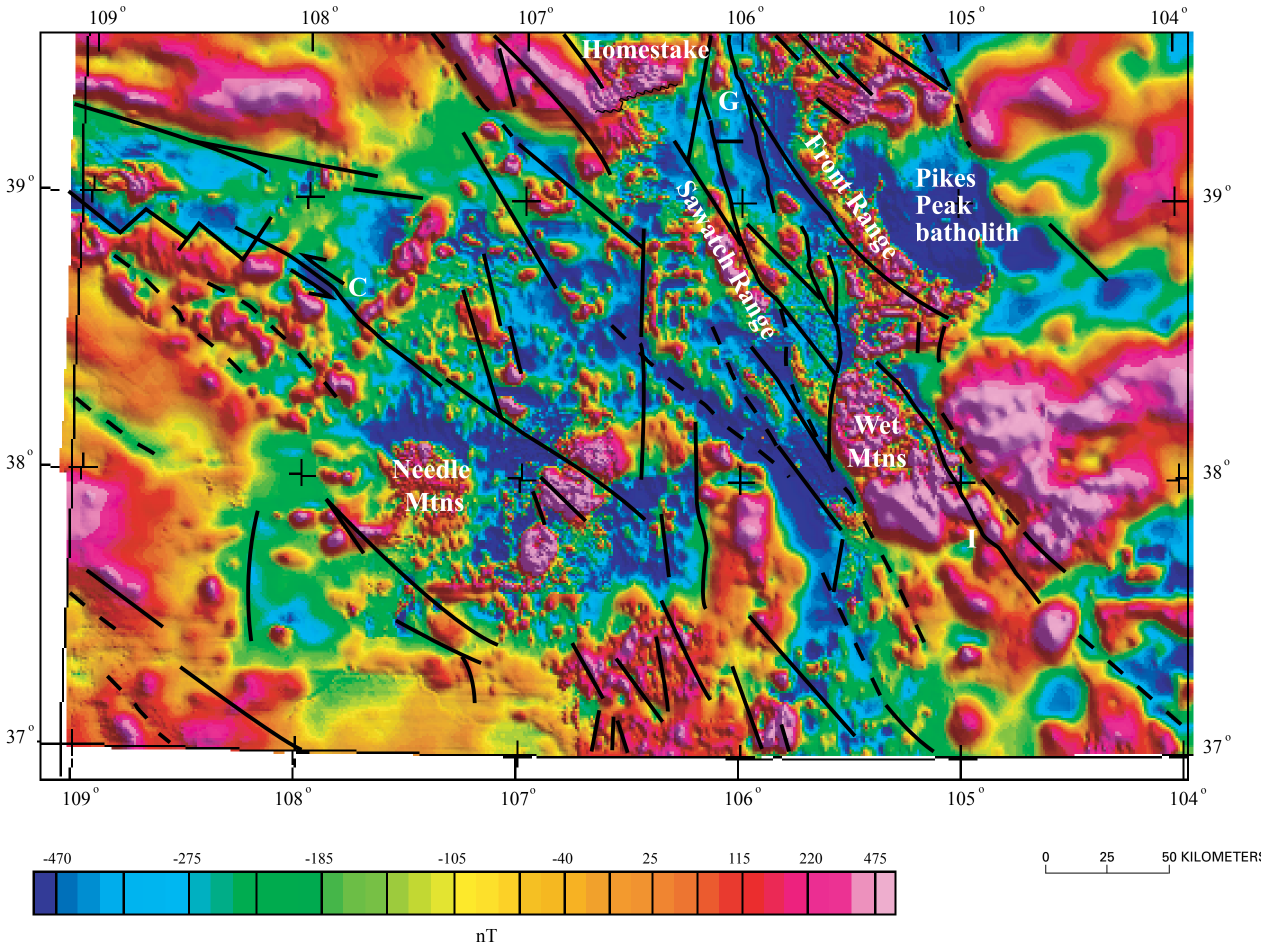

Figure 2. Aeromagnetic map of southwestern Colorado, showing traces of major shear zones of the Trans–Rocky Mountain fault system. Solid line, fault known from geologic mapping, dash line fault inferred from magnetic data. C, Cimarron–Red Rocks shear zone; G, Gore fault; I, Ilse fault; H, Homestake shear zone.

