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Paleoseismological investigations in the northern Tien Shan near Bishkek, Kyrgyzstan

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The northern Tien Shan of Kyrgyzstan and Kazakhstan was affected by a series of major earthquakes in the late 19th and earliest 20th centuries: 1885 (Ms 6.9), 1887 (Ms 7.3), 1889 (Ms 8.3), and 1911 (Ms 8.1). These events are amongst the largest known intraplate earthquakes worldwide and their spatial and temporal association is intriguing. The cause and recurrence (likely 10^3 to 10^4 yrs) of such earthquakes remains enigmatic. To gather more information about this sequence and prior events along the faults, we started paleoseismological investigations at two sites near the Kyrgyz capital Bishkek, where youthful scarps in alluvial-fan deposits attest to ground deformation during and prior to these major events.

The first site is located south of the village of early 20th century German immigrants Rot Front, about 43 km southeast of Bishkek, in the vicinity of the inferred epicentral area of an earthquake in 1475 (M6.4). The alluvial fan slopes about 6° north and is incised by narrow and few-meter deep gullies. The scarp has a lobate plan-view, expressed by a left-stepping en-echelon alignment of smaller scarp segments in the west and one scarp segment with a right step to the east of the central scarp. Profiles across the main scarp show slope offsets between 1 and 1.6 m, but all profiles are strongly convex along the upper part of the scarp with a narrow depression below it. Trenching the scarp, however, revealed no definitive faulting. The site is located in an area of farming activity and possibly previous settlements and at an elevation above 1100 m. This complicates the interpretation of these features, because in addition to anthropogenic activity, soil creep associated with a late Pleistocene permafrost regime may also explain the scarp formation.

The Panfilovskoie site is located about 35 km west of Belovodskoie, the epicenter of the 1885 (Ms 6.9) earthquake, and about 75 km west of Bishkek. Two scarps (less than a km apart) are developed in an alluvial fan, which nests inside a late Pleistocene loess terrace. The northern, more prominent scarp, can be followed for about 4 km across the alluvial fan. The scarp strikes approximately E-W. It is aligned with a cumulative break in topography of about 13 m in the loess-covered surface to the west. The trace of the scarp suggests a dominant reverse faulting mechanism. The subordinate southern scarp trends ENE-WSW and is mainly comprised of left-stepping segments, suggesting a minor left-lateral component of motion due to oblique shortening. The alluvial fan is composed of different lobes with distinct offsets between about 1.1 m and 2.7 m. Trenching the main scarp in the intermediate offset fan surface reveals that deformation was associated with a hanging-wall collapse scarp, further indicating the high angle nature of the rupture at this location. At least two earthquakes can be distinguished. Rupture during the most recent event with an offset of $\sim$ 1m cuts to within a few centimeters of the current topographic surface. Following the Wells & Coppersmith relationships (1994), a M6.9 earthquake could produce an average displacement of about 0.9 m, consistent with the observations at Panfilovskoie. Thus, the ultimate earthquake might be the 1885 event.

Active seismicity, historic fault scarps, and neotectonic features in the landscape clearly show that the northern Tien Shan is prone to generating large earthquakes. Future work will include cosmogenic nuclide dating of the alluvial fan surfaces, detailed geomorphic mapping of the sites, scarp and related terrace riser diffusion modeling, and possibly further trenching of the same or adjacent scarps in order to verify the observations and to establish a detailed earthquake history for the area.