

Anomalous(?) Early Jurassic deformation in the western U.S. Cordillera

Sandra J. Wyld*
Michael J. Quinn
James E. Wright

Department of Geology and Geophysics, MS-126, Rice University, 6100 Main Street, Houston, Texas 77005

ABSTRACT

New data from the Black Rock Desert of northwest Nevada indicate that Paleozoic and early Mesozoic magmatic arc rocks in this area were affected by regional shortening deformation and metamorphism in the Early Jurassic (ongoing at ~201 Ma). This is ~30–50 m.y. prior to the time at which significant Jurassic shortening deformation is thought to have begun in the western U.S. Cordillera and is further anomalous because the Early Jurassic time frame in most other arc assemblages of the Cordillera is characterized by accumulation of strata and neutral to extensional tectonism. These conflicting relations support the following conclusions. (1) The Black Rock Desert is probably separated from other arc assemblages to the west and south (in the Klamath Mountains and Sierra Nevada) by a younger strike-slip fault boundary that juxtaposes arc elements with different Early Jurassic structural histories. (2) Tectonic conditions varied along the Early Jurassic plate margin such that shortening occurred to the north but not to the south, an aspect of the Mesozoic evolution of the Cordillera that has not been previously appreciated. At present, regional Early Jurassic deformation is documented only in the Black Rock Desert, but it may have impacted a much larger area in this part of the Cordillera, based on relations in the Blue Mountain province of Oregon and the Luning-Fencemaker fold-and-thrust belt of central Nevada.

INTRODUCTION

Rocks of early Mesozoic age exposed in the western U.S. Cordillera include a belt of Triassic to Jurassic plutons and volcanic strata (Fig. 1) that reflect arc magmatism associated with generally east-dipping subduction. To the east lies a sequence of deep-marine strata deposited in a Triassic to Early Jurassic back-arc basin (basinal terrane; Fig. 1). Elsewhere, the back-arc region was largely emergent during the early Mesozoic.

One of the most prominent features across the arc to back-arc area is a record of Middle to Late Jurassic regional shortening deformation (Harper and Wright, 1984; Oldow, 1984; Sharp, 1988; Wright and Fahan, 1988; Walker et al., 1990; Smith et al., 1993). This orogenic event is recognized from the Klamath Mountains, Sierra Nevada, and Mojave Desert to western Utah and spanned an age range from ~170 to 150 Ma. In contrast, the Early Jurassic was a time when the arc region was largely either tectonically neutral or undergoing extensional tectonism. This conclusion is based on a continuous record of deposition during the Early Jurassic in arc assemblages from the Klamath Mountains southward through southwest Arizona, coupled with evidence for Early Jurassic intra-arc extension southeast of the central Sierra Nevada (e.g., Busby-Spera, 1988; Wright and Miller, 1988; Saleeby and Busby-Spera, 1992).

The shift from extensional or neutral tectonism in the Early Jurassic to widespread shortening deformation in the mid-Middle to Late Jurassic has been taken as a fundamental characteristic of the

Mesozoic evolution of the western U.S. Cordillera. In this paper, we summarize new data indicating that these relations do not apply everywhere. Specifically, we show that early Mesozoic arc assemblages in the Black Rock Desert area of Nevada (Fig. 1) underwent a major episode of shortening deformation in the Early Jurassic, some 30–50 m.y. prior to the timing of shortening documented in other areas. These new data lead to a revised interpretation of the tectonic evolution of the Cordillera during the Early Jurassic.

BLACK ROCK DESERT—GEOLOGIC FRAMEWORK

The Black Rock Desert contains several mountain ranges uplifted during Cenozoic Basin and Range extension, including the Pine Forest Range and Jackson Mountains (Figs. 1 and 2). Paleozoic strata in the Pine Forest Range and Jackson Mountains include sedimentary and volcanic rocks that range from Devonian or older(?) to Permian and reflect marine deposition in or near a volcanic arc (Russell, 1984; Maher, 1989; Wyld, 1990, 1991; Quinn, 1996). Mesozoic rocks include Triassic to Cretaceous sedimentary and volcanogenic strata (submarine to subaerial), as well as numerous intrusions, that generally reflect voluminous, proximal arc magmatism (Russell, 1984; Maher, 1989; Wyld, 1990, 1991; Quinn, 1996). Regional deformation and metamorphism of Jurassic age is a widespread feature in the Pine Forest Range and Jackson Mountains. In the following sections, we summarize key structural and geochronologic data indicating that much of this deformation occurred in the Early Jurassic.

