Earth and Planetary Science Letters 497 (2018) 193–203

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

A 6000-year-long paleoseismologic record of earthquakes along the Xorkoli section of the Altyn Tagh fault, China

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ARTICLE INFO

Article history:
Received 30 August 2017
Received in revised form 24 May 2018
Accepted 6 June 2018
Available online xxxx
Editor: A. Yin

Keywords:
Altyn Tagh fault
paleoearthquake
fault section
recurrence behavior
strike-slip fault

ABSTRACT

Long records of paleoearthquakes are essential for understanding earthquake recurrence behavior of active faults and for evaluating regional seismic hazard. However, paleoseismic data on the Altyn Tagh fault (ATF), one of the longest strike-slip fault in Asia, are scarce. We document a long paleoseismic record along the Xorkoli section of the central ATF. Eight and probably nine earthquakes are identified based on event evidence in the form of open fissures, folds, unconformities, and upward fault terminations, with modeled mean (95% confidence) ages of A.D. 1598 (1491–1741) yr (event A), A.D. 797 (676–926) yr (B), B.C. 668 (732–589) yr (C), B.C. 956 (1206–715) yr (D), B.C. 1301 (1369–1235) yr (E), B.C. 2105 (2233–1987) yr (F, probable), B.C. 2663 (2731–2601) yr (G), B.C. 2818 (2878–2742) yr (H), B.C. 3396 (3522–3205) yr (I). The mean recurrence interval is 620 ± 410 yr with a coefficient of variation (COV) of 0.67, indicating that earthquake recurrence is weakly periodic, with individual intervals ranging from as short as 150 yr to as long as 1460 yr. A global compilation of 35 strike-slip paleoseismic sites yields a similar average COV of 0.69. Synthesis of paleoseismic sites from the central ATF indicates that not all earthquakes ruptured to the eastern end of the Xorkoli section, within the Aksay restraining bend. Given that the 420-yr elapsed time since the most recent event, well within a COV of mean interval, a large surface-rupturing earthquake could occur at any time along the central ATF.

1. Introduction

Long records of paleoearthquakes on a variety of fault types and geometries are essential for testing hypotheses for earthquake recurrence behavior. For example, paleoseismic studies along the Alpine fault (New Zealand) suggest that an isolated strike-slip fault or fault section with a simple geometry and high slip rate may exhibit periodic recurrence behavior (Berryman et al., 2012), with a coefficient variation (COV = mean recurrence interval divided by its standard deviation) less than 0.5. In contrast, faults with lower slip rates, complex geometry, or that interact with other faults may exhibit less periodic (COV > 0.5) or even clustered behavior (COV > 1.0) (Madugo et al., 2012; McAuliffe et al., 2013; Rockwell, 2010). Stress concentration along a fault bend may control nucleation or termination point for earthquake rupture (King and Nabelek, 1985). Numerical rupture simulations (Harris and Day, 1993; Lozos et al., 2011) and historical earthquake ruptures (Wesnousky, 2006) support the hypothesis that fault geometry exhibits a strong control on rupture extent. Complex geometries, such as fault bends or large steps, can store significant strain energy over multiple earthquake cycles, permitting an occasional rupture to break through the bend (Duan and Oglesby, 2005), resulting in a rare, larger event that could increase the COV of recurrence interval.

In this paper we present results from a paleoseismologic study at the Copper Mine site on the Xorkoli section of the left-lateral ATF in western China. This section defines a 210 km-long stretch where the trace of the ATF is relatively simple and rectilinear (Fig. 1). The arid climate and continuous sedimentation here are favorable for the preservation of the deformation related to the paleoearthquakes. Well-constrained paleoearthquake

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https://doi.org/10.1016/j.epsl.2018.06.008
0012-821X/