Geologic Characteristics

The Trans–Rocky Mountain fault system (fig. 1) is a complex array of braided and branching faults, commonly en echelon, with locally accompanying en echelon folds. Initial structures formed chiefly under ductile (mylonite) conditions, as indicated by exposures of deeply exhumed Precambrian basement rocks (Tweto, 1980c). Commonly, mylonitic textures are partly degraded by structures indicative of more brittle conditions of deformation caused by reactivation under lower temperature-pressure conditions or higher strain rate at higher crustal levels.

Examples of typical known strike-slip faults include the Cimarron–Red Rocks shear zone in the Gunnison River area (C, fig. 2) and the Gore and Ilse faults (G and I respectively, fig. 2) in Colorado, as described by Tweto (1980c), and the Clearwater shear zone in Idaho (Sims and others, 2005). In Montana, abundant northwest-striking transcurrent faults with predominant sinistral displacements have been identified in the mountain ranges within the southwestern part of the State (Schmidt and Garihan, 1983; Ruppel, 1982). The Lewis and Clark fault is a major segment of the fault system in Montana; it records predominant dextral strike-slip displacement, apparently resulting chiefly from Late Cretaceous reactivation (Wallace and others, 1990).

The transcurrent fault system has been mapped across a broad area in the well-exposed east-central part of the Colorado Front Range (Gable, 2000) (fig. 3). In this area, steeply dipping folds on northwest to east-west axes predated the faulting and presumably formed by regional north-south shortening, accompanying sinistral transpression. The transcurrent faults are several kilometers long, wavy, braided or anastamosing and branching northwest-striking sinistral strike-slip fault arrays and accompanying conjugate north- to