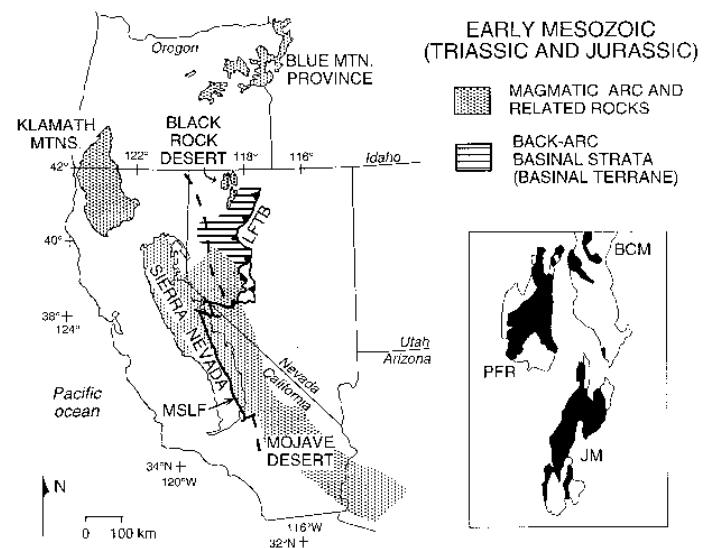


Figure 1. Map of western U.S. Cordillera showing distribution of early Mesozoic arc and back-arc basin assemblages, frontal thrusts of Luning-Fencemaker fold-and-thrust belt (LFTB; Oldow, 1984), and Mojave-Snow Lake strike-slip fault (MSLF; solid line where well located, dashed line where inferred; Schweickert and Lahren, 1990). Inset is of Black Rock Desert, showing Pine Forest Range (PFR), Jackson Mountains (JM), and Bilk Creek Mountains (BCM), with pre-Cenozoic rocks shown by solid pattern.

*Present address: Department of Geology, University of Georgia, Athens, GA 30602-2501.

EAST-CENTRAL PINE FOREST RANGE

Pre-Cenozoic rocks in the east-central Pine Forest Range include a thick sequence (~8–10 km structural thickness) of Paleozoic and Mesozoic strata intruded by Jurassic and Cretaceous plutons (Fig. 2). The stratigraphic sequence includes rocks of Devonian or older (?) to latest Mississippian age, Permian age, and Middle(?) to Late Triassic age (Ladinian or Carnian to Norian); two unconformities are present within the Mississippian to Triassic part of the section and reflect uplift and erosion but no significant deformation (Wyld, 1990, 1991; Fig. 2). The sequence youngs consistently from north to south and is coherent in the sense that no significant faults disrupt it; however, bedding and stratigraphic layering generally dip moderately to steeply to the southwest (Wyld, 1990, 1996; Fig. 2). This architecture reflects wholesale tilting of the stratigraphic succession sometime after the latest Triassic. Jurassic plutons include the 201 Ma Big Creek pluton and 185 Ma Theodore pluton (TP and BCP in Fig. 2; U-Pb zircon ages [Wyld, 1996]).

Jurassic deformation in the east-central Pine Forest Range involved the development of a northwest-striking ductile shear zone within Devonian and older(?) rocks (Fig. 2) and is expressed within younger units in the form of a strain gradient to the south away from the shear zone (Wyld, 1996). Structures formed during this deformation include a generally northwest-striking, steeply southwest-dipping foliation (Fig. 2) that changes progressively from a weak low-grade slaty cleavage in the Triassic strata into an amphibolite-grade schistose to mylonitic foliation associated with a strong stretching lineation within the oldest rocks. Scarce folds are also present and change with increasing stratigraphic depth from open to isoclinal. The shear zone is defined by a belt of pervasively mylonitized rocks that is ~2 km wide and is cut out to the north by a Cretaceous pluton (Fig. 2).

