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Morphology and mechanics of large collapses: Sotano de las Golondrinas, Mexico

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The dynamics and mode of formation of large karst pipes are not yet fully understood. We present precise Lidar and structural field data of the 340+ m deep open karst shaft el Sotano de las Golondrinas, and test the geometry on a a simplified 2D evolution model. The Golondrinas shaft is located in the San Luis county, northeastern México and is developed in massive, early cretaceous (Barremian-Coniacian) reef- limestones (El Abra/ El Doctor fm.). It is a bell-shaped breakout dome that has reached the land surface, i.e. a classical Einstrurtzdoline. The dimensions and shape makes it to an interesting case study, as it has similar dimensions as breccia-pipes encountered in many paleokarsts, but is incompletely filled, so that internal structure can be easily inspected. Second, with regard to stress mechanisms controlling roof collapse, the large dimensions (270 – 130 m diameter at the base) reduce the influence (anisotropy) of geological structures in comparison to smaller pipes (e.g. <70 m diameter). We may thus test morphology against the shape of various tectonic and gravitational stress distributions. During our field campaign in 2009, it was decided to re-map the cavity using laser (Lidar and rangefinders) in order to obtain exact dimensions and high-resolution images of morphology and geologic structure. The maximum explored depth is a fissure at -512 m with the main floor between 325 and 400 meters below the skylight entrance of 80 m diameter. Overall, the shaft is cigar-shaped and oval in outline. Its horizontal length/width ratio at floor level is about 2.31, with an azimuth of elongation of about 125 degrees true.

The shaft is developed along a major, steep fracture zone (115[U+F0B0], true) which makes up the north wall. The fracture has no detectable off-set, in all very few faults were observed. The strike of the guiding fracture, the azimuth of elongation and the direction of the least horizontal stress direction (111[U+F0B0], true) coincide. Where it occurs, bedding is almost horizontal.

A simple 2D grid model was made to test morphological evolution of collapse into a dissolving void, using dissolution rate, yield strength and bed thickness as input parameters. Breakdown processes was represented with a beam model on unsupported beds. So far, our experiments mimic the observed bottle-shaped morphology.

Probability-based models of sinkhole hazard are closely related to the expected mature architecture of the collapse-pipe field. As a comparison to the Sotano de los Golondrinas, a late Paleozoic to early Mesozoic field of collapse pipes exposed on Svalbard consists of > 250-m-tall breccia-filled collapse pipes in limestone but related to deep dissolution of underlying gypsum. The average pipe diameter is 60 m, pipes are typically asymmetric by 15% of the diameter but aspect rations similar to Golondrines are not uncommon. Several of the 50 pipes reach diameters of over 150m. The lack of terrigenous material inside the pipes suggests they did not reach the surface.

Collapse breccia pipes form strong vertical heterogeneities in rock properties such as porosity and permeability, matrix density, cement, mechanical strength and lithology, affecting fluid-flow characteristics on a meter to hundred-meter scale. It is rare that pipe fields are well exposed at the kilometre scale. Studies at the km scale are fundamental for understanding basic karst and