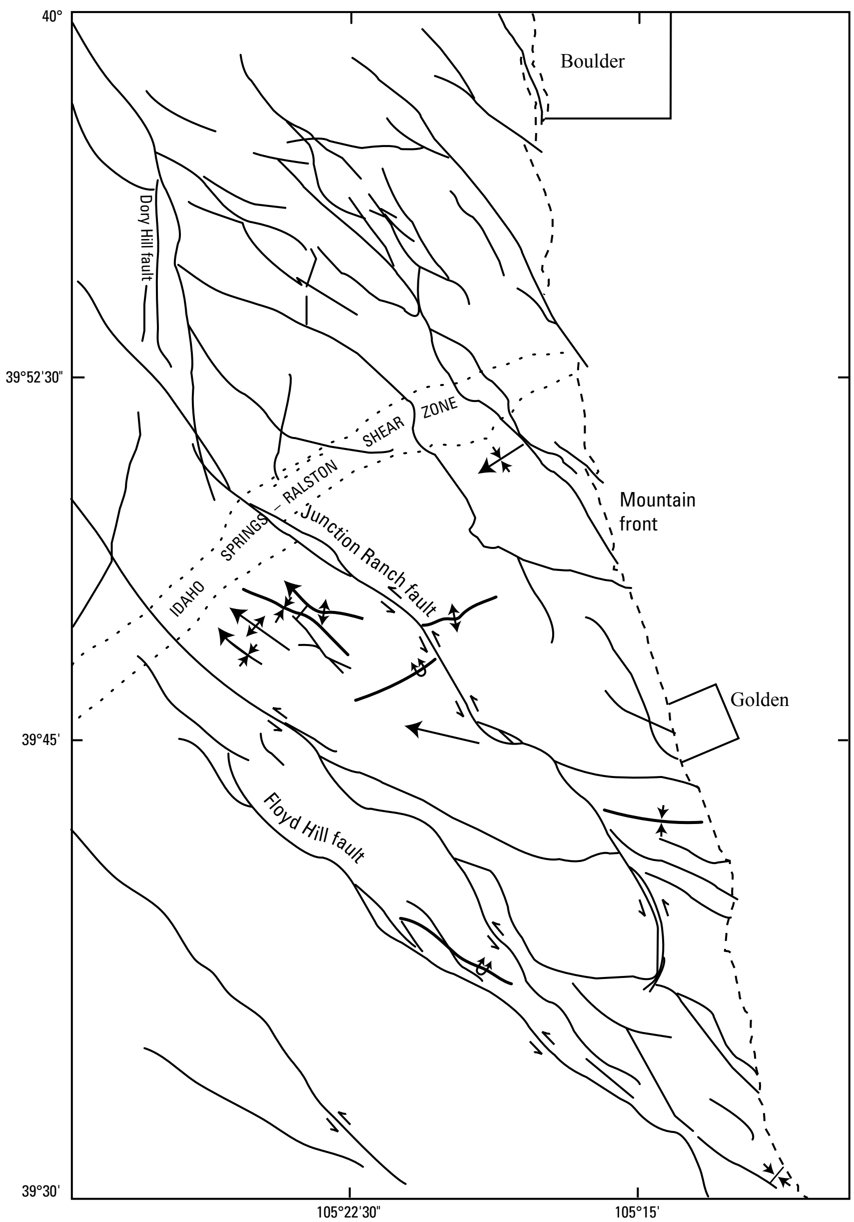

Figure 3. Transcurrent faults in central Front Range, Colorado adapted from Gable (2000). The faults are dominantly sinistral; they transect and are younger than the Idaho Springs–Ralston shear zone. The north-striking faults are dextral faults having small displacements. Northeast-trending folds formed during deformation (Berthoud orogeny) accompanying Idaho Springs–Ralston shear zone. Northwest-trending, en-echelon folds formed during deformation accompanying the sinistral strike-slip faulting.

Tertiary porphyritic dikes are offset about 30 m. In 3-D, the apparent difference in offset may be due to vertical displacement of a dipping fault or Tertiary dike, suggesting that the fault was reactivated subsequent to emplacement of the Tertiary dikes. The main sinistral strike-slip faults in the east-central Front Range generally are relatively narrow, but the fracture pattern indicates that the entire region has undergone similar transpressional shear. Throughout most of the region (fig. 3), the interiors of fault-bounded blocks are not appreciably deformed, for example, older foliations and folds are virtually undisturbed (Gable, 2000). The northwest-striking faults shown in figure 3 are reflected by the fine-scale northwest-southeast magnetic fabric in the area north of the Pikes Peak batholith, shown in figure 2.

A rose diagram plot of strike-slip fault orientations in the Rocky Mountain region (fig. 4), determined from regional Precambrian basement geologic maps of Colorado (Sims and others, 2001), Wyoming (Sims and others, 2001), Montana (Sims and others, 2004) and Idaho (Sims and others, 2005), indicates that the faults predominantly strike N. 30°–50° W. Principal displacement zones (fig. 1); for example, Lewis and Clark, Clearwater, and St. Jo shear zones in Montana, and Cimarron–Red Rocks and nearby Uncompahgre shear zone in Colorado (designated as principal components of the Snake River–Wichita fault zone; Sims and others, 2001), strike N. 55°–70° W. A lesser number of faults strike N. 30° W. to N. 20° E. and N. 70°–90° W. Strike-slip faults in the northwest sector of the rose diagram chiefly have both known or inferred sinistral and dextral displacements. Some major faults in central Colorado (for example, the Gore and Ilse shear zones, fig. 2) strike north-northwest.

northeast-striking dextral faults. The sinistral faults have horizontal displacements of as much as 1.5 km (Junction Ranch fault; fig. 3); the north-striking dextral faults have smaller horizontal displacements. For example, detailed mapping of a major north-northeast-striking fault (Dory Hill fault) within the western part of the region of figure 3 (Central City district; Sims and others, 1963) shows horizontal dextral displacement of Paleoproterozoic rock units of about 100 m; steeply dipping

The principal faults in the Trans–Rocky Mountain fault system commonly are expressed topographically by northwest-trending linear deep valleys (see Thelin and Pike, 1991) that cut across and displace the older structural grain, as for example the Lewis and Clark lineament in Montana (Smith, 1965). The combined Gore–Ilse fault complex in Colorado also comprises a prominent north- to northwest-trending topographic corridor between the Front Range and Sawatch Range (fig. 2).