Relations discussed in detail in Wyld (1996) indicate that the shear zone was originally a subhorizontal ductile thrust that has now been tilted on its side along with its upper plate of less deformed rocks. This conclusion is based on a variety of features, including structural relations, the spatial pattern of regional deformation and metamorphism relative to the stratigraphic architecture of the area, the lack of any Jurassic normal faults in the lower strain rocks south of the shear zone, and Jurassic structural relations elsewhere in the Black Rock Desert, all of which are consistent only with formation of the shear zone during an episode of shortening deformation. Syntectonic mineral assemblages and the structural thickness of the

upper plate indicate that the ductile thrust developed at a depth of ~8–10 km (Wyld, 1996). Tilting of the crustal section is believed to have been caused in part by intrusion of the Cretaceous Granite Mountain plutonic complex (GMC in Fig. 2) and in part by differential uplift of the Pine Forest Range during Cenozoic Basin and Range extension (Wyld, 1996).

Maximum and minimum age limits for Jurassic deformation in the east-central Pine Forest Range are defined by the latest Norian age of the youngest deformed strata and by the presence of a thermal aureole around the 185 Ma Theodore pluton that statically overprints the mylonitic fabric in the shear zone (Wyld, 1996). Several features also indicate that the 201 Ma Big Creek pluton was intruded during deformation (Wyld, 1996). For example, andalusite and cordierite are found in metapelitic rocks near the pluton margin and exhibit textural relations clearly indicating that they grew during development of the regional fabric. In addition, the bulk of the pluton is undeformed, indicating that it cannot be pre-tectonic because it is surrounded by wall rocks deformed into schists and mylonites under amphibolite-grade conditions. However, the pluton cannot be post-tectonic because rocks near the pluton margin and associated dikes display a weak to mylonitic solid-state foliation parallel to the regional wall-rock foliation. These contrasting features are consistent only with (late) syntectonic intrusion. Collectively, these relations indicate that regional deformation in the east-central Pine Forest Range occurred in the Early Jurassic, was ongoing at ~201 Ma, and was over by at least 185 Ma.

NORTHERN PINE FOREST RANGE

Metamorphic tectonites also occur in the northern Pine Forest Range where they are surrounded by Jurassic and Early Cretaceous plutons (Fig. 2). The tectonites include a Triassic orthogneiss dated at ~230 Ma (preliminary U-Pb zircon age) and a biotite schist unit that is intruded by the orthogneiss and was derived from a protolith similar to mid-Paleozoic rocks of the east-central Pine Forest Range (see units Trog and Pzbs in Fig. 2). Regional deformation in these tectonites is manifested by a generally northwest- to west-striking foliation that developed under upper greenschist- to amphibolite-grade conditions and is axial planar to isoclinal folds in the schist unit. The exact age of this deformation is not tightly constrained, but it must be younger than ~230 Ma and older than an ~180 Ma Jurassic pluton (preliminary U-Pb zircon age) that cuts directly across the regional fabric in numerous places; these timing con-

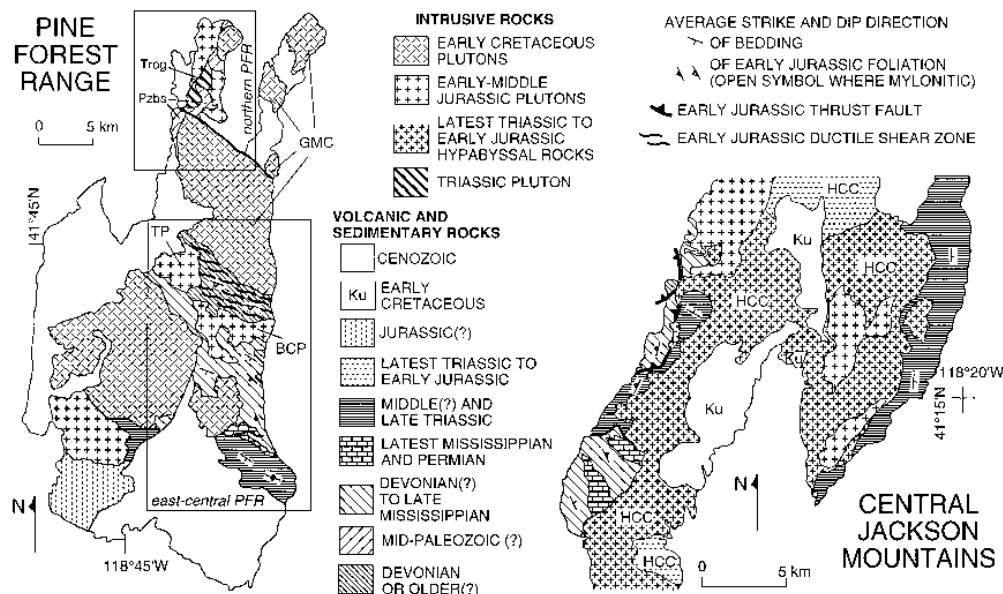


Figure 2. Simplified geologic maps of Pine Forest Range (PFR) and central Jackson Mountains. Note different scales. Abbreviations as follows: BCP—Big Creek pluton; GMC—Granite Mountain plutonic complex; HCC—Happy Creek igneous complex; Ku—Cretaceous strata, undivided; Pzbs—mid-Paleozoic(?) biotite schist; TP—Theodore pluton; Trog—mid-Triassic orthogneiss.

