Tectonophysics 457 (2008) 239–253

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Modern strain localization in the central Walker Lane, western United States: Implications for the evolution of intraplate deformation in transtensional settings

Benjamin Surpless *

Department of Geosciences, Trinity University, One Trinity Place, San Antonio, TX 78209, United States

ARTICLE INFO

Article history:
Received 9 May 2007
Received in revised form 16 June 2008
Accepted 2 July 2008
Available online 13 July 2008

Keywords:
Transtension
Walker Lane
Lake Tahoe
Strain partitioning
North American–Pacific plate boundary

ABSTRACT

Approximately 25% of the differential motion between the Pacific and North American plates occurs in the Walker Lane, a zone of dextral motion within the western margin of the Basin and Range province. At the latitude of Lake Tahoe, the central Walker Lane has been considered a zone of transtension, with strain accommodated by dip-slip, strike-slip, and oblique-slip faults. Geologic data indicate that extension and strike-slip motion are partitioned across the central Walker Lane, with dip-slip motion resulting in E–W to ESE–WNW extension along the present-day western margin of the central Walker Lane since approximately 15 Ma, and dextral strike-slip motion across a zone further east since as early as 24 Ma. GPS velocity data suggest that present-day strain continues to be strongly partitioned and localized across the same regions established by geologic data. Velocity data across the central Walker Lane suggest a minimum of 2 mm/yr extensional strain focused along the western margin of the belt, with very little extension across either the central or eastern portions of the Walker Lane. These data indicate very little dextral motion across the central and western portions of the domain, with dextral motion of 3–5 mm/yr presently focused along a discrete zone of the eastern part of the central Walker Lane, coincident with existing, mapped strike-slip faults. Historic seismic data reveal little seismic activity in areas of Late Holocene dip-slip motion in the west or dextral motion in the east, suggesting a period of quiescence in the earthquake cycle and the likelihood of future activity in both areas. Based on this and previous studies, it is likely that a combination of pre-Cenozoic crustal structure, a relatively weak lithosphere beneath the Walker Lane, and long-term low stress ratios in the crust have permitted the long-term partitioning of dextral and extensional strain exhibited across the central Walker Lane. The present-day location of dextral strain in the central Walker Lane is subparallel with dextral deformation documented in the northern Walker Lane, suggesting that as strain continues to accumulate, these two discrete zones could become a continuous strike-slip system which will play a more important role in the future accommodation of relative Pacific–North American plate motion.

1. Introduction

Relative motion between the North American and Pacific plates has resulted in a broad zone of distributed dextral shear on the western margin of North America (e.g., Atwater, 1970; Atwater and Stock, 1998). While most of this motion has been accommodated by the San Andreas strike-slip fault system (e.g., Bennett et al., 1999; DeMets and Dixon, 1999), GPS data indicate that faults in the western Basin and Range province account for approximately 25% of the total strain between the Pacific and North American plates (Minster and Jordan, 1987; Dixon et al., 1995; Bennett et al., 1999). South of latitude 36°N, most of this relative plate motion is accommodated within 100–200 km of the San Andreas fault (Bennett et al., 1999), but further north, through-going deformation associated with dextral motion also occurs to the east of the Sierra Nevada, along the Walker Lane belt (Fig. 1), separated from the San Andreas fault system by the Sierra Nevada–Great Valley microplate (e.g., Argus and Gordon, 1991).

The central Walker Lane (Fig. 1) is the locus for both dextral motion associated with the North American–Pacific plate boundary as well as significant extension associated with classic Basin and Range deformation. The pattern of faulting within the Walker Lane is more complex than that associated with the San Andreas system and might be the result of both the lower total cumulative dextral slip along the Walker Lane relative to the San Andreas as well as the different associated stress field of the Walker Lane (extensional) relative to the San Andreas (contractional) (e.g., Wesnousky, 2005a). Numerous geologic and geodetic studies of the Walker Lane reveal conflicting interpretations of how strain is accommodated across the region. Flesch et al. (2000) and Bennett et al. (2003) suggest distributed dextral shear and extension across the Walker Lane at most latitudes, while Oldow (2003) and Hammond and Thatcher (2004) hypothesize a zone of dextral-dominated transtension in the east and a zone of extension-dominated transtension in the west. Unruh et al. (2003) suggest focused dextral deformation along the entire Sierra Nevada

* Tel.: +1 210 999 7110; fax: +1 210 999 7090.
E-mail address: bsurples@trinity.edu.