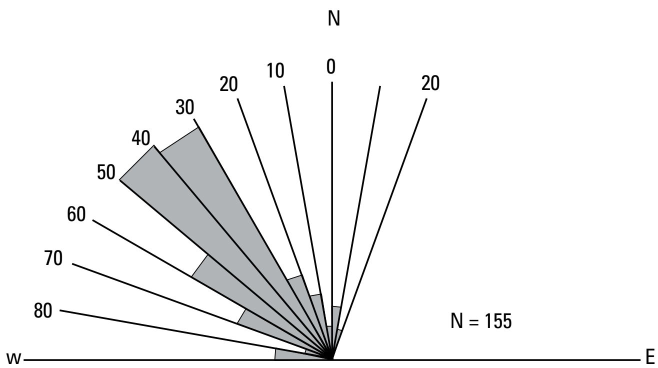

Figure 4. Rose diagram showing strike of the transcurrent faults in the Rocky Mountain region. Compiled from existing Precambrian basement geologic maps by Sims. See text for discussion.

Mechanics of Deformation

The Trans–Rocky Mountain fault system is interpreted to have resulted from transpressional tectonics, as defined by Dewey and others (1998). Earlier northwest- to east-striking folds were followed by ductile shears. Transpression and transtension deviate from simple shear (Sylvester, 1988) because of a component of, respectively, shortening or extension orthogonal to the deformation zone. Such three-dimensional noncoaxial strains principally develop in response to obliquely convergent or divergent relative motions across crustal deformation zones.

Evidence for a conjugate relationship of the sinistral northwest and dextral north-south faults is given by the repeated field observations of the consistent geometry and opposing displacement directions of the two structures.

Regional Extent and Age

The Trans–Rocky Mountain fault system has been interpreted to be part of a continent-scale strike-slip fault system (Sims and others, 2008). This interpretation is based on the kinematic similarity and orientation of Late Archean shear zones in the southern part of the Archean Superior province (Hudleston and others, 1988) and those within Paleoproterozoic rocks in the Rocky Mountain region (Sims and others, 2008).

The transcurrent faults are interpreted to have formed during two distinct major orogenic events in Neoarchean and Paleoproterozoic times. They formed in each orogeny during the transition from crystal-plastic to ductile-brittle deformation, for example, following development of the main internal structures in the rocks—foliation and folds. Hudleston and others (1988) and Bauer and Hudleston (1995) have demonstrated that the fault system in the southern Archean Superior province formed late in major dextral transpression during the approximate interval 2.7–2.6 Ga. A west- to northwest-striking transcurrent fault exposed in the Ferris Mountains in Wyoming, within the Archean Wyoming province, and interpreted here to be an Archean component of the Trans–Rocky Mountain fault system, has been dated at about 2.7 Ga (Bowers and Chamberlain, 1993)—the shear zone cuts a 2.732 Ga granitic pluton and is crosscut by a circa 2.71 Ga pluton.

The age of the Paleoproterozoic transcurrent faults is less well known than that of the Neoarchean faults. The transcurrent faults in the central Front Range (fig. 3) transect the Boulder Creek batholith and therefore are younger than 1.725 Ga (Premo and Fanning, 2000). In Arizona, Karlstrom and Bowring (1988) present evidence that faults interpreted by me to be of this system are about contemporaneous with emplacement of the 1.7 Ga Crazy Basin Quartz Monzonite. Minimum age for the faults in Colorado is given by the Iron Dike (1.36 Ga) dated by Braddock and Peterman (1989). The Neoarchean faults initiated as dextral faults and the Paleoproterozoic faults formed as sinistral faults.