straints are consistent with the timing of deformation in the east-central Pine Forest Range. It is possible that these metamorphic tectonites may be part of the lower plate of the ductile thrust mapped farther to the south.

JACKSON MOUNTAINS

Our work has focused on the central Jackson Mountains, most of which is underlain by the Happy Creek igneous complex and Jurassic plutons (Fig. 2). Recent studies by Quinn et al. (in press) have shown that the Happy Creek complex is composed mostly of hypabyssal intrusive rocks with only rare volcanogenic deposits, and that it is confined in age to the interval latest Triassic to mid-Early Jurassic because it postdates deposition of latest Triassic strata and predates intrusion of crosscutting plutons dated at 196–190 Ma (U-Pb zircon ages). Overlying the Happy Creek complex along a major unconformity are Lower Cretaceous sedimentary and volcanic strata (Fig. 2; Russell, 1984; Quinn et al., in press). Wall rocks of the Happy Creek complex include strata of Late Triassic (Carnian to Norian) and Paleozoic (Permian, Devonian to Mississippian, and Devonian or older[?]) age (Fig. 2) that are lithologically similar to and directly correlative with coeval units in the Pine Forest Range (Russell, 1984; Quinn, 1996). Although not distinguished in Figure 2, Triassic strata on the west side of the range are slightly older than those on the east side.

Two phases of Mesozoic shortening deformation are recorded in the central Jackson Mountains, one of which (D1) predates emplacement of the Happy Creek complex and the other of which (D2) postdates the complex (Quinn et al., 1995; Quinn, 1996). Our concern here is with the earlier phase, which is most obvious in the Paleozoic and older Triassic units (Carnian to Norian) exposed on the west side of the range. There, D1 deformation is manifested by variably oriented folds and axial-planar foliation (variable orientation reflects younger deformation) and is characterized by increasing strain and syntectonic metamorphic grade with increasing stratigraphic depth. Thus, the foliation changes from a low-grade slaty cleavage in the younger rocks through a greenschist-grade phyllitic foliation to an amphibolite-grade schistose to mylonitic foliation in the older rocks. In the northern part of the area on the west side of the range, a stacked couplet of northeast-striking, northwest-dipping thrusts (Fig. 2) also successively places older rocks that underwent higher-grade D1 deformation over younger rocks that underwent lower-grade D1 deformation. These thrusts are brittle structures that postdate development of the D1 foliation but, as shown below, only by a relatively short interval of time.

D1 structures affect rocks as young as Norian and are cut by hypabyssal rocks of the Happy Creek complex, which is itself unaffected by D1 deformation (Quinn et al., 1995; Quinn, 1996). West-side thrusts also involve rocks as young as Norian and are cut in several places by hypabyssal rocks of the Happy Creek complex (Fig. 2; Quinn, 1996). Given that the Happy Creek complex is older than the 196–190 Ma age of crosscutting plutons, D1 deformation and thrusting are both constrained to the interval latest Triassic to Early Jurassic. Furthermore, one sample of amphibolite schist deformed during D1 has yielded an $^{40}\text{Ar}/^{39}\text{Ar}$ hornblende plateau age of 201 ± 2 Ma (Quinn et al., 1995; Quinn, 1996). We therefore conclude that D1 deformation in the Jackson Mountains occurred in the Early Jurassic at ~ 201 Ma and that thrust faulting on the west side of the range occurred somewhat later in the Early Jurassic, but prior to 196 Ma.

The pattern of increasing Early Jurassic (D1) strain and syntectonic metamorphic grade with increasing stratigraphic depth in the Jackson Mountains mimics that in the east-central Pine Forest Range, and the age of deformation in both areas is similar. This finding suggests that Paleozoic and Triassic rocks of the Jackson

Mountains may occupy the upper plate of the Early Jurassic ductile shear zone exposed in the east-central Pine Forest Range (Quinn, 1996). In the Jackson Mountains, however, deeper levels of the upper plate were juxtaposed against shallower levels along thrust faults that also developed in the Early Jurassic. These faults are interpreted to reflect the last stages of Early Jurassic shortening in the Black Rock Desert region (Quinn, 1996).

