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Tectonophysics 396 (2005) 227–244

TECTONOPHYSICS

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Kinematics, mechanics, and potential earthquake hazards for faults in Pottawatomie County, Kansas, USA

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Received 18 September 2003; accepted 6 December 2004
Available online 13 January 2005

Abstract

Many stable continental regions have subregions with poorly defined earthquake hazards. Analysis of minor structures (folds and faults) in these subregions can improve our understanding of the tectonics and earthquake hazards. Detailed structural mapping in Pottawatomie County has revealed a suite consisting of two uplifted blocks aligned along a northeast trend and surrounded by faults. The first uplift is located southwest of the second. The northwest and southeast sides of these uplifts are bounded by northeast-trending right-lateral faults. To the east, both uplifts are bounded by north-trending reverse faults, and the first uplift is bounded by a north-trending high-angle fault to the west. The structural suite occurs above a basement fault that is part of a series of north–northeast-trending faults that delineate the Humboldt Fault Zone of eastern Kansas, an integral part of the Midcontinent Rift System. The favored kinematic model is a contractional stepover (push-up) between echelon strike-slip faults. Mechanical modeling using the boundary element method supports the interpretation of the uplifts as contractional stepovers and indicates that an approximately east–northeast maximum compressive stress trajectory is responsible for the formation of the structural suite. This stress trajectory suggests potential activity during the Laramide Orogeny, which agrees with the age of kimberlite emplacement in adjacent Riley County. The current stress field in Kansas has a N85°W maximum compressive stress trajectory that could potentially produce earthquakes along the basement faults. Several epicenters of seismic events (<M2.0) are located within 10 km of the structural suite. One epicenter is coincident with the northwest boundary of the uplift. This structural suite, a contractional stepover between echelon northeast-trending right-lateral faults, is similar to that mapped in the New Madrid Seismic Zone, and both areas currently feature roughly east–west maximum compressive stress trajectory. Based on these similarities, the faults in Pottawatomie County have the potential for seismicity. The results demonstrate that mechanical analysis of minor structural features can improve our knowledge of local earthquake hazards.

Keywords: Tectonics; Strike-slip faults; Numerical modeling; Stable continental regions; Earthquake hazards

1. Introduction

A paucity of earthquakes, including microearthquakes, affects the accuracy of the earthquake-hazard

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0040-1951/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2004.12.002

values in stable continental regions (SCRs). Earthquake hazard maps of the central United States (Frankel et al., 1997) contain vast subregions where the probability of a major earthquake is very low. In reality, the probability of an earthquake in these subregions is poorly defined and is assumed to be low. The State of Kansas is located in a low earthquake hazard area, and other plates have SCRs with regions where the earthquake hazard is poorly defined and may even be underestimated. At first glance, the central United States portion of the North American Plate SCR may appear to be structurally featureless; however, numerous minor displacement structures exist throughout the region. These minor structural features are routinely overlooked as a source of information regarding tectonics and earthquake hazards.

Detailed studies of surface structural patterns are needed to improve our understanding of the tectonics and related neotectonics of the stable continental region of the North American Plate. Much has been learned about the structure of the New Madrid Seismic Zone (NMSZ) from earthquake foci, trenching, and seismic surveys (Russ, 1982; Van Arsdale, 2000; Champion et al., 2001 and references therein). The NMSZ has also yielded significant information on the paleoseismology of the SCR (Obermeier, 1989; Saucier, 1989, 1991; Tuttle and Schweig, 1995; Tuttle et al., 1999). However, the faults that comprise the structural suite of the NMSZ are poorly exposed at the surface. In Kansas, less is known about the neotectonics and seismic hazards; however, the seismic areas in the eastern part of the state have well exposed bedrock and the faults, and displacement patterns can be determined.

The current seismic hazard for Kansas is based on a limited data set. Historic accounts provide evidence for 27 earthquakes that occurred prior to 1977 (DuBois and Wilson, 1978; Steeples et al., 1990). This includes the 1867 earthquake, the largest in Kansas (MMI VII), near Wamego in Pottawatomie County (Fig. 1). In addition to the historic data, a seismic network was operated in Kansas from 1977 to 1989 (Hildebrand et al., 1988; Steeples et al., 1990). Recently, Kansas has relied on the national network and a local array of seismographs deployed around Tuttle Creek Reservoir near Manhattan, Kansas.

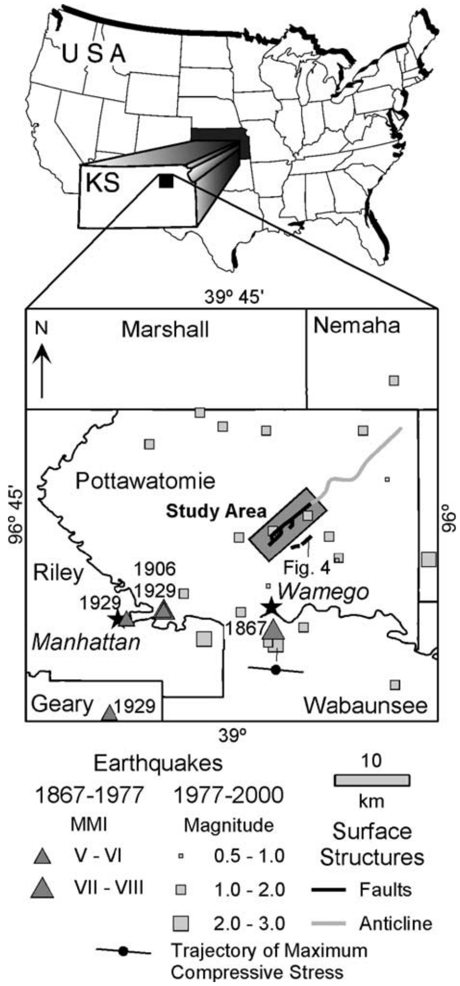

Fig. 1. Map showing the location of the study area, mapped structures, and earthquakes in Pottawatomie County, Kansas. The figure also shows the trajectory of the maximum compressive stress based from the world stress map data set (Reinecker et al., 2004). The stress trajectory is based on an earthquake focal mechanism for an earthquake indicated by the leader line.

The U.S. Geological Survey Ground Shaking Hazard Map of the United States (Frankel et al., 1997) shows the peak acceleration with a 10% probability of exceedance in 50 years as less than 3% g for Kansas compared 20–25% g for the NMSZ. This may be an accurate representation of the seismic hazard for Kansas. In order to improve the understanding of the earthquake hazard in Kansas, a structural mapping project was conducted to examine the tectonics and neotectonics of faults in northeastern