Dynamics

The protracted Precambrian faulting and the coherent pattern of the structures throughout the interior of the North American plate suggest a common causal mechanism: continent-scale transpression resulting from upper mantle deformation that involved oblique shortening and progressed temporally from crystal-plastic through ductile, to brittle deformation. This mechanism is the same as the bottom-driven deformation of Tikoff and others (2002, 2004).

Field studies within the continental basement indicate that the primary stress directions through later Precambrian time have been orthogonal, involving predominant north-northwest–south-southeast shortening during Neoarchean time, as indicated by the kinematics in the southern Superior province (Hudleston and others, 1988), and predominant northeast-southwest shortening during major orogeny in late Paleoproterozoic time.

Teleseismic images of the North America subcontinental upper mantle (Van der Lee and Nolet, 1997; Dueker and others, 2001) provide mirror images of fundamental orthogonal Archean and Paleoproterozoic basement shear zones and faults (Sims and others, 2005): (1) northeast-striking ductile shear zones, which formed (Berthoud orogeny) in Mesoproterozoic (1.42 Ga) time, and (2) northwest-striking strike-slip ductile-brittle faults, which formed during the intervals 2.7 and 1.7 Ga. This coherence of solid lithosphere structure and mantle structure suggests that the upper-mantle structure was established during Neoarchean time (see also Karlstrom and Humphreys, 1998, for a similar old interpretation), and has persisted at least through the Paleoproterozoic. The forces that formed the northwest-striking structures are also perpendicular to the present-day southwestward (absolute) motion of the North America plate (Schutt and Humphreys, 2001).

Rejuvenation

The basement fault system had a major role in the subsequent tectonic evolution of the continent interior. In the Rocky Mountain region, in particular, reactivation of the faults and local reworking of intervening blocks episodically since early Mesoproterozoic time have strongly influenced sedimentary patterns, intracratonic magmatism, and regional structural features, such as Mesozoic thrust faults (Sims and others, 2008).

The Trans–Rocky Mountain fault system has been reactivated repeatedly since its inception. The rejuvenation chiefly involved reactivation of the primary shear zones, but also involved local crustal reworking, as discussed by Holdsworth and others (2001), resulting in prograde metamorphism and/or magmatism within fault-bounded blocks. The rejuvenation is exemplified by the geology along and adjacent to the Clearwater shear zone in Idaho (fig. 5), an area that has been mapped in moderate detail (Evans and Green, 2003; O'Neill, written commun., 2008).

In the Clearwater shear zone, geologic mapping indicates several distinct and separate tectono-magmatic episodes, ranging in age from about 1.5 Ga to at least the Tertiary, which can be directly or indirectly related to rejuvenation of the transcurrent fault system. This area is symbolic of the rejuvenation throughout at least the western part of the continent.