DISCUSSION

The relations discussed above indicate that an episode of regional shortening deformation and metamorphism affected the Black Rock Desert during the mid-Early Jurassic. This timing is anomalous with respect to the Early Jurassic record in other Mesozoic assemblages lying to the west and south. Specifically, as noted in the introduction, continuous deposition occurred throughout the Early Jurassic in arc assemblages from the Klamath Mountains to southwest Arizona with no evidence for shortening deformation, and deposition was locally accompanied by extensional tectonism. This discrepancy poses a problem in terms of plate-tectonic reconstructions; if the early Mesozoic arc assemblages are currently arranged in the same positions relative to one another as they were in the Early Jurassic, then the relations outlined above require that arc assemblages nearer to the plate boundary underwent neutral to extensional tectonism while arc assemblages closer to the back-arc region (Black Rock Desert) underwent shortening deformation. This scenario, however, has no analogue or explanation either in terms of the structural record at modern convergent boundaries or in models of stress distribution in the upper plate of a convergent system (e.g., Nakamura and Uyeda, 1980; Bott et al., 1989; Wdowinski et al., 1989).

This problem suggests that the current relative positions of the different arc assemblages do not reflect their Early Jurassic arrangement. An attractive solution is to infer that post-Early Jurassic strike-slip faulting has shuffled the older geology, and an obvious candidate fault is the Mojave-Snow Lake fault (Fig. 1). This fault accommodated some 450 km of dextral strike-slip motion along the central Sierra Nevada in the Early Cretaceous and is inferred to continue north between the Black Rock Desert and Klamath Mountains (Fig. 1; Schweickert and Lahren, 1990, 1993), possibly coinciding in part with the strike-slip Pine Nut fault of Oldow (1984) whose history of motion is less clearly defined. Figure 3 shows a reconstruction of the western U.S. Cordillera prior to movement on the Mojave-Snow Lake fault. This reconstruction restores the area of Early Jurassic intra-arc shortening (Black Rock Desert) to a position north of the area of no Early Jurassic intra-arc shortening and allows two obvious possible explanations for the spatially variable Early Jurassic record. (1) The Early Jurassic plate margin was curved. Given an appropriate relative-convergence vector between the North American plate and the subducting oceanic plate, this curvature could result in a large orthogonal component of convergence in the vicinity of the Black Rock Desert, which would promote shortening deformation in the upper plate, but a larger transverse component to the south, which would promote strike-slip faulting in the upper plate and could account for a record of neutral to extensional tectonism. (2) Restricted collision of an island arc or some other crustal mass occurred along the northern part of the plate boundary (in the vicinity of the Black Rock Desert) but did not affect the plate margin farther to the south.

There are several important implications of the reconstruction and interpretive models laid out above. First, reconstruction of several hundred kilometres of post-Early Jurassic strike-slip displacement along a fault located between the Black Rock Desert and Klamath Mountains-Sierra Nevada provides viable explanations for what is otherwise an inexplicable record of Early Jurassic shortening

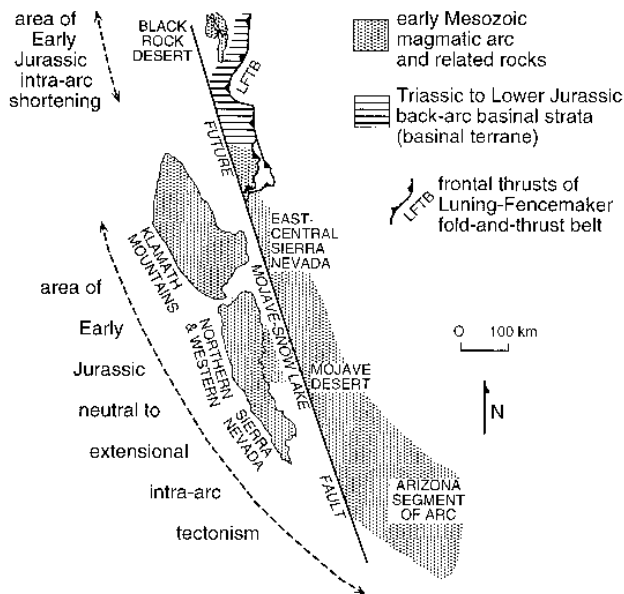


Figure 3. Locations of key areas and features noted in text reconstructed to show relative positions prior to motion along Early Cretaceous Mojave-Snow Lake dextral strike-slip fault (based on Fig. 2 of Schweickert and Lahren, 1990). LFTB—Luning-Fencemaker fold-and-thrust belt.

