Improvements for the prediction of karst occurrences in tunnelling

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Many of the recent tunnel constructions show that the geological uncertainty is a major issue, in which karst processes are often involved (e.g. Tunnel of Granges (SO), Tunnel of Sauges (NE), Tunnel of Engelberg (OW), Tunnel of Flims (GR), Tunnel of Alpnach (NW)). It induces economic, social, security and environment problems. So far, the scientific background for the prediction of karstic dissolution voids is not sufficient. Methods for detection of voids a few meters in front of tunnel working face are being developed (e.g. Pesendorfer et al. 2004), but no method is available for prediction at a more regional scale.

Geolep and SISKA started a project aiming at improving the prediction of the position and characteristics of karst conduits within a karst massif. The analysis of the existing literature, together with the analysis of the geometry of large cave systems in close relation with their geological context should make it possible to determine the parameters controlling the speleogenesis, and to provide a better predictability of dissolution voids in a karstic rock mass. This project is supported by the SNF.

A first and coarse analysis of the geometry of cave conduit networks shows that conduits do neither develop homogeny nor randomly.

Conduit position appears to be controlled mainly by two sets of parameters: by the position of the system outlet at the time it has formed (paleospring), and by the existence of initial discontinuities along which most of the conduits are located (fig. 1).

Two kinds of discontinuities (also called “inception horizon”) can be distinguished: the tectonical ones (fractures) and the lithological ones (bedding planes). In most cases bedding planes appear to be more significant for controlling conduit position at regional scale. Therefore a special attention in our work is dedicated to them.

After Lowe (2000) bedding planes can play different roles with respect to speleogenesis.

- *No role:* only a small proportion of the bedding planes present in a carbonate sequence seems to be favourable to karstification.
- *Aquifer:* In bulk carbonate sequences the bedding plane may provide the first possible water routes (aquifer) because of a slightly higher primary permeability than the adjacent rock mass.
- *Aquiclude:* Some bedding planes (e.g. shaly ones) are more impervious (lower permeability) than the surrounding rock mass. They act as aquicludes, and favour the water flow at the contact zone with the adjacent carbonate.
- *Turning nonaggressive water into corrosive solutions:* The weathering of certain minerals such as sulfides, can produce acidic solutions, which can at least locally increase the dissolution capacity. Such an additional acidic dissolution has a minimal effect on the context of the later passages, but its contribution to the initial permeability development of a bedding plane can be significant.
- *An increase of the primary porosity of the bedding planes* is also possible through the dissolution of highly soluble minerals such as gypsum or related to a change in mineralogy as for example dolomitization or dedolomitization,
- *A combination of them*.

To define in what extent bedding planes control karst development in a rock mass the geometry of several large cave conduit networks are being analysed. Once identified as highly karstified bedding planes are investigated in details with respect to their geological conditions. Our main study site is the cave system of the Siebenhengste region, but systems from all over the World will be analysed as well.

Concerning the paleospring position, it has to be reconstructed from geomorphological analysis of the cave system. In the Siebenhengste cave system, paleosystems were identified within the framework of previous projects.

The Siebenhengste region north of Interlaken (BE) is one of the most significant cave areas in the World. The main part of the caves (in total almost 300 km of mapped passages) has evolved in the massive Urgonian limestone of the Schrattenkalk-Formation, with a thickness of around 180 m. The limestone dips 10-30° towards the southeast as a large slab. This dipping slab is cut by a series of faults more or less parallel to the strike of the beds, resulting in a E-W horizontal displacements.

To analyse the complex cave system (superposition of passages) and its geology it was necessary to visualise them in a 3D model. A high degree of precision is required in order to be able to define if conduits develop along the same bedding planes in all respective blocs shifted by faults.
We could show that the karst conduits aren't distributed randomly but are related to a restricted set of faults and bedding planes. It seems to be possible to identify 3 horizon in the sequence of the Schrattenkalk-Formation of the Siebenhengst region how are favourable to the karstification. A detailed study of the properties of the bedding planes relative to the surrounding rock mass and there importance for the speleogenesis is still under investigation. For instance, the roof of some passages follows a silex layer located in the lower part of the Schrattenkalk-Formation.

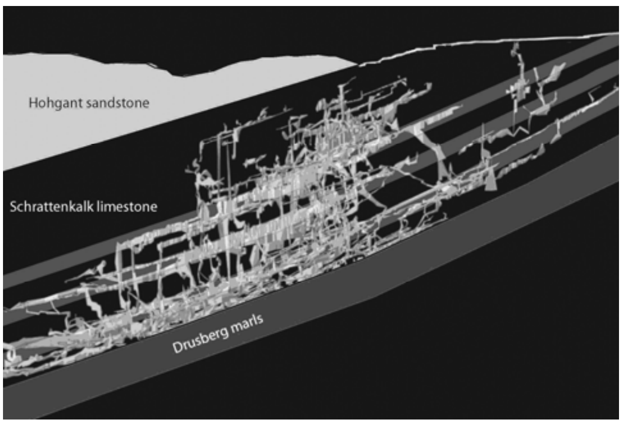

Figure 1: Horizontal projection of one part of the Siebenhengste cave system. Three potential "inception horizons" can be identified within the Schrattenkalk limestone. The thickness of the limestone is nearly 180 meters.

REFERENCES

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