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Possibilities and Limits to predict the 3D Geometry of Karst Systems within the Inception Horizon Hypothesis

M. Filipponi (1) and P.-Y. Jeannin (2)

1. Laboratoire de géologie de l'ingénieur et de l'environnement (GEOLEP), Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland
2. Swiss Institute of Speleology and Karstology (SISKA), Switzerland

(marco.filipponi@epfl.ch / Phone: +41 21 693 23 55)

Karst problems worldwide create huge annual costs as well as social, security-related and environmental problems that are increased due to insufficient understanding of speleogeneis. Problems are not only restricted to engineering constructions such as for example tunnels, buildings or dams but concern also the management and protection of karst water, that is, in many parts of the World, an important or even the only groundwater resource. The main question beyond these problems is to know if there is a conduit network, if yes, where, and in some cases to know its characteristics (e.g. active/fossil, phreatic/vadose, size, etc.).

Recent research analysing the 3D geometry of the some of the largest conduit network in the World (almost 2000 km of analysed cave conduits) showed remarkably that the development and position of karst conduits under phreatic conditions is strongly related to a restricted number of so called inception horizons. An "inception horizon" is a part of a rock succession (most of the time in the order of some centimetre to decimetre) that is particularly susceptible to the effects of the earliest cave forming processes by virtue of physical, lithological or chemical deviation from the predominant carbonate facies within the surrounding sequence. Probably less that 10% of the existing bedding partings of a limestone sequence are inception horizons and guide more than 70 % of the phreatic conduits. It also appeared clearly that the influence of these horizons onto the 3D geometry of cave systems is high.

This fact improves significantly the prediction of karst conduits by identifying the stratigraphical horizons where cave inception took place. It has been possible to reproduce the 3D cave pattern of different cave systems by using the position and orientation of the inception horizons as well as the history of the landscape evolution (e.g. spring position). This forward analysis provides a first idea of the geometry of the conduits as well as a better understanding of the development of a karst system in time and space (vertical section). Generally different parts of a rock mass are in a different karstification state at the same time: Whereas the “deep phreatic” parts are at an early stage of karstification (i.e. inception) with a very slow development of dissolution voids along the inception horizons, active development of a conduit network takes place in the “shallow phreatic” part, where hydraulic gradients are steeper. However conduits develop preferably along inception horizons previously prepared when this part of the rock mass was still under deep phreatic conditions. This preparation of the karstification under deep phreatic conditions, together with hydrogeological boundary conditions explains also how inception horizons can competitive with fractures for karstification, as well as why some potential inception horizons have not been involved for the “final” cave development under phreatic conditions.

However the reproduction of the cave patterns by the position and orientation of the inception horizons as well as the landscape evolution (hydrogeological boundary conditions) is a very rough approach that can be improved by introducing also the major joint sets and faults. With this adaptation and the assumption, that the conduits developments take favourably place at the intersection between the inception horizons and the fractures, it was also possible to reconstruct the characteristic phreatic loops, which are observed in the real cases.

Nevertheless it is yet not possible to completely reconstruct the “true” geometry as well as to predict the exact position of the karst conduits. However the identification of the position of inception horizons in a rock mass as well as the reconstruction of the hydrogeological history will provide a substantial increase of information for karst hydrogeological investigations as well as for engineering purposes.