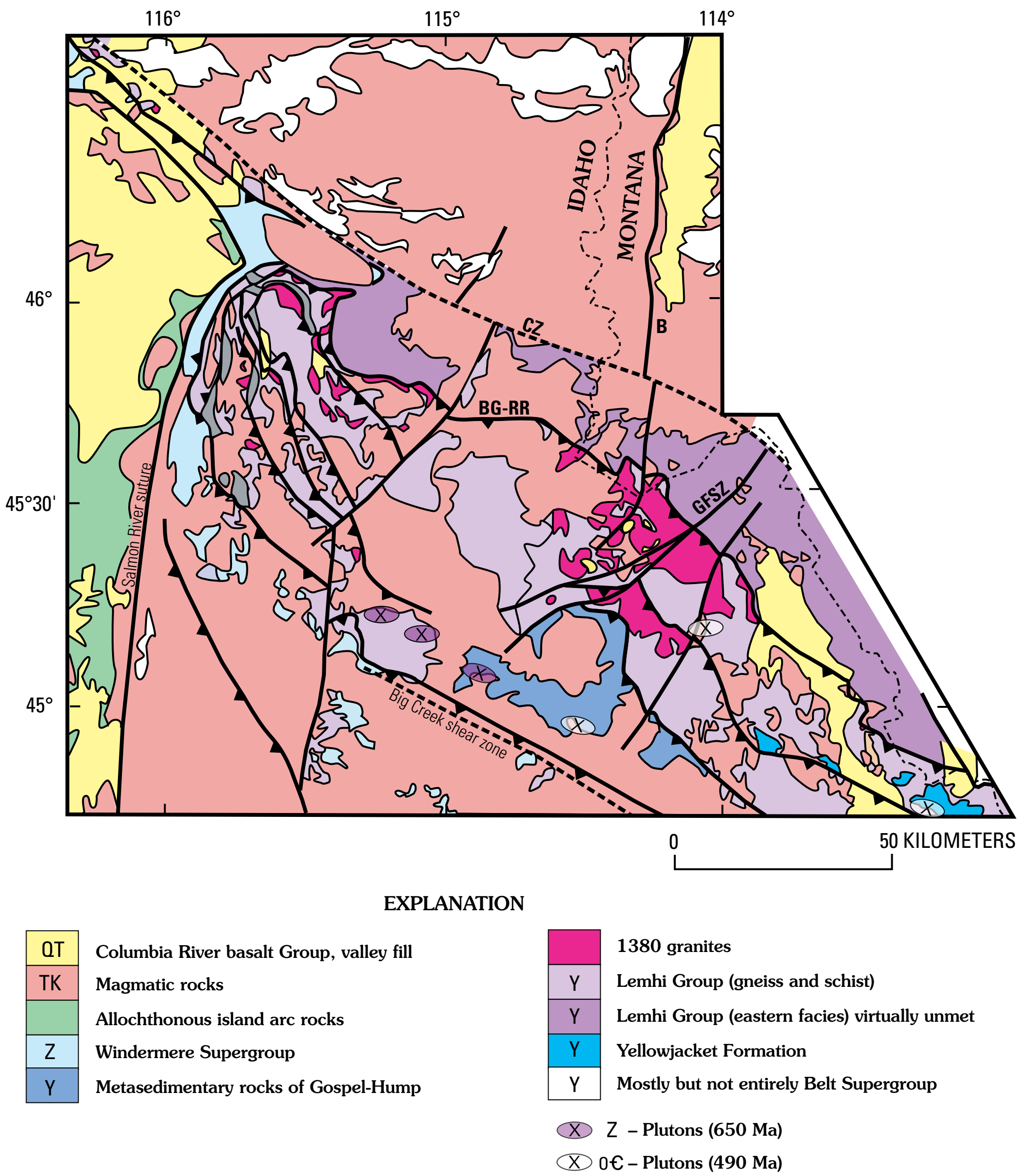

Figure 5. Map of central Idaho compiled by Karen Lund. This region illustrates many of the rejuvenated structures related to the Trans–Rocky Mountain fault system. B, Bitterroot mylonite zone; BG–RR, Brushy Gulch–Red River thrust fault; Cz, Clearwater shear zone.

Belt Supergroup Sedimentation

The oldest recognized event apparently related to reactivation of the northern part of the Trans–Rocky Mountain strike-slip fault system took place before and during deposition of the 1.47–1.40 Ga Belt Supergroup (Evans and others, 2000). The Clearwater shear zone (fig. 5) effectively separates depocenters between the Belt Supergroup and the combined Lemhi Group and Yellowjacket Formation to the south, suggesting that the Clearwater shear zone was active tectonically during deposition of the Mesoproterozoic sedimentary rocks and that it probably constituted a topographic barrier between the two basins. This observation supports the hypothesis of Winston (1986) that the Belt Supergroup and correlative rocks were deposited in isolated cratonic basins within the continent. O'Neill and others (written commun., 2008) have confirmed this observation and extended the fault by field mapping several kilometers to the southeast; they named the larger fault the Great Divide Megashear. The position of the western margin of the continent, as interpreted from geologic and initial strontium data (0.706 Sr line; fig. 1), is considered to approximate the position of the continental margin relative to the Belt basin in Mesoproterozoic time (Sims and others, 2005).