deformation in the Black Rock Desert, and this fact offers compelling evidence that such a fault does actually exist. Early Jurassic relations in the Black Rock Desert therefore provide strong support for interpretations that the Mojave-Snow Lake fault (or some comparable structure) continues through this area (e.g., Schweickert and Lahren, 1990, 1993).

Second, the relations discussed above argue that conditions varied from south to north along the length of the Early Jurassic plate margin, both in terms of tectonic interactions and the structures caused by these interactions. This aspect of the Early Jurassic history of the western U.S. Cordillera has not previously been appreciated and deserves further study. One important question concerns the regional extent of Early Jurassic shortening. Two areas are of interest in this context: the back-arc basinal terrane, which remains adjacent to the Black Rock Desert after removing motion along the Mojave-Snow Lake fault (Fig. 3), and the Blue Mountain province, which lies north of the Black Rock Desert in Oregon (Fig. 1). Strata in the basinal terrane were affected by multiple phases of folding and faulting during development of the Luning-Fencemaker fold-and-thrust belt (Oldow, 1984). Structures within this belt are routinely assumed to be Middle to Late Jurassic in age, but timing constraints for all phases of deformation are scarce and poorly defined. Significantly, however, the basinal terrane shoaled in the mid-Early Jurassic, after which there is no further record of deposition, consistent with onset of shortening deformation and associated uplift during this time frame (Speed, 1978). In conjunction with the data presented here, these relations suggest that early-phase Luning-Fencemaker folds and thrusts may be Early Jurassic and therefore much older than previously inferred. It is also intriguing to note that there is clear evidence for Early Jurassic shortening in the southern Blue Mountain province (Dickinson and Thayer, 1978) although the potential regional significance of this has received little prior attention. It therefore appears possible that a previously unappreciated but widespread episode of shortening deformation affected the northern part of the U.S. Cordillera in the Early Jurassic.

