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Non-destructive in situ mapping of macroholes, cracks and inhomogeneities of stalagmites in cave environments

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Intact and vulnerable, candle-stick type stalagmites can be used as prehistoric-earthquake indicators during seismic-hazard analysis of a given region, because they are old enough to survive several earthquakes. The continued intactness of the stalagmites indicates a lack of earthquakes that had the strength to destroy them. To make sure that the stalagmites are intact, we have to image their internal structure in order to estimate the steadiness more accurate and potential failure in the last few thousand years, during their evolution.
These stalagmites play an important indicator role and carry fundamental information; however, legally they are strictly protected natural objects in Europe. Therefore it is impossible to examine them in the laboratory by conventional equipment such as computer tomography (CT) or X-ray, because this would require taking samples. With the presented non-destructive methods (ultrasound and acoustic tomography) we tried to detect macroholes, cracks and velocity anomalies inside the stalagmites on the mm scale in situ, in the cave.
The acoustic tomography applied in the current work is an existing method in forest research. Forest researchers use it to non-destructively detect the size and location of decayed or hollow parts in the trunk and this technique is able to detect the velocity changing of wave propagation and anomalies in the stalagmites as well. The other method that we use is ultrasound imaging, which uses (and is able to calculate) the velocity of sound propagation. Here, the frequency used is much higher (typically 250 kHz to 5 MHz), which increases resolution but at the same time decreases penetration depth compared to acoustic tomography. In this latter work, through transmission and TOFD (time-of-flight-diffraction) ultrasound methods are using thickness-mode ultrasound transducers (Panametrics, Olympus). Such equipment is well-adapted to the cave environment and this is the first time that it has been used for these aims and in situ in cave environment.