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Reconstruction of surface slips associated with past multi-segment earthquakes on the North Anatolian fault system

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Recent research shows that active fault systems produce multi-segment earthquakes, however, we have yet to understand the faulting behavior of various spatial patterns of segments. We systematically conducted three-dimensional trenching surveys to reconstruct the detailed slip history of a fault segment that ruptured as one of the multi-segment ruptures along the North Anatolian fault system.

Along the 1944 earthquake segment, the trench site recorded a maximum right-lateral slip of up to 6 m that was associated with the 1944 Bolu-Gerede earthquake (M 7.4). Fault exposures show evidence of four paleoearthquakes. Radiocarbon dates, a refined probability density distribution, and correlation with historical earthquakes place the mean repeat time at ~330 years. Four discrete paleo-slips yield a slip per event of 5.0+/-0.8 m with a coefficient variation of 0.2. Our research suggests that multi-segment earthquakes exhibit various spatial patterns, regardless of recurrence with quasi-periodicity and characteristic slip. Coincidentally, the fault geometry exhibits extremely linear traces, suggesting simple stress accumulation and release through earthquake cycles. Furthermore, the 1944 event did not occur in a single segment, and the Gerede segment probably ruptured within a slip-pulse-like rupture during a multi-segment earthquake. We conclude that a segment with simple fault geometry along a strike-slip fault system plays an important role in forecasting the timing of future multi-segment earthquakes, but the spatial extent of such earthquakes needs to be explored further.

In contrast, 3-D trenching survey on the 1942 earthquake segment revealed paleoseismological evidence of unusually large slip during a single multi-segment earthquake in 1668. We found right -lateral slips of 2?3 m on the Niksar segment of the NAFS during the 1942 earthquake, but paleoslips of up to 8 m in the same region during the preceding 1668 event. The last earthquake before the 1668 event was during the 6th century; thus, the interval between these was much longer than the 274 years between the 1942 and 1668 earthquakes. We show that the 1668 earthquake followed a long quiescent period and that the rupture jumped across an 11-km-wide fault discontinuity. The 11-km jump in 1668 caused large slips that released the vast accumulation of strain during the preceding long quiescence. We anticipate that fault segments that slip irregularly with variable amounts control the propagation and termination of earthquake ruptures. Recognition of such segments is important for reconstruction of past multi-segment earthquakes and for prediction of future devastating events.

Keywords: active fault, characteristic earthquake, surface slip, paleoseismology