Quaternary Slip History for the Central Altyn Tagh Fault Reveals Time-Varying Slip Rate

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Although the Tibetan Plateau is cut by a number of major (>1000 km long) strike-slip faults (e.g., Molnar and Tapponnier, 1975), it remains unclear how much deformation is localized along these first-order structures (e.g., Tapponnier and others, 2001) as opposed to distributed within the domains they bound (e.g., England and Molnar, 2005). Disagreements over the rates at which these major faults slip have clouded the debate over the kinematics of deformation within the collision (e.g., Cowgill, 2007; England and Molnar, 2005). Thus, rates and histories of slip on these major faults must be measured accurately before the long-term kinematics within the collision zone can be established (Cowgill, 2007). The largest active major strike-slip fault in Tibet is the left-slip Altyn Tagh fault (ATF), which defines the NW margin of the Tibetan plateau. The latest Quaternary slip rate along the ATF has been disputed for two decades, with reported Quaternary rates varying by almost a factor of three (Peltzer and others, 1989; Mériaux and others, 2004; Bendick and others, 2000; Cowgill, 2007). To address this problem, we have determined the post-16 ka slip history of the central ATF between 86.5° and 88.5°E longitude using morphochronology (i.e., measurement of the age and offset of faulted landforms, Mériaux and others, 2004).

We first evaluated how the determined slip rate varies as a function of epistemic uncertainties in morphochronologic data, including the impact of uncertainties in the age (Cowgill, 2007) and magnitude of lateral erosion (Gold and others, 2009) of a fluvial terrace riser. We then obtained new morphochronologic data from 9 risers at 5 sites (Fig. 1a): Yuemake (Cowgill and others, 2009), Tuzidun (Gold and others, 2009), and Kelutelage, Yukuang, and Keke Qiapu (Gold and others, in review). We also used new field observations to reinterpret the Cherchen He site (Cowgill, 2007). Data are summarized in Figure 1b. To analyze this volume of morphochronologic data, we developed a Monte Carlo approach for determining slip histories from suites of morphochronologic data that allows us to determine both precise average slip rates and evaluate the extent to which such rates have varied over time (Gold and Cowgill, in review). Figures 1c-d show the results of this analysis as applied to the central Altyn Tagh fault. When considered as population, compatibility relationships between age-displacement measurements trims the sizes of individual data boxes, and the grey field on Figure 1d shows the resulting portion of age-displacement that the slip history could occupy. Application of our method of Monte Carlo modelling of such data yields a population of 1000 slip histories that fit the data (space limitations preclude showing the paths here). A Mode II linear regression through these modelled histories yields a preliminary average rate of 9.1 ± 1.1 mm/yr from 16.6 ± 3.9 ka to present, however, this approach forces upon the data an assumption of no temporal variations in slip rate. Thus, a more reasonable approach is to simply contour the slip histories to determine a mean slip history with alpha-95 confidence bounds and thus evaluate the extent to which such an assumption is warranted. Figure 1d shows such a best-fit slip history for the central Altyn Tagh fault, and reveals a phase of accelerated strain release in the mid Holocene. Specifically, from ~6.7 to ~5.9 ka, 20 m of slip was released at a short-term rate (~28 mm/yr) that is 3 times greater than the average rate (~9 mm/yr).

We interpret this pulse to represent a cluster of two to six, Mw > 7.2 earthquakes. It is unlikely that this pulse is due to a single large-magnitude earthquake because slip is too large to have reasonably been released in a single event. To our knowledge, this is the first possible earthquake-cluster detected using morphochronologic techniques. This approach we use here is essential for testing block models of continental tectonics, in which frequent reorganization of the active fault network leads to secular variation in slip along faults at timescales of 10-100 kyr.

