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The Rurrand Fault, Germany: A Holocene surface rupture and new slip rate estimates

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Very low deformation rates in continental interiors are a challenge for research on active tectonics and seismic hazard. Faults tend to have very long earthquake recurrence intervals and morphological evidence of surface faulting is often obliterated by erosion and sedimentation. The Lower Rhine Graben in Central Europe is characterized by slow active faults with individual slip rates of well less than 0.1 mm/a. As a consequence, most geodetic techniques fail to record tectonic motions and the morphological expression of the faults is subtle. Although damaging events are known from this region, e.g. the 1755/56 Düren earthquakes series, there is no account for surface rupturing events in instrumental and historical records. Owing to the short temporal coverage with respect to the fault recurrence intervals, these records probably fail to depict the maximum possible magnitudes. In this study we used morphological evidence from a 1 m airborne LiDAR survey, near surface geophysics, and paleoseismological trenching to identify surface rupturing earthquakes at the Rurrand Fault between Cologne and Aachen in W Germany. LiDAR data allowed identifying a young fault strand parallel to the already known main fault with the subtle morphological expression of recent surface faulting. In the paleoseismological trenches we found evidence for two surface rupturing earthquakes. The most recent event occurred in the Holocene, and a previous earthquake probably happened in the last 150 ka. Geophysical data allowed us to estimate a minimum slip rate of 0.03 mm/a from an offset gravel horizon. We estimate paleomagnitudes of MW5.9-6.8 based on the observed offsets in the trench (<0.5 m per event) and fault scaling relationships. Our data imply that the Rurrand Fault did not creep during the last 150 ka, but rather failed in large earthquakes. These events were much stronger than those known from historical sources. We are able to show that the Rurrand Fault did not rupture the surface during the Düren 1755/56 seismic crisis and conclude that these events likely occurred on another nearby fault system or did not rupture the surface at all. The very long recurrence interval of 25-65 ka for surface rupturing events illustrates the problems of assessing earthquake hazard in such slowly deforming regions. We emphasize that geological data must be included in seismic hazard and surface rupture hazard assessments in order to obtain a complete picture of a region's seismic potential.