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The relationship between normal and strike-slip faults in Valley of Fire State Park, Nevada, and its implications for stress rotation and partitioning of deformation in the east-central Basin and Range

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ABSTRACT

This study expands on our earlier studies of the evolution of fracturing and faulting in the Jurassic aeolian Aztec Sandstone exposed over a large area in the Valley of Fire State Park, southeastern Nevada. Based on a nearly three-dimensional data set collected from 200-m-high cliff-face exposures with stair-case morphology composed of steep and flat parts, we find that a series of inclined, relatively low-angle normal faults and their splay fractures are precursors of the strike-slip fault network that we previously documented. We discuss the significance of this finding in terms of the tectonics of the broader area, stress rotation, partitioning of deformation, and the development of fracture clusters with compartmentalization of the structures as a function of spatial, depositional and deformational domains.

1. Introduction

During the last two decades, we have studied the deformation of the Mesozoic sandstones, particularly the Jurassic Aztec Sandstone cropping out in the Valley of Fire State Park, southeastern Nevada, and its immediate vicinity. The Geosciences Research Program of the DOE Basic Energy Sciences division has supported this project for many years, based on the premise that understanding the nature and distribution of the fractures and faults in such an exhumed paleo-reservoir/aquifer would lead to important breakthroughs in structural geology, including its application to fractured reservoirs/aquifers characterization, CO_2 sequestration and a wide variety of environmental problems. As a result of this research, several structure types and assemblages of different structures have been documented and analyzed in great detail, and their flow properties have been assessed.

We previously documented how strike-slip faults formed from an initial array of joint zones by shearing of the joints, splay fracturing, and the subsequent shearing of the splay fractures in the Aztec Sandstone cropping out in the Valley of Fire State Park (Myers and Aydin, 2004; Flodin and Aydin, 2004). We analyzed the splay angle (kink angle) and its variation in terms of various physical and geometric parameters (de Joussineau et al., 2007) and determined the geostatistical properties of the strike-slip faults with increasing slip magnitude (de Joussineau and Aydin, 2007), which had resulted from splay fracturing and sequential shearing. We measured the petrophysical properties of the different components of the fault zones (Flodin et al., 2005) and assessed their impact on fault zone permeability upscaling (Jourde et al., 2002; Flodin et al., 2004; Ahmadov et al., 2007; Zhou et al., 2013), as well as on paleo-fluid flow (Eichhubl et al., 2004) responsible for sandstone units with the spectacular diagenetic alteration colors to which the Park scenery owes its beauty. Finally, we analyzed the statistics and mechanics of strike-slip fault growth by a linkage process that created an associated damage zone eventually leading to the formation of cataclastic fault rock (de Joussineau and Aydin, 2007; Aydin and Berryman, 2010).

Most, if not all, of the data for these studies were collected from excellent outcrops, but primarily using 2-D map-view images and observations. Two-dimensional models have their merits, and they can often be extrapolated to visualize the third dimension. However, such extrapolations are limited because the projections are based upon assumptions with uncertain validity. Here, we present our results on primarily normal and strike-slip fault relationships

