Paleoseismological study in the context of a NPP site

1) Objectives

Seismic hazard is nowadays considered to be one of the primary factors controlling the safety and cost of building construction. It is therefore extremely important to obtain an unbiased view of seismic hazard, which is difficult, since the necessary long-term information is usually missing, since we have an instrumentally-recorded seismicity information only for about a century, and even the historical record is generally too short (and incomplete). In principle, such long-term information may be gained by looking for telltale signs of paleoearthquakes that predate the available catalogue information, or by looking for signs of the absence of (large) earthquakes. We focus here on the latter approach, using speleothems that are still intact. The continued intactness of the stalagmites indicates a lack of earthquakes that were strong enough to destroy them.

For that purpose, this study focuses on stalagmites located less than 270 km far from the NPP:
A)
There are previous studies about speleothem examinations for paleoearthquake research in the Central European region. They have begun with a series of research projects named „Comprehensive investigation of recent and paleoearthquake occurred in the Carpathian Basin" financed by Hungarian Scientific Research Fund (No.:T038099) between 2000-2005 in Hungary (Szeidovitz et al. 2005, 2007, 2008) and in Slovakia 2012-2013 (Gribovszki et al. 2013) at the territory of the Gömör-Torna Karst.

During the Hungarian and Slovak stalagmite investigations several candle-stick-shaped intact stalagmites with low eigenfrequency have been identified and analysed. By the parameters (mechanical, elastic, dimensional) of these intact stalagmites, the "critical" horizontal ground acceleration has been calculated. "Critical" horizontal ground acceleration refers to the value where the stalagmite would break. Among the investigated stalagmites were ones whose "critical" horizontal ground acceleration were lower than the values estimated by probabilistic seismic hazard analyses. These results gave new and more constraining (lower) horizontal ground acceleration values for Northern Hungary. These examinations have impact on the seismic hazard assessment of the Middle-European region, as well as neighbouring territories.

We plan to summarize the results of these previous studies, because they reported about investigations in caves located less than 270 km far from the NPP.

B)

We have already identified (but as far as have not yet investigated thoroughly) sets of particularly sensitive stalagmites in the Little Carpathians (in Slovakia, northward from Pozsony) and in Sattelberg (in Austria, eastward from Graz) (see Figure 1 and 2 below).

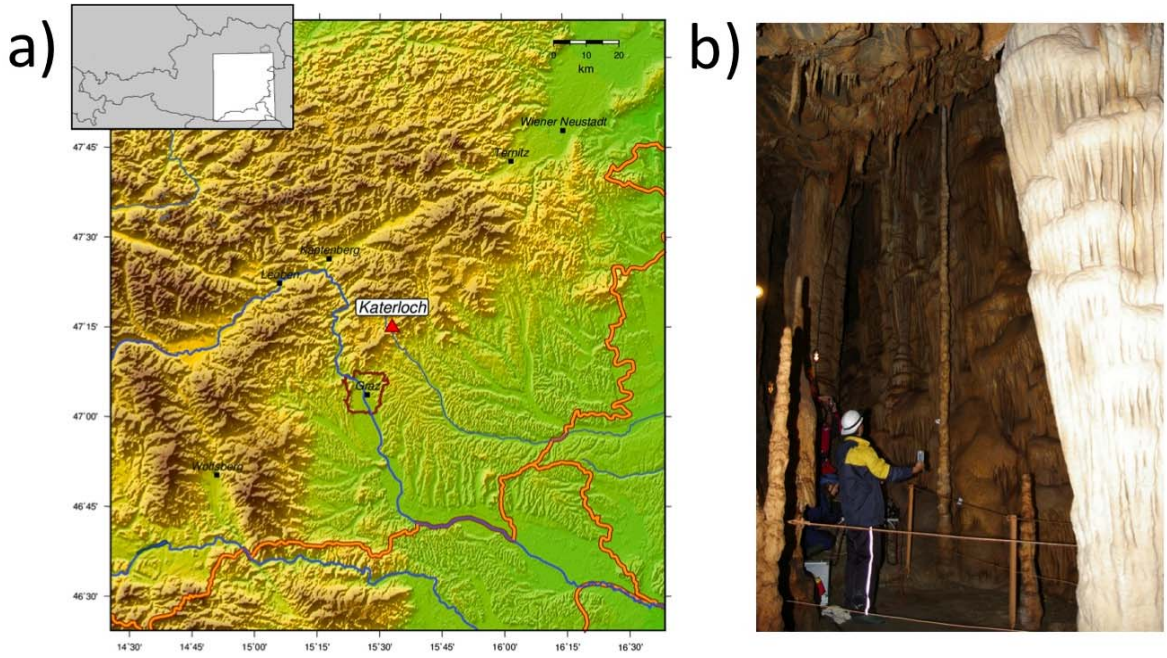

Figure 1: A suitable stalagmite in the Graz area, which we have already identified for the project. a) site of the Katerloch cave, b) the stalagmite in Fantasy Hall (height: 6.5 m, average diameter: 0.12 m).

