Geophysical Research Abstracts
Vol. 19, EGU2017-6213, 2017
EGU General Assembly 2017

Basic processes and factors determining the evolution of collapse sinkholes: a sensitivity study

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Collapse sinkholes appear as closed depressions at the surface. The origin of these karst features is related to the continuous dissolution of the soluble rock caused by a focussed sub-surface flow. Water flowing along a preferential pathway through fissures and fractures within the phreatic part of a karst aquifer is able to dissolve the rock (limestone, gypsum, anhydrite). With time, the dissolved void volume increases and part of the ceiling above the stream can become unstable, collapses, and accumulates as debris in the flow path. The debris partially blocks the flow and thus activates new pathways. Because of the low compaction of the debris (high hydraulic conductivity), the flow and the dissolution rates within this crushed zone remain high. This allows a relatively fast dissolutional and erosional removal of the crushed material and the development of new empty voids. The void volume expands upwards towards the surface until a collapse sinkhole is formed.

The collapse sinkholes exhibit a large variety of shapes (cylindrical, cone-, bowl-shaped), depths (from few to few hundred meters) and diameters (meters up to hundreds of meters). Two major processes are responsible for this diversity: a) the karst evolution of the aquifer - responsible for the dissolutional and erosional removal of material; b) the mechanical evolution of the host rock and the existence of structural features, faults for example, which determine the stability and the magnitude of the subsequent collapses.

In this work we demonstrate the influence of the host rock type, the hydrological and geological boundary conditions, the chemical composition of the flowing water, and the geometry and the scale of the crushed zone, on the location and the evolution of the growing sinkhole. We demonstrate the ability of the karst evolution models to explain, at least qualitatively, the growth and the morphology of the collapse sinkholes and to roughly predict their shape and location. Implementing simple rules that describe the mechanical collapse, we come to the conclusion that a complete quantitative and qualitative description of a collapse sinkhole is possible, but for this it is necessary to take into account also the mechanical properties of the rock and the processes determining the mechanics of the collapses.