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Ouachita, Appalachian, and Ancestral Rockies deformations recorded in mesoscale structures on the foreland Ozark plateaus

Randel Tom Cox *

Department of Earth Sciences, Johnson Hall, University of Memphis, Memphis, TN 38152, U.S.A.

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ABSTRACT

Mesoscale structures in Paleozoic rocks of the Ozark plateaus reveal four Pennsylvanian deformation episodes in midcontinent North America. The two earliest episodes can be assigned to progressive northwestward docking of the Ouachita terrane with North America. Early extensional structures (Event 1) indicate a northwest/southeast maximum horizontal stress (Hmax) during Early Pennsylvanian Ouachita terrane advance. Event 2 extensional and strike-slip structures indicate Hmax across the Ozark plateaus that varies systematically from north-northwest/south-southeast in the south to northeast/southwest in the north. This suggests development of a slip-line deformation field in response to minor northeastward lateral escape of lithospheric blocks away from the northwestward-moving Ouachita terrane's leading edge, which acted as an indenter in western Arkansas, southeastern Oklahoma, and Texas. Younger contractional and strike-slip structures of Event 3 indicate northeast/southwest Hmax across the entire Ozark plateaus, and deformation orientation and intensity are not readily assigned to Ouachita foreland deformation and may be related to Middle Pennsylvanian Ancestral Rockies contractional deformation. Finally, Event 4 contractional structures indicate northwest/southeast Hmax consistent with southern Appalachian late stage convergence. Deformation episodes are localized along basement fault zones, particularly at major bends, suggesting minor restraining-bend uplifts along strike-slip faults. Geometries of conjugate normal fault and hybrid shear joint arrays indicate localized areas of high differential stress consistent with basement block uplift at these bends. High-angle faults reactivated in a reverse sense and bedding-parallel veins suggest tensile minimum stresses and pore fluid pressures exceeding lithostatic stress, consistent with brine pulses driven into the midcontinent during Late Paleozoic orogeny (as proposed by other authors).

1. Introduction

The Ozark Plateaus (OP) of the midcontinent region of North America extend across Missouri from the Mississippi and Missouri Rivers to eastern Kansas and Oklahoma and include the Springfield and Salem plateaus as well as the Boston Mountains of northern Arkansas. The OP affords good exposure in a cratonic setting foreland to an orogenic belt, the late Paleozoic Appalachian–Ouachita system (Fig. 1), and a regional analysis of kinematics of deformation of the OP has been lacking. Knowledge of the kinematics of intraplate deformation can provide useful information about far-field paleostresses and plate boundary interactions and thus is valuable in constraining models of plate motions and collisions, especially in Paleozoic time and earlier for which magnetic sea-floor anomalies are not available. Mesoscale (outcrop scale) structures in orogenic forelands record strains arising from orogenic events, but with nominal rotation of strain axes. Therefore, paleostress orientations are more readily reconstructed from foreland structural data than from the more intensely deformed orogen (Hancock, 1985; Thatcher and Hill, 1991). On the OP, strain is low. Except immediately adjacent to large fault planes, bedding dips are 0° to 20° and slip on mesoscale faults is typically <1 m.

This study presents a regional field investigation of OP mesoscale deformation and an interpretation of the relationship of this deformation to late Paleozoic orogenic activity. The area studied (Fig. 1) largely encompasses the OP outcrop area of Precambrian and Paleozoic rocks that is inboard of large faults of the adjoining Arkoma foreland basin. Mesoscale structures that formed as a result of mild brittle deformation are exposed in roadcuts, quarries, mines and river bluffs and include slickensided normal, strike-slip, reverse, and thrust faults, various subsidiary fault and joint arrays (pinnate, Riedel, Riedel', P, and X fractures), mode I joints, veins, clastic dikes, fault-propagation folds, kink bands, cataclasite seams (deformation bands), and tectonic stylolites. Occasional joints have plumose structure or calcite mineralization, but most do not show surface ornamentation.

Qualitative interpretations of Late Paleozoic tectonic style on the OP and adjacent parts of midcontinent North America have been varied. Thrust loading of the North American craton margin during the Appalachian–Ouachita orogeny has been proposed as the driving force

* Tel.: +1 901 678 4361.
E-mail address: randycox@memphis.edu.

