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Constraints on Long-Term Seismic Hazard From Vulnerable Stalagmites

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Earthquakes hit urban centers in Europe infrequently, but occasionally with disastrous effects. Obtaining an unbiased view of seismic hazard is therefore very important.
In principle, the best way to test Probabilistic Seismic Hazard Assessments (PSHA) is to compare them with observations that are entirely independent of the procedure used to produce PSHA models. Arguably, the most valuable information in this context should be information on long-term hazard, namely maximum intensities (or magnitudes) occurring over time intervals that are at least as long as a seismic cycle.
Long-term information can in principle be gained from intact and vulnerable stalagmites in natural caves. These formations survived all earthquakes that have occurred, over thousands of years - depending on the age of the stalagmite. Their “survival” requires that the horizontal ground acceleration has never exceeded a certain critical value within that time period.
Here we present such a stalagmite-based case study from the Little Carpathians of Slovakia. A specially shaped (candlestick style), intact and vulnerable stalagmite (IVSTM) in Plavecká priepast cave was examined. This IVSTM is suitable for estimating the upper limit of horizontal ground acceleration generated by pre-historic earthquakes. Therefore the effect of the assumed Carnuntum earthquake (not before 340 A.D.) and the well documented Jókő earthquake (09 January 1906 GMT) were compared to the constraints determined from the IVSTM.
The behaviour of IVSTM under seismic forcing was analysed numerically. The eigenfrequencies, time-dependent vibration and the stress acting at different parts of the stalagmite were determined. This modeling is a non-intrusive study, using up the dimensions and mechanical parameters of these specially shaped stalagmites, to obtain failure accelerations, where the stalagmite would be broken.

The approach, used in our study, yields significant new constraints on the seismic hazard, as tectonic structures close to Plavecká priepast cave did not generate strong paleoearthquakes in the last few thousand years. A particular importance of this study results from the seismic hazard of two close-by capitals: Vienna and Bratislava.