Central Idaho Disturbance

A tectono-magmatic event of local extent, previously designated as the Central Idaho disturbance (Sims and others, 2005) and earlier as the Salmon River arch (Armstrong, 1975), is confined to a 70-km-wide belt adjacent to the Clearwater shear zone. The disturbed belt lies between the Clearwater zone and the Big Creek fault zone to the south (fig. 5) and extends northward between the Atlanta and Bitterroot lobes of the Cretaceous Idaho batholith. It consists principally of migmatitic gneiss and schist that are intruded by diabase, gabbro-diorite, and megacrystic granite. The tectono-magmatic belt is now exposed in the upper plate of the Mesozoic Brushy Gulch–Red River thrust (fig. 5). The belt has been the subject of controversy for more than a quarter of a century. The argument revolves around the question of whether or not some of the metamorphic rocks in the belt are pre-Belt Supergroup in age, as proposed earlier by Armstrong (1975). Sims and others (2005) suggested that at least some of the metamorphic rocks could be about 1.7 Ga in age and grossly equivalent with 1.7 Ga juvenile crust inferred to underlie the Mesoproterozoic sedimentary rocks in the region. The central Idaho disturbance is similar in age and, probably, origin to the East Kootenay orogen in adjacent British Columbia, Canada (Leech, 1962; McMechan and Price, 1982).

Late Neoproterozoic Transform Faulting

During the rift-drift breakup of Rodinia in late Neoproterozoic time (Stewart, 1972), the Clearwater zone is interpreted to have had a major role in sculpting the shape of the western continent margin, in a manner suggested by Vauchez and others (1997). The 0.706 Sr isotope line coincides closely with the Clearwater zone (fig. 1) and a north-trending shear zone to the south, which during the Mesozoic Sevier orogeny probably localized the Salmon River suture zone (Lund and Snee, 1988; Sims and others, 2005). Reactivation of these and related strands of the Trans–Rocky Mountain fault system on the continental margin (Sims and others, 2005) can account for the zig-zag pattern of the Pacific rifted margin.

Late Neoproterozoic and Cambrian–Ordovician Alkalic Plutonism

Two apparently discrete episodes of alkalic plutonism are recognized within the central Idaho disturbed belt, between the Clearwater and Big Creek shear zones (fig. 5)—an older episode dated at 650 Ma and a younger episode of 490 Ma (Karen Lund, unpub. data). These bodies intrude mainly amphibolite-grade gneisses inferred to have formed principally from Lemhi Group and Yellowjacket Formation protoliths (Lund and others, 2004). They are aligned northwest-southeast, suggesting that they were intruded along preexisting shears of the Trans–Rocky Mountain fault system. These alkalic plutons are comparable in age, composition, and orientation to the Iron Hill and other similar alkalic plutons of early Paleozoic age localized along the Cimarron–Red Rocks shear zone in southwestern Colorado (Sims and others, 2001).

Mesozoic Sevier Thrust Faulting

Many of the major east-vergent Sevier thrust faults strike northwest-southeast, subparallel to the strike of the Trans–Rocky Mountain fault system (fig. 5). Faults spatially associated with the Clearwater zone include the newly defined east-central Idaho thrust belt (Lund and others, 2003b; Tysdal and others, 2003). These thrust faults are segmented by inherited north- and northeast-striking faults that apparently acted as tear faults during Sevier thrust faulting (Tysdal, 2002; Lund, 2004; Lund and others, 2003; Tysdal and others, 2003). The ancient basement structures are interpreted to have focused strain during northeast-southwest directed Mesozoic Sevier deformation, resulting in neoformed thrust faults.