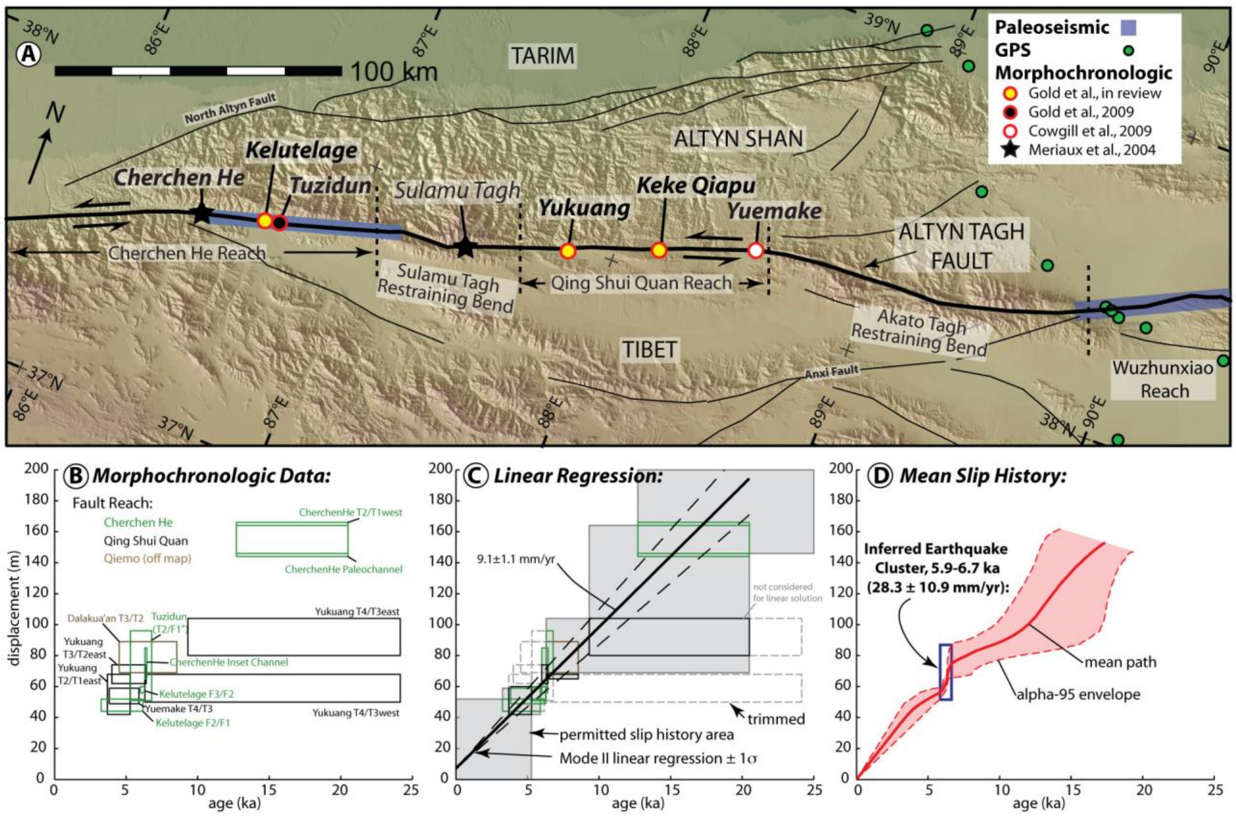

Figure 1. Slip rate sites and summary of slip history analysis. A) Map of the central Altyn Tagh fault showing locations of morphochronologic studies and prior geodetic and paleoseismic investigations. B) Summary of age-displacement measurements along the ATF. Different colors indicate data from different reaches (data from Qiemo reach is from Xu and others, 2005, west of the area shown in part A). C) Considering the data as a population yields compatibility constraints that trim the sizes of individual data boxes and yields the grey field. Monte Carlo modelling of such data then yields a population (not shown) of slip histories fitting the data. D) Contouring the slip histories yields the best-fit slip history and associated confidence interval.

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