Enhancing paleoseismological record through multi-methods cave deformation analysis tested in diverse Hellenides tectonic regimes

Paleoseismology delves into the history of earthquakes using geological clues. Earthquakes cause deformations, and these effects provide insights into their intensity. However, these signs can fade over time, posing challenges for studies of prehistory. Fortunately, caves preserve hidden deformations, shielding them from erosion. Damaged cave speleothems allow for dating deformations, determining when they occurred, while cave passage offsets enable the reconstruction of stresses that reactivated faults. Furthermore, damaged speleothems provide a wealth of seismological information. However, there is a discrepancy between laboratory tests, modeling, and field observations. Contrary to model predictions, caves in regions with significant seismic activity often contain long, slender stalagmites and stalactites that should be prone to damage. Recent use of the Finite Element Method (FEM) has been employed to predict speleothems' vulnerability. Still, these tests were conducted in regions with low seismic activity and only on intact stalagmites. This project aims to test FEM analysis in an area known for earthquakes. We plan to conduct FEM analyses, not only replicating previous studies on intact stalagmites but also expanding them to include damaged speleothems. Moreover, the analyses conducted in areas with a known history of seismic events will allow us to revise their impact on caves and, subsequently, enhance our understanding of cave speleothems vurnability to earthquakes.

Therefore, Greece, rich in limestone and caves, offers ideal research locations. Four distinct regions will be investigated: Crete (near the Hellenic Subduction Zone), Amorgos (site of the largest 20th-century earthquake in Greece), Eastern Macedonia and Thrace (experiencing strong earthquakes despite low-strain rates), and the Corinth Rift (undergoing rapid extension). While current seismic activity in the Aegean region is well understood, paleoseismic research has primarily focused on the Holocene (the past 12,000 years) with a few exceptions. Despite the considerable potential offered by Greece's limestone-rich areas, cave systems in this region have yet to be explored in a tectonic context. This project promises to significantly expand our understanding of paleoseismology in Europe's most dynamic areas, extending the temporal boundaries of knowledge to at least around 0.5 million years ago and potentially even further through using the U-Pb method. In addition to geochronological studies of damaged speleothems to determine the timing of deformations, the research will also involve stress reconstruction based on the displacements of cave passages along fault lines. All of this, combined with the aforementioned FEM modeling, will allow for the expansion of the paleoseismic record, including identifying recurrence intervals for strong earthquakes, seismic sources, and perhaps even the magnitudes of prehistoric earthquakes.

This project is also significant for local communities as it offers the opportunity to improve assessments of earthquake recurrence intervals, thereby contributing to the enhancement of seismic hazard assessments in densely populated regions such as Eastern Macedonia, Crete, and the Gulf of Corinth. By advancing both local and regional perspectives in paleoseismology, we can derive universal insights. The development and calibration of speleothem vulnerability analysis will enable the widespread application of this methodology in other regions, encompassing both plate boundaries and intraplate areas.