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Quantified sensitivity of lakes to record historic earthquakes: Implications for paleoseismology

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Seismic hazard assessment is a challenging issue for modern societies. A key parameter to be estimated is the recurrence interval of damaging earthquakes. In moderately active seismo-tectonic regions, this requires the establishment of earthquake records long enough to be relevant, i.e. far longer than historical observations. Here we investigate how lake sediments can be used for this purpose and quantify the conditions that enable earthquake recording. For this purpose, (i) we studied nine lake-sediment sequences to reconstruct mass-movement chronicles in different settings of the French Alpine range and (ii) we compared the chronicles to the well-documented earthquake history over the last five centuries.

The studied lakes are all small alpine-type lakes based directly on bedrock. All lake sequences have been studied following the same methodology; (i) a multi-core approach to well understand the sedimentary processes within the lake basins, (ii) a high-resolution lithological and grain-size characterization and (iii) a dating based on short-lived radionuclide measurements, lead contaminations and radiocarbon ages. We identified 40 deposits related to 26 mass-movement (MM) occurrences. 46% (12 on 26) of the MMs are synchronous in neighbouring lakes, supporting strongly an earthquake origin. In addition, the good agreement between MMs ages and historical earthquake dates suggests an earthquake trigger for 88% (23 on 26) of them. Related epicenters are always located at distances of less than 100 km from the lakes and their epicentral MSK intensity ranges between VII and IX. However, the number of earthquake-triggered MMs varies between lakes of a same region, suggesting a gradual sensitivity of the lake sequences towards earthquake shaking, i.e. distinct lake-sediment slope stabilities. The quantification of this earthquake sensitivity and the comparison to the lake system and sediment characteristics suggest that the primary factor explaining this variability is the sedimentation rate. Indeed, an increasing sedimentation rate implies an increasing sensitivity to earthquake shaking with a apparent threshold of 0.5-1 mm.yr-1.

To improve the paleoseismic event catalogue, further studies in small alpine-type lakes are needed. They should (i) focus on lake systems with sedimentation rates $\geq$ 1mm.yr-1, (ii) consider inter-lakes correlation over less than 100 km for epicentral earthquake MSK intensity $<$ IX and (iii) control carefully that no significant change in sedimentation rates occurs within the record, which could falsify recurrence-interval assessment.