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Large prehistoric northern alpine earthquakes revealed by slope failures in lakes

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Chronology, magnitudes and epicenters of prehistoric earthquakes in central Switzerland can be reconstructed by temporal and spatial correlation of multiple subaqueous landslide deposits in lakes through high-resolution seismic surveys, radiocarbon-dated sediment cores and spatial calculations using an empirical seismic attenuation model. Results reveal evidences of three strong paleo-earthquakes during the last ˜15'000 years with magnitudes larger than the maximum values previously predicted for this intraplate region (moment magnitudes M>6.5). Additionaly, these data indicate ongoing neotectonic activity along the northern alpine front.

Large earthquakes often spur subaqueous landslides that are recorded in the sedimentary archive. For example, the historically well described 1601 A.D. M=6.2 earthquake in central Switzerland, triggered 13 synchronous subaquatic landslides in Lake Lucerne (Schnellmann et al. 2002). In sedimentary deposits of Swiss lakes we thus can track coeval mass movement deposits as subsurface "fingerprint" of prehistoric seismic events. Furthermore, previous studies showed that lake sediments record the intensity of seismic shaking independent of the earthquake focal mechanism (Monecke et al., 2004). In Lake Zurich, basinwide spatial and temporal reconstruction of subaqueous mass movement deposits reveal three multiple mass movement horizons assigned to prehistoric earthquakes that occurred 2200+/-55, 11530+/-185 and 13840+/-145 cal yr B.P. These dates coincide with three of the five reconstructed prehistoric earthquakes recorded in the subsurface of Lake Lucerne (Schnellmann et al., 2006). Based upon this matching event stratigraphy in the two lakes, we postulate that three major regional paleo-earthquakes occurred that were strong enough to trigger multiple mass movements in the two different lakes that are ˜40 km apart. Minimum moment magnitudes satisfying the observed lacustrine landslides were calculated ap-

plying a grid search approach with calibrated attenuation models. Considering positive and negative evidences for all three prehistoric earthquakes from other paleoseismic archives and implementing geologic, structural and seismotectonic information, two potential earthquake-mechanisms with potential epicentral locations are discussed; (1) A deep-seated strike slip fault scenario below the alpine foreland striking perpendicular to the northern alpine front (NAF), and (2) a seismically active alpine thrust fault system striking parallel to the NAF. Both scenarios require minimal $M>6.5$ in order to induce basinwide slope failures in Lake Zurich and Lake Lucerne simultaneously. These estimated paleomagnitudes for the three identified prehistoric earthquakes are larger than the strongest historically known earthquake in central Switzerland and they occurred in an area where no information on active faults existed to date based upon the instrumental and historical record. Furthermore, these paleoearthquake reconstructions indicate that the Greater Zurich area, in contrast to previous assumptions, may also be exposed to strong seismic shaking.