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Millennial seismicity of the Upper Rhine Graben

Miklos Kazmer[1,2] and Klaus Reicherter[3]
[1]Eotvos University, Department of Paleontology, Budapest, Hungary (mkazmer@gmail.com)
[2]MTA-ELTE Geological, Geophysical and Space Science Research Group, Budapest, Hungary
[3]RWTH Aachen University, Neotektonik and Georisiken, Aachen, Germany

The apparent seismic quiescence of the Upper Rhine Graben, as opposed to the Lower Rhine Graben, inspired authors to put the question whether it is real or due to short sampling (Stein et al. 2015). Lack of destructive earthquakes in the Leydecker (2011) historical catalogue (except two in the very north and south) made us to survey an alternative source of seismic documentation. We carried out archaeoseismological studies on the built environment: on Roman cities of Mogontiacum (Mainz) and Augusta Raurica (Kaiseraugust) on opposite ends of the Upper Rhine Graben, and on Medieval sites: the cathedrals of Mainz, Worms, Speyer, Strasbourg and Basel, the monastery churches of Lorsch, Ladenburg and Achern, altogether at 19 sites. Buildings were checked for seismic deformation. Detailed architectural history of construction, destruction and repair was created for each. Dating of (re)construction was achieved by studying published historical documents. Known earthquake epicenters were re-positioned, intensities corrected (usually raised), and previously unknown, highly destructive events recognized and dated. The 1080 AD Mainz earthquake (I=VI) is shifted to Speyer, causing collapse and rebuilding of the imperial cathedral there (I=IX). An additional earthquake occurred there in early modern times, damaging the newly built parts. The late 12thcentury has seen the rebuilding of the Strasbourg cathedral: surviving Romanesque parts still carry evidence for earthquake damage, covered by the Gothic cross-nave. A strange belfry was added to the western front to reinforce the two towers in unsatisfactory status in 1384. Destruction of the 1356 Basel earthquake is much larger than previously recorded: churches citywide carry evidence for damage followed by substantial reconstruction. The Upper Rhine Graben was seismically active in the past two millennia: instrumental quiescence is is misleading, causing dangerously low hazard estimates.