0040-1951/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2008.07.001

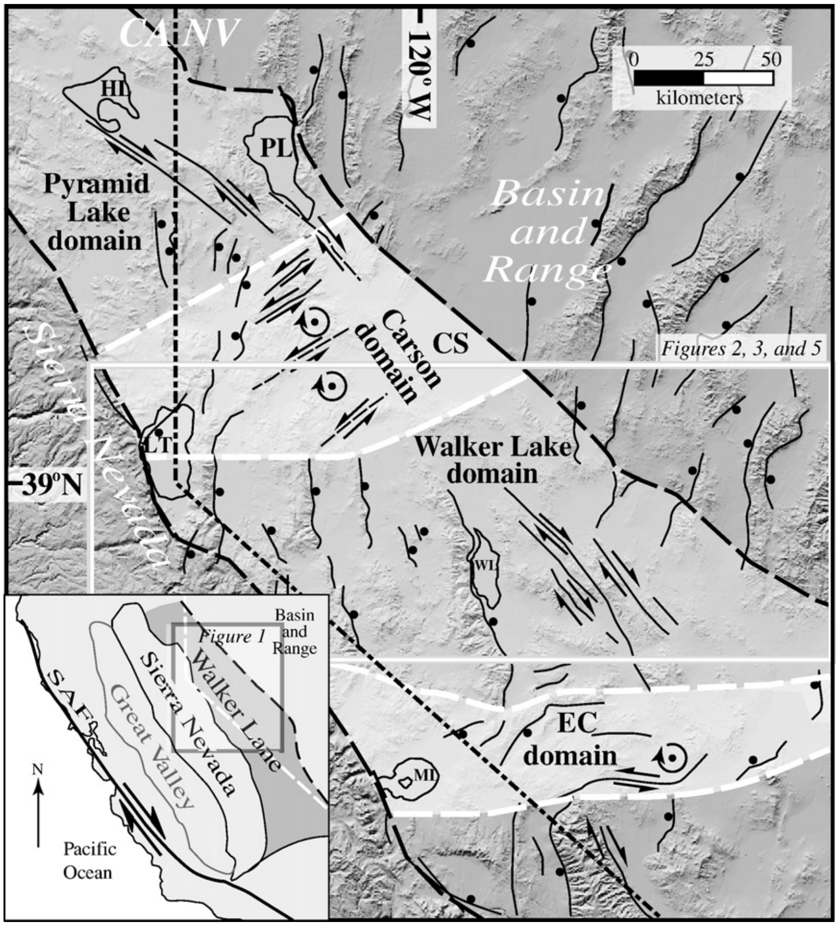

Fig. 1. Digital shaded relief map and location map of the central and northern Walker Lane showing the four structural domains of Stewart (1988), separated by dashed white lines, and the major normal and strike-slip faults in each domain. Sense of motion is indicated on all faults. Block rotations discussed in text are indicated. The region shown in Figs. 2, 3, and 5 is boxed in white. The bold, black, dashed lines indicate the boundaries of the Walker Lane as delineated by Stewart (1988). Abbreviations: EC — Excelsior — Coaldale; HL — Honey Lake; PL — Pyramid Lake; LT — Lake Tahoe; WL — Walker Lake; ML —Mono Lake; CS — Carson Sink; and SAF — San Andreas fault (modified after Ichinose et al., 1998).

range front fault system, with extension proximal to the range front related to northwestward migration of the Sierra Nevadan microplate, rather than Basin and Range extension.

Integrating previous geologic and seismic studies with recently published Global Positioning System (GPS) velocity data helps resolve this controversy. These data show a clear partitioning of present-day strain, with localization of most dextral deformation across a very narrow region in the eastern portion of the central Walker Lane and most extensional deformation focused in the west, proximal to the present-day Sierra Nevada range front fault system. These findings, combined with recent data from the northern Walker Lane, have significant implications for the evolution of intraplate deformation in transtensional settings and provide evidence for the future of the Walker Lane in the context of Pacific–North American plate interactions.

2. Geologic setting of the central Walker Lane

2.1. Structural domains of the central and northern Walker Lane

The Walker Lane is a complex zone of dextral and extensional deformation subdivided into structural domains based on the dominant mode of faulting in each domain (Fig. 1; Stewart, 1988). North of latitude 38°N, the domains are the Excelsior–Coaldale domain, the Walker Lake domain, the Carson domain, and the Pyramid Lake domain. Although dextral strike-slip faults have not been documented in all domains (Fig. 1), models of deformation based on geologic and geodetic data emphasize the importance of dextral deformation across all domains (e.g., Cashman and Fontaine, 2000; Oldow, 2003; Unruh et al., 2003; Hammond and Thatcher, 2004; Faulds et al., 2005).

The Excelsior–Coaldale domain is not cut by any through-going dextral faults (e.g., Stewart, 1993; Oldow, 1993) and is hypothesized to have been the locus of north–south directed extension related to the transfer of dextral displacement from the southern Walker Lane to the central Walker Lane in the north (e.g., Oldow et al., 1994). This domain is now thought to be the location where significant left-lateral strike-slip faults accommodate clockwise rotation of fault blocks about a vertical axis (e.g., Freund, 1974; Nur et al., 1986; Petronis et al., 2002; Wesnousky, 2005b), consistent with dextral motion along the eastern region of the Walker Lane belt (Fig. 1). The position of displacement transfer structures in the Excelsior–Coaldale domain might be related to the position of the continental edge during the Paleozoic, based on isotopic studies across the region (e.g., Kistler, 1991; Oldow et al., 1994).

The Walker Lake domain displays both well-defined northwest-striking dextral strike-slip faults in the east and major subparallel N–NNW-striking Basin-and-Range-style normal faults, in the western part of the domain (Figs. 1 and 2A). The timing of initiation of extensional faulting and associated deformation at this latitude becomes younger to the west (e.g., Dilles and Gans, 1995; Schweickert et al., 2000; Stockli et al., 2002; Surpless et al., 2002), so is relatively immature relative to the onset of dextral faulting in the eastern part of the domain or normal faulting in the Basin and Range further east. This younger deformation in the west may explain some of the structural complexity across the region.