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Could the collapse of a massive speleothem be the record of a large paleoearthquake?

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Earthquake forecast and seismic hazard models are generally based on historical and instrumental seismicity. However, in regions characterized by moderate strain rates and by strong earthquakes with recurrence longer than the time span covered by historical catalogues, different approaches are desirable to provide an independent test of seismologically-based models. We used non-conventional methods, such as the so-called "Fragile Geological Features", and in particular cave speleothems, for assessing and improving existing paleoseismological databases and seismic hazard models. In this work we present a detailed study of a massive speleothem found collapsed in the Cola Cave (Abruzzo region, Central Apennines, Italy) that could be considered the record of a large paleoearthquake. Radiometric dating and geotechnical measurements are carried out to characterize the collapse time and the mechanical properties of speleothem. We performed theoretical and numerical modelling in order to estimate the values of the horizontal ground acceleration required to failure the speleothems. In particular we used a finite element method (FEM), with the SAP200 software, starting from the detailed geometry of the speleothem and its mechanical properties. We used several individual seismogenic source geometries and four different ground motion prediction equations to calculate the possible response spectra. We carried out also a seismic noise survey to understand and quantify any ground motion amplification phenomenon. The results suggest two faults located in the Fucino area as the most probable causative sources of the cave speleothem collapses, recorded $\sim$4-5 ka ago, with a Mw=6.8 $\pm$ 0.2. Our approach contributes to assess the existence of past earthquakes integrating the classical paleoseismological trenches techniques, and to attribute the retrieved event to geometrically-defined individual seismogenic sources, which represents a key contribution to improve fault-based seismic hazard models.