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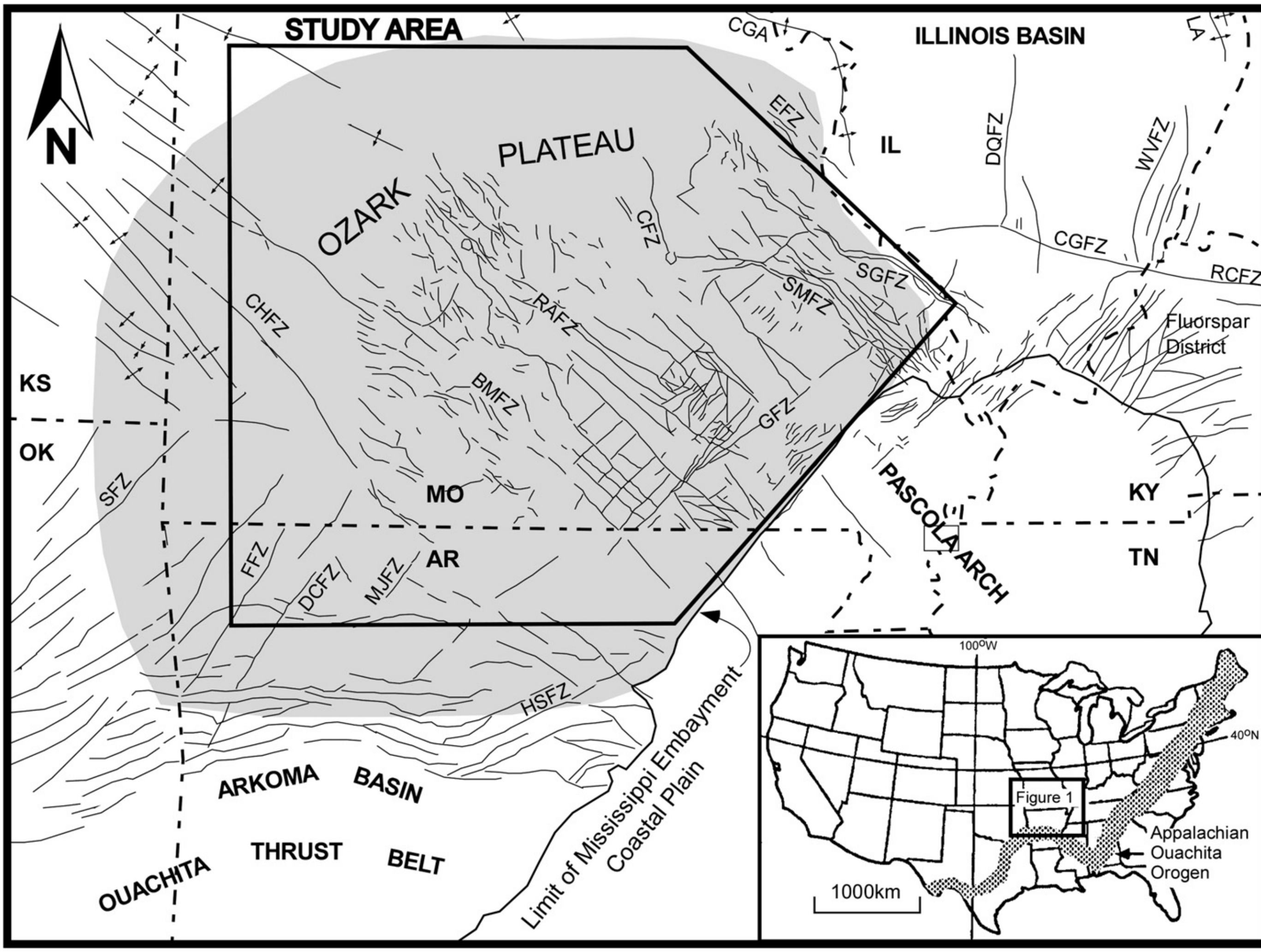

