Neotectonic evolution of the Northern Calcareous Alps determined through fault-slip analysis, radiometric dating of cave deposits, and morphology of deep karst systems

Although the Alps are located in the heart of Europe and have been studied by geologists since the 19th century, they still hide many secrets. Some of them may be deciphered through cave research. Caves represent an environment isolated from external erosive factors. The isolation preserves sediments and tectonic structures, which surface remarks have been erased by constant erosion. This is especially important in mountainous areas, where glaciers and rivers have obliterated information about processes prior to the last ice age. Moreover, cave deposits are perfect for radiometric dating - determining the absolute age of rocks. These caves' preservation properties can be perfectly applied for studying tectonics and geomorphology of the Northern Calcareous Alps. This part of the Alps is cut by a series of faults along which there were displacements of several dozen kilometers from the Late Oligocene to the Miocene (between 25 and 8 million years ago). These faults generate earthquakes, but there is little evidence of their activity recorded in the rocks on the ground surface and caves can provide such proof. One of the richest cave regions globally, the so-called Salzburg Alps (Austria), is cut by the Königssee-Lammertal-Traunsee (KLT) fault zone, wherein many deep caves evolved along the structures associated with this zone.

Thanks to observations of mountains' geological structures from the perspective of caves, we can obtain new information about the study area's tectonic activity. In caves, we can study offset passages along faults imperceptible or utterly invisible on the surface. By combining the fault studies with analysis of the speleothems damaged as a result of the fault activity and the data obtained from the speleothems radiometric dating, it is possible to determine when the tectonic movements occurred. Therefore, it is possible to capture a rapid, short-term event from the past, related to the uplift of the massif, or even to place in time the past earthquake.

The caves also provide information about long-term processes, sometimes lasting for millions of years. Caves evolve simultaneously with mountain valleys; hence they might be used to study the erosion rates controlling valleys development and thus infer the uplift rate. Cave systems develop at or slightly below the water table. As the local water table falls down in response to the valley incision by glaciers or rivers, another network of caves is formed. Thus, under the right conditions, the valley cutting sequence is maintained in the cave's successive levels.

During the three-year project, the research in the caves of the Salzburg Alps will allow to 1) reconstruct the stress tensors on the faults based on the offset passages, and 2) to determine fault activity timing via broken speleothem radiometric dating in the caves of the Hoher Göll, Hagengebirge, Tennengebirge, and Leoganger Steinberge massifs; 3) determine the age of successive cave levels in karst massifs and thus 3) pick the pace of the valley incision and the related time intervals of massifs uplift.

Crucial to achieving the goals of this proposal is to constrain the timing of tectonic processes. For this purpose, the cave speleothems will be dated using the ratio of radioactive isotopes of uranium and thorium - in the case of younger infiltrates (up to 0.5 million years), and of uranium-lead to older precipitates. The individual cave levels' age will be determined by the burial age of the cave clastic sediments (sand and gravel). Isotopes of the aluminum, beryllium, and neon will be used, produced almost exclusively in the first two meters below the ground surface, resulting from interaction with cosmic rays (i.e., cosmogenic nuclides). Rocks and sediments initially exposed on the Earth's surface can be deposited in a cave while retaining information about the initial cosmogenic nuclide concentration. This method allows for dating in the time range from ~ 300 ka to 18 million years.

The research project will reveal whether the Königssee - Lammertal - Traunsee fault zone was active during the last 10 million years and which traces of this activity recorded in the caves. The use of various dating techniques will enable us to determine the variability of this activity over time and detect even short periods of increased activity. Finally, it should allow filling existing knowledge gaps in the evolution of the Eastern Alps.