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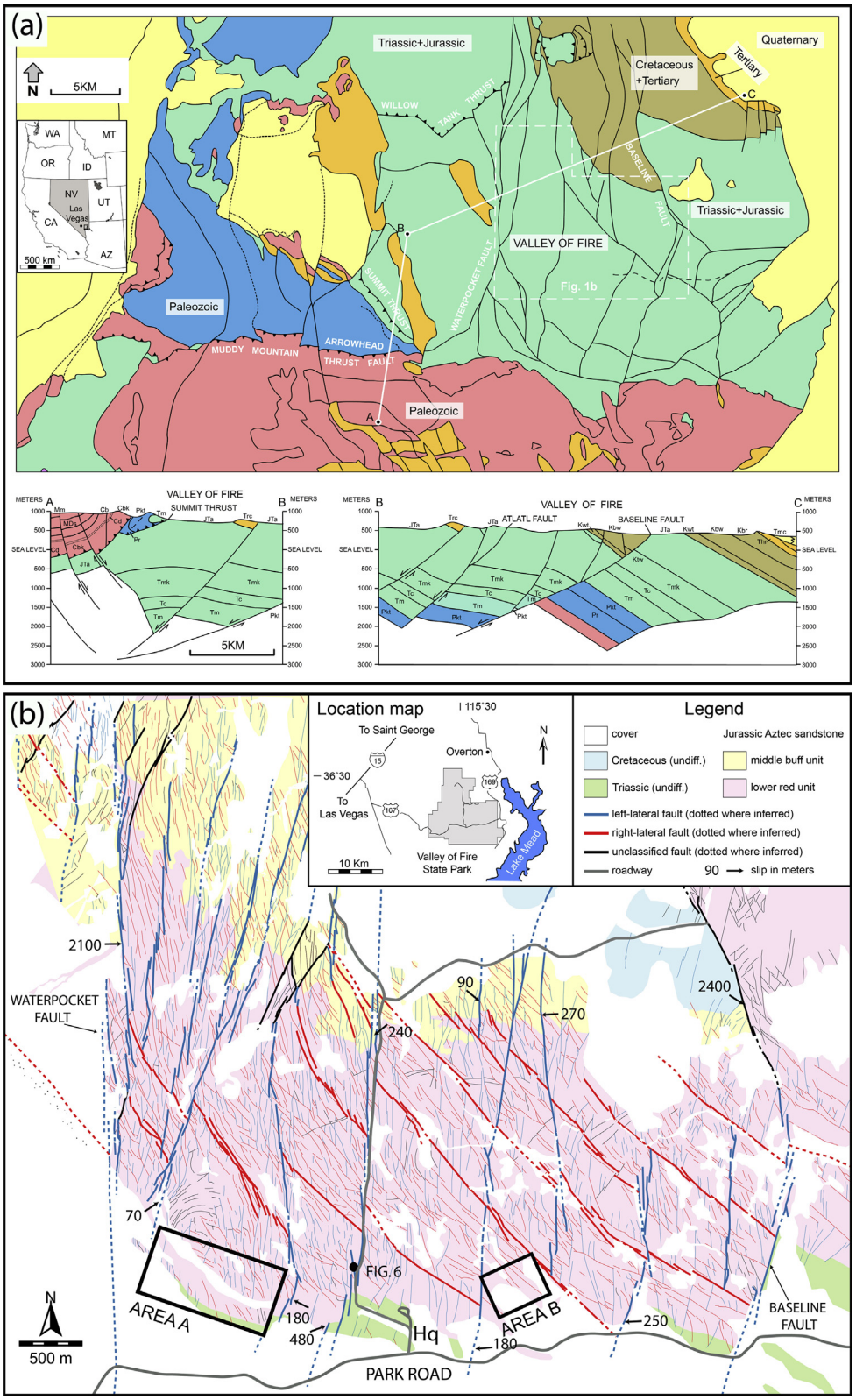

Fig. 1. (a) Geologic map of Valley of Fire State Park and its vicinity, with cross-sections AB, showing the Muddy Mountains Thrust system, and BC, showing the faults interpreted by the original author to be primarily normal faults. Simplified from Bohannon (1983a). Inset shows the location map. (b) Detailed geological map of the central part of Valley of Fire State Park, Nevada showing a predominantly left- and right-lateral strike-slip fault system (see the polygon with dashed white lines at the center of Fig. 1a). Apparent lateral offsets and their approximate locations are shown by numbers and arrows next to the fault traces. Locations of the detailed study areas (Area A and Area B in Fig. 2, and Fig. 6 by the internal Park road), and the park Headquarters (Hq) are also marked. Slightly changed from Flodin and Aydin (2004).