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REFERENCES CITED

- Bott, M. H. P., Waghorn, G. D., and Whittaker, A., 1989, Plate boundary forces at subduction zones and trench-arc compression: *Tectonophysics*, v. 70, p. 1–15.
- Busby-Spera, C. J., 1988, Speculative tectonic model for the early Mesozoic arc of the southwest Cordilleran United States: *Geology*, v. 16, p. 1121–1125.
- Dickinson, W. R., and Thayer, T. P., 1978, Paleogeographic and paleotectonic implications of Mesozoic stratigraphy and structure in the John Day inlier of central Oregon, in Howell, D. G., and McDougall, K. A., eds., *Mesozoic paleogeography of the western U.S.*: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Symposium 2, p. 147–161.
- Harper, G. D., and Wright, J. E., 1984, Middle to Late Jurassic tectonic evolution of the Klamath Mountains, California-Oregon: *Tectonics*, v. 3, p. 759–772.
- Maher, K. A., 1989, *Geology of the Jackson Mountains, northwest Nevada* [Ph.D. thesis]: Pasadena, California Institute of Technology, 491 p.
- Nakamura, K., and Uyeda, S., 1980, Stress gradient in arc-back arc regions and plate subduction: *Journal of Geophysical Research*, v. 85, p. 6419–6428.
- Oldow, J. S., 1984, Evolution of a late Mesozoic back-arc fold and thrust belt, northwestern Great Basin, U.S.A.: *Tectonophysics*, v. 102, p. 245–274.
- Quinn, M. J., 1996, *Pre-Tertiary stratigraphy, magmatism, and structural history of the central Jackson Mountains, Humboldt County, Nevada* [Ph.D. thesis]: Houston, Texas, Rice University, 243 p.
- Quinn, M. J., Wright, J. E., and Wyld, S. J., 1995, Tectonic evolution of the Mesozoic continental arc in northwest Nevada—Constraints from the Jackson Mountains, Black Rock Desert: *Geological Society of America Abstracts with Programs*, v. 27, no. 6, p. A-286.
- Quinn, M. J., Wright, J. E., and Wyld, S. J., in press, The Happy Creek igneous complex and tectonic evolution of the early Mesozoic arc in the Jackson Mountains, northwest Nevada: *Geological Society of America Bulletin*.
- Russell, B. J., 1984, Mesozoic geology of the Jackson Mountains, northwestern Nevada: *Geological Society of America Bulletin*, v. 95, p. 313.
- Saleeby, J. B., and Busby-Spera, C., 1992, Early Mesozoic tectonic evolution of the western U.S. Cordillera, in Burchfiel, B. C., Lipman, P. W., and Zoback, M. L., eds., *The Cordilleran orogen: Conterminous U.S.*: Boulder, Colorado, Geological Society of America, *Geology of North America*, v. G-3, p. 107–168.
- Schweickert, R. A., and Lahren, M. M., 1990, Speculative reconstruction of the Mojave-Snow Lake fault: Implications for Paleozoic and Mesozoic orogenesis in the western United States: *Tectonics*, v. 9, p. 1609–1629.
- Schweickert, R. A., and Lahren, M. M., 1993, Triassic-Jurassic magmatic arc in eastern California and western Nevada: Arc evolution, cryptic tectonic breaks, and significance of the Mojave-Snow Lake fault, in Dunne, G., and McDougall, K., eds., *Mesozoic paleogeography of the Western United States—II*: Society of Economic Paleontologists and Mineralogists, Pacific Section, Book 71, p. 227–246.
- Sharp, W. D., 1988, Pre-Cretaceous crustal evolution in the Sierra Nevada region, California, in Ernst, W. G., ed., *Metamorphism and crustal evolution, western coterminous United States* (Rubey Volume 7) Englewood Cliffs, New Jersey, Prentice-Hall, p. 824–864.
- Smith, D. L., Wyld, S. J., Wright, J. E., and Miller, E. L., 1993, Progression and timing of Mesozoic crustal shortening in the northern Great Basin, western U.S.A., in Dunne, G., and McDougall, K., eds., *Mesozoic paleogeography of the western United States—II*: Society of Economic Paleontologists and Mineralogists, Pacific Section, Book 71, p. 389–406.
- Speed, R. C., 1978, Paleogeographic and plate tectonic evolution of the early Mesozoic marine province of the western Great Basin, in Howell, D. G., and McDougall, K. A., eds., *Mesozoic paleogeography of the western U.S.*: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Symposium 2, p. 253–270.
- Walker, J. D., Martin, M. W., Bartley, J. M., and Coleman, D. S., 1990, Timing and kinematics of deformation in the Cronese Hills, California, and implications for Mesozoic structure of the southwestern Cordillera: *Geology*, v. 18, p. 554–557.
- Wdowinski, S., O'Connell, R. J., and England, P., 1989, A continuum model of continental deformation above subduction zones: Application to the Andes and the Aegean: *Journal of Geophysical Research*, v. 94, p. 10331–10346.
- Wright, J. E., and Fahan, M. R., 1988, An expanded view of Jurassic orogenesis in the western United States Cordillera: Middle Jurassic (pre-Nevadan) regional metamorphism and thrust faulting within an active arc environment, Klamath Mountains, California: *Geological Society of America Bulletin*, v. 100, p. 859–876.
- Wright, J. E., and Miller, E. L., 1988, The early Mesozoic APW path of North America and its correspondence to western U.S. Cordilleran continental margin tectonics: *Geological Society of America Abstracts with Programs*, v. 20, no. 7, p. A350–A351.
- Wyld, S. J., 1990, Paleozoic and Mesozoic rocks of the Pine Forest Range, northwest Nevada, and their relation to volcanic arc assemblages of the western U.S. Cordillera, in Harwood, D. S., and Miller, M. M., eds., *Late Paleozoic and early Mesozoic paleogeographic relations: Klamath Mountains, Sierra Nevada, and related rocks*: Geological Society of America Special Paper 255, p. 219–237.
- Wyld, S. J., 1991, *Geology and geochronology of the Pine Forest Range, northwest Nevada: Stratigraphic, structural and magmatic history, and regional implications* [Ph.D. thesis]: Stanford, California, Stanford University, 429 p.
- Wyld, S. J., 1996, Early Jurassic deformation in the Pine Forest Range, northwest Nevada, and implications for Cordilleran tectonics: *Tectonics*, v. 15, p. 566–583.

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