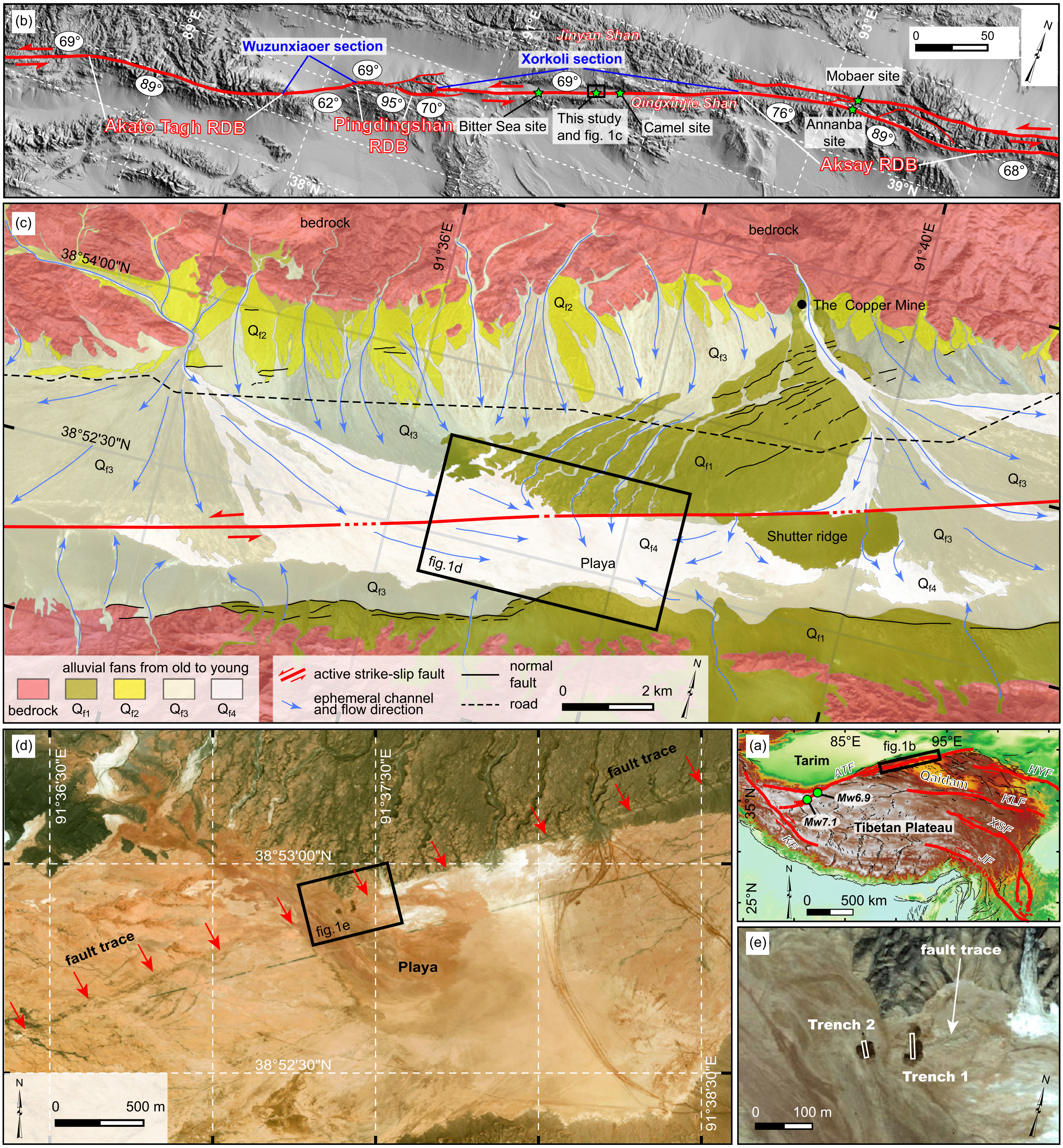

Fig. 1. (a): Fault map of India–Asia collision zone. Bold red lines and black lines indicate large strike-slip faults and normal or thrust faults respectively in Tibet. ATF—Altyn Tagh fault; HYF—Haiyuan fault; KLF—Kunlun fault; XSF—Xianshuihe fault; KF—Karakoram fault; JF—Jiali fault (modified from Tapponnier et al., 2001). (b): Shaded-relief map of the central section of the ATF and locations of paleoseismic sites. Fault strikes are shown in ellipses. RDB—restraining double bend. (c): The interpretation of the satellite image of the Copper Mine site, showing strike-slip fault cutting alluvial fans and playa. Discontinuous normal faults with degraded scarps are located along the piedmont and diagonal across Q_{f1}, perhaps related to an earlier time when the fault transgressively stepped across and created the basin. (d) and (e): Satellite images of the Copper Mine site. Background images of (c)∼(e) are from Google Earth. (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)