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Calibration of lacustrine paleoseismological records in the Eastern Alps with historical earthquake data: potential and challenges

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Abstract

In intraplate settings with moderate seismicity, recurrence intervals of strong earthquakes (M_w >6) typically exceed the short time span of instrumental and historical data. In order to assess the seismic hazard in such regions, lake sediments can be used as earthquake archives: they can record strong seismic shaking as mass transport deposits (MTDs), turbidites or sediment deformations and can reach back several thousands of years. To provide information on paleo-earthquake size, however, the sedimentary imprints need to be thoroughly calibrated with independent information on seismic shaking strength.

In Carinthia (Eastern Alps, Austria), numerous lakes have experienced several devastating historical earthquakes with local intensities ranging from V-XI (EMS-98 scale), although located in an intraplate environment. Due to these events well-spaced in time (AD1348, AD1511, AD1690, AD1857 and AD1976), exceptional historical documentation and shakemaps based on a local intensity prediction equation, we can examine the relationship between seismic intensity and the type and size of sedimentary imprint in the lakes.

Eight lakes – differing in size, morphology, catchment lithology and sediment composition – were investigated by a dense grid of reflection seismic profiles (~460 km overall), numerous sediment cores (~100, up to 14 meters long) and multibeam bathymetry. Mapping of MTDs, their scarps and associated turbidites as well as accurate dating (radiocarbon and varve counting on sediment thin sections) showed that the AD1348 earthquake (M_w ~7) led to extensive slope failures in the bigger lakes. The AD1511 (M_w ~6.9) and AD1690 (M_w ~6.5) events, although reportedly exhibiting intensities comparable to those of AD1348, however, are only recorded as minor MTDs and turbidites in some of the lakes. This could be due to different reasons: 1) The recurrence interval of earthquakes with high local intensities is too short to critically recharge the slopes with sediment. 2) The real intensities at the lake sites were different than what we can reconstruct from historical records. 3) The individual events differed in frequency content, shaking duration and/or directivity.

We try to overcome these problems by comparing the traces of a single event in the different lakes and by integrating our vast lake data and historical intensity data points into a probabilistic model, narrowing down possible earthquake scenarios. In the smaller lakes, even the biggest earthquakes are only recorded as thin event deposits or lack entirely, indicating lower sensitivity to seismic shaking.

Our study shows that studying one lake, let alone one sediment core, is insufficient to reconstruct a region's seismic history. Due to the exceptional setting of Carinthia, however, we can constrain the intensity pattern and localise the most likely epicentral region and fault source of past earthquakes. In an ongoing study, we use this calibration to construct long calibrated lacustrine records for the last 14 ka.