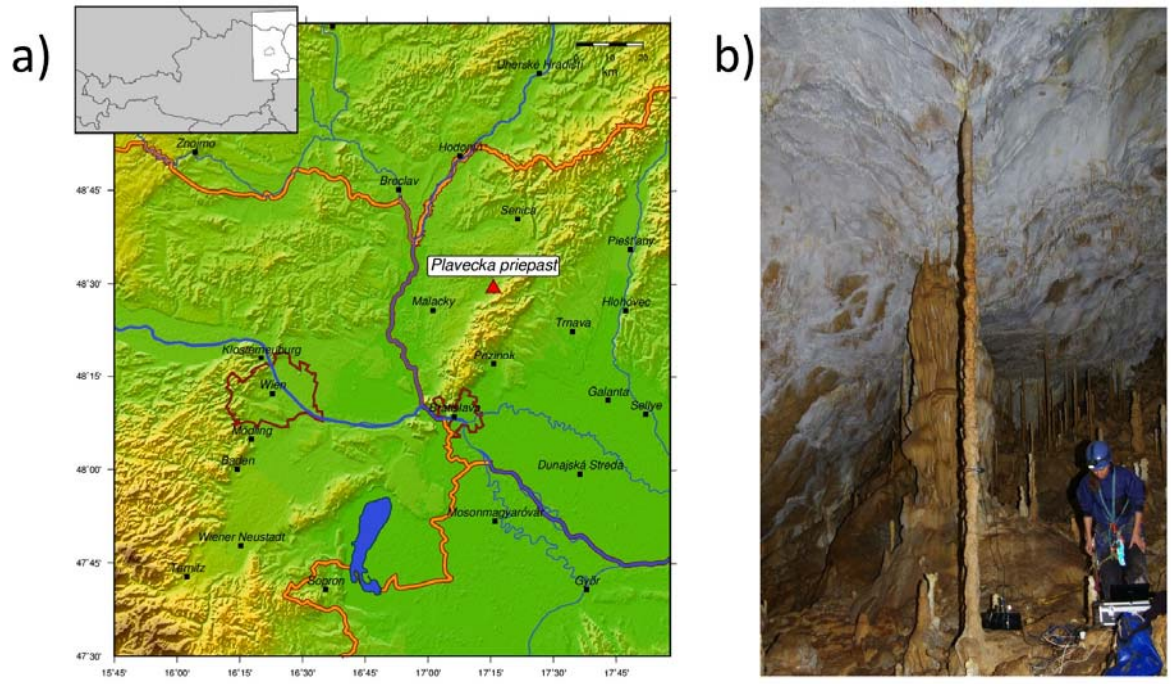

Figure 2: A suitable stalagmite in the Vienna/Pozsony area, which we have already identified for the project. a) site of the Detrekői-zsomboly (Plavecka Priepast) cave, b) the stalagmite (height: 4 m, average diameter: 0.08 m).

It is likely that their analysis will produce useful upper bounds on horizontal accelerations; therefore we plan to investigate them thoroughly. That information will probably allow stronger conclusions on long-term seismic hazard than has been available in the past. As stated above, such information can be of great value for making the right strategic decisions.

C) We plan to search for new intact and vulnerable stalagmites inside Hungary as well: Csodabogyós cave (Keszthely Mountain), Mecsek Mountain, Pilis Mountain.

2) Aims and method of the project

This project will develop new constraints on seismic hazard from intact, vulnerable candle-stick type stalagmites; since these formations have survived all earthquakes during their "lifetime", they can give upper bounds on maximum horizontal ground acceleration for very large time spans.

This new observations provides a range of important applications, for example it can be used to calculate the seismic hazard for the surrounding regions of the investigated caves. For this purpose, we will investigate paleoearthquakes that have occurred (during or) before historic times. The research of the relationship between earthquakes and the growth, tilting and breaking of speleothems is promising. Several investigations of this kind have been performed in recent years showing that this approach is reasonable and can give useful constraints (Forti and Postpischl 1984, 1988; Delaby 2001; Cadorin et al. 2001; Lacave et al. 2000, 2004; Kagan et al. 2005, Becker et al. 2006, Bednárik 2009).

We will perform stalagmite investigations in order to estimate the upper limit for horizontal ground acceleration generated by paleoearthquake. Similar technique was used previously in Hungary, Bulgaria and Eastern Slovakia (Szeidovitz et al. 2005, 2007, 2008, 2008a, Paskaleva et al. 2006, 2008, Gribovszki et al. 2008, 2013, 2013a).

We will look for speleothems in Hungary and surrounding countries that are well suited to the paleoseismic investigations. Indeed, we have already found several stalagmites that will be useful for this study (see Figures 1 and 2). A necessary condition for stalagmites to be useful in this context is that they have a large height/diameter ratio, and that they have nearly cylindrical shape. The exact name of these kind of formations is candle-stick type stalagmite. Our preliminary investigations suggest that such stalagmites can break even at low horizontal acceleration. These speleothems can therefore be used as indicators, whether or not large paleoearthquakes have occurred within the given region. During our research the density, the Young's modulus and the tensile failure stress of speleothems samples will be measured in a geo-mechanical laboratory for subsequent theoretical modeling, whereas the natural frequency

and the dimensions of intact speleothems is determined by in-situ observations. The value of horizontal ground acceleration resulting in failure and the natural frequency of speleothems will be assessed by theoretical calculations. The ages of the samples originating from a specific stalagmite will be determined by U-Th dating.

The above-mentioned stalagmites (Fig. 1 and 2) have rather good quality for a study like the one performed here, also in comparison with the examples reported in the literature. We will look for more suitable stalagmites in Hungary as well. For that purpose we have contacted speleologists throughout Hungary in collaboration with the administration of different national parks.

We will also think of strategies how this constraint can be combined with more classical constraints, e.g. from instrumentally observed seismicity and historical records of intensity of shaking.

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