Geophysical Research Abstracts
Vol. 20, EGU2018-16600-4, 2018
EGU General Assembly 2018

Passive geophysics inside underground cavities: examples of HVSR surveys in the caves of Han-sur-Lesse, Belgium and Bruniquel, France.

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The study of detrital cave infills is a powerful tool to obtain information on the cavity development, its environmental and climatic evolution as well as possible markers of anthropogenic perturbations. For caves where archaeological traces or remains are present on the archaeological floor, the least invasive investigation methods are generally preferred over potentially damaging procedures like physical sampling, hammering, piercing and digging. Amongst the passive geophysical methods applicable in a cave environment, passive H/V spectral ratio analysis (HVSR) of ambient noise is of particular interest to study a cave's infill and geometry (e.g. Nehme et al, 2013), as the soft, detrital nature of cave infills usually presents a good seismic velocity contrast with the underlying bedrock.

This study present the results of HVSR surveys conducted in two caves: Han-sur-Lesse in Belgium (testing) and Bruniquel, South of France (main survey). The Bruniquel case in particular is renown for the discovery of the oldest underground Neanderthal constructions (Jaubert et al. 2016).

We used a portable acquisition system (24-bit digital Cityshark II (LEAS) connected to a 1s Lennartz LE-3Dlite seismometer) to record ambient noise. For the Bruniquel survey, where a first bedrock depth profiling was attempted in 2017, 15 minutes to 3 hours recordings were performed at 15 different places in and around the constructions in the cave (300m from the entrance), along one measurement outside the cavity.

The temporal recordings were carefully analysed in GEOPSY to calculate the resonance frequency of each measurement. The 15 measurements points show a variation in resonance frequency between 12.5 Hz and 15.3 Hz. Until now, any indication of Vs of the infill (mainly clays) stays unresolved and only arbitrary values from literature can be used. A frequency to depth conversion was performed considering a Vs of 250 m/s, which results in depth estimation of the limestone bedrock between 4.4 m and 5.3 m. A slightly lower Vs of 180 m/s would result in a depth variation between 3.6 m and 2.9 m.

Complementary analysis was performed to deduce the azimuthal direction in which the H/V peak has its maximum peak amplitude. For the majority of points acquired in Bruniquel, the polarization map shows a dominant N150°E orientation which is oblique to the E-W orientation of the gallery. This dominant polarization can tentatively be linked to the geometry and shape the eroded/original cave floor below the clayey infill. Apart from the main cave also other galleries show this N150°E orientation, which likely corresponds to the orientation of the main geological faults in the area which may have facilitated erosion.

[1] C. Nehme, et al., The use of passive seismological imaging in speleogenetic studies: an example from Kanaan Cave, Lebanon. International journal of Speleology, 42 (2013): 97–108
[2] Jaubert, J., et al., Early Neanderthal Constructions deep in Bruniquel Cave in Southwestern France. Nature, 534 (2016): 111–114