Metamorphic Core Complexes

The Precambrian basement strike-slip fault system actively participated in the development of Eocene metamorphic core complexes in the northwestern United States (Sims and others, 2005). Notably, the Bitterroot core complex, which includes the Bitterroot lobe of the Idaho batholith, is bounded by conjugate faults interpreted herein to be components of the Trans–Rocky Mountain fault system (fig. 5) that were reactivated during formation of the core complex. The eastern boundary, the north-striking Bitterroot mylonite zone (Hyndman, 1980; Foster and Fanning, 1997), coincides with a sharp magnetic linear low that extends from east-central Idaho northward through western Montana nearly to the Canada border (Sims and others, 2004); it is interpreted as a reactivated fault of the system. The sinistral Clearwater shear zone forms the southern margin of the complex. These structures formed zones of weakness, the reactivation of which probably localized the core complex.

Summary and Discussion

The Trans–Rocky Mountain fault system, previously overlooked as a significant component of the architecture of the North American continent, is a fundamental continent-scale Precambrian basement structural system. Abundant evidence indicates that the fault system formed during the Neoarchean and late Paleoproterozoic orogenies; it segmented the continent into mostly coherent blocks of different dimensions that have been rejuvenated repeatedly since Mesoproterozoic time. Reactivation of these intracratonic structures controlled many aspects of subsequent tectonism, sedimentation, and magmatism. Knowledge of these structures enhances our understanding of the early crustal evolution and the subsequent tectonic history of the North American continent.

The fault system consists predominantly of northwest-oriented, steeply dipping strike-slip ductile shears and faults and conjugate sets of northerly striking transfer faults. The fault system was initiated in Neoarchean time during late stages of dextral transpression (orogenesis) that progressed from crystal-plastic to brittle deformation. The Neoarchean faults are best known from structural studies in the southern part of the Archean Superior province, where they transect regional folds with east-west axes in the Archean rocks (Hudleston and others, 1988, and references therein). Faults of the Neoarchean age also are recognized on the Archean Wyoming province and a major fault of this system has been dated at about 2.7 Ga (Bowers and Chamberlain, 1993). Regional deformation under transpressional conditions resumed at about 1.70 Ga, after accretion of 1.8–1.72 Ga magmatic arc rocks in the Colorado province.

The driving force for the development of the Trans–Rocky Mountain fault system is attributed here to subcontinental mantle deformation, a mechanism discussed by several investigators (for example, Silver, 1996; Tikoff and others, 2004). This mechanism can account for inception of the continent-scale Trans–Rocky Mountain fault system and the repeated tectonism along the same tectonic axis. The model presented here accords with new geodynamic models for plate motions, based on seismic anisotropy beneath the North and South American continents (Russo and Silver, 1996; Silver, 1996; Tikoff and others, 2002, 2004), that invoke mechanical coupling and subsequent shear between the lithosphere and the asthenosphere such that a major driving force for plate motion is deep-mantle flow. The model of subcontinental mantle deformation previously has been proposed to explain the Andes Cordillera in South America, and by analogy, the U.S. Rocky Mountains (Russo and Silver, 1996). The inadequacy of plate tectonic theory to explain major deformation within the continents has been pointed out previously by Molnar (1988).

An implication of this tectonic thesis is that subcontinental mantle deformation (or bottom-driven deformation; Tikoff and others, 2004) must be taken into account as a major, if not principal, cause of late Precambrian deformation (since 2.7 Ga), at least in the North American craton, and perhaps on other cratons. This inference is supported by the regional extent and structural similarity of the Precambrian shear zones and their structural coincidence with upper-mantle teleseismisity, as well as the general absence of diagnostic features of modern plate tectonics, such as ophiolites. It is widely recognized (Silver, 1996; Karlstrom and Humphreys, 1998; Savage, 1999) that in older continental regions seismic anisotropy in the lithosphere has been frozen since Precambrian time.

Acknowledgments

This manuscript is based on regional geologic studies of the Precambrian basement rocks in the continental United States, with emphasis on the Rocky Mountain region. Definition of the fault system is based on extrapolation from known basement structures determined by geologic mapping and interpretation of new aeromagnetic anomaly data. Reviews by Robert L. Bauer and A.W. Stokes improved an earlier version of the manuscript.

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