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Assessing fault activity in intracontinental settings: paleoseismology and geomorphology in SE Kazakhstan

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Earthquake recurrence intervals of active faults often exceed the time span covered by instrumental, historical, and archaeological earthquake records in continental interiors. The identification of active faults then often relies on finding the geomorphological expression of surface faulting preserved in the landscape. In rather arid areas, single earthquake scarps can be preserved for thousands of years, but erosional and depositional processes will eventually obliterate features such as fault scarps and offset geological markers. Active faults with very long intervals between surface ruptures might therefore remain undetected, which constitutes a major problem for tectonic studies and seismic hazard assessment. Here we present data from the 50 km-long 'Charyn Canyon' thrust fault in the northern Tien Shan (SE Kazakhstan). Remote sensing, Structure-from-Motion (SfM), differential GPS, field mapping, and paleoseismic trenching were used to reveal the earthquake history of this fault. Radiocarbon dating, infra-red stimulated luminescence (IRSL), and scarp diffusion modelling were used for bracketing the occurrence of paleo-earthquakes. In the paleoseismological trenches we identified two surface rupturing events within the last ∼37 ka BP. The most recent earthquake took place between 3.5 - 7.3 ka BP, the penultimate event occurred between ∼17-37 ka BP. We estimate magnitudes of ∼MW6.5-7.3. Only the younger event has a morphological expression as a 25 km-long fault scarp of ∼2 m height. This implicates that a major landscape reset occurred between these two earthquakes, most likely related to the significant climatic change that marked the end of the last glacial maximum. Similar observations from other paleoseismic investigation sites in this area support this interpretation. Our study shows that faults in the northern Tien Shan tend to break in strong earthquakes with very long recurrence intervals. As a consequence, morphological evidence for the most recent active faulting can be easily obliterated by erosion and deposition, often driven by a change in climatic conditions. This is a major problem for active fault studies and must be taken into account in seismic hazard assessments and studies of the regional tectonics. Due to the large number of active faults in the Tien Shan, the overall seismic hazard remains very high.