Fig. 1. Limits of the study area and mapped surface structures of the Ozark plateaus region. Thin black lines are faults. BMFZ = Bolivar–Mansfield fault zone; CFZ = Cuba fault zone; CHFZ = Chesapeake fault zone; CGA = Cap au Gres anticline; CGFZ = Cottage Grove fault zone; DCFZ = Drake's Creek fault zone; DQFZ = Du Quoin fault zone; EFZ = Eureka fault zone; FFZ = Fayetteville fault zone; GFZ = Greenville fault zone; HSFZ = Heber Springs fault zone; LA = La Salle anticline; MJFZ = Mount Judea fault zone; RAFZ = Red Arrow fault zone; RCFZ = Rough Creek fault zone; SFZ = Seneca fault zone; SGFZ = Ste. Genevieve fault zone; SMFZ = Simm's Mountain fault zone; WVFZ = Wabash Valley fault zone. Gray = general extent of Ozark plateaus. Mapped structures were compiled from McCracken (1971), Trace and Amos (1984), Patterson (1986), Noger (1988), Pratt et al. (1992), Haley (1993), Harrison (1995), Nelson (1995), Orndorff and Harrison (1997, 2001), McDowell (1998), Orndorff et al. (1999), McDowell and Harrison (2000), Hudson et al. (2001), Harrison et al. (2002), Weems (2002), Harrison and McDowell (2003), Hudson and Murray (2003, 2004), Orndorff (2003), Weary and Schindler (2004), Weary and Weems (2004), Weary and McDowell (2006), Hudson and Turner (2007), and Weary (2008a,b).

reactivating structures of foreland uplifts and basins in the mid-continent region (Quinlan and Beaumont, 1984; and Arbenz, 1989). In the loading model, flexing of the plate margin causes vertical displacements along fault zones to be the dominant style of brittle deformation. Indeed, the majority of early fault descriptions for the Ozark region report normal separations (McCracken, 1971), and along the eastern flank of the Ozarks, Tikrity (1968) and Gibbons (1972) describe late Paleozoic high-angle "upthrust" reverse faults. More recently Hudson (2000) describes normal and dextral slip along east-west and northeast-striking faults, respectively, on the southern flank of the OP and attributes these movements to progressive westward thrust loading of the Ouachita orogen.

An alternative interpretation assigns Pennsylvanian and Permian contractional structures throughout the midcontinent to a broad deformation event that includes the Ancestral Rockies uplifts in New Mexico and Colorado (Kluth and Coney, 1981; Denison, 1989; McBride and Nelson, 1999; Marshak et al., 2000). Ye et al. (1996) argue that northeast and southwest verging folds and high-angle reverse faults of this deformation episode in Texas, Oklahoma, Missouri, and Illinois are evidence of far-field inboard deformation related to northeast-dipping low-angle subduction along the southwestern margin of North America. Crustal shortening associated with this set of structures is parallel to the Appalachian–Ouachita orogenic front and thus cannot be easily attributed to that orogeny (McBride and Nelson, 1999; Barbeau, 2003). The high-angle reverse fault style of deformation characteristic of the OP is similar to that of the Ancestral Rockies uplifts.

Viele (1983), Kaiser and Ohmoto (1988), Sloss (1988), and Viele and Thomas (1989) suggest that strike-slip fault movements hundreds of kilometers inboard of the orogenic belt were related to the Alleghanian–Ouachita collision event. Although none suggested the presence of major "escaped terranes," strike-slip faulting does extend into the craton in the vicinity of the OP. For example, Harrison and Schultz (1994) interpret the Ste. Genevieve fault system in Missouri and Illinois (Fig. 1) as a strike-slip fault system, and Clendenin et al. (1989, 1993), Langenheim and Hildenbrand (1997), and Clendenin and Diehl (1999) report that other faults in the eastern Ozark region show significant strike-slip offset. Similarly, Patterson (1986) demonstrated strike-slip offset on near vertical faults in northeastern Oklahoma on the Seneca fault system (Fig. 1).

Tectonic interpretations on the southeast of the OP do not show consensus. McKeown et al. (1990) proposed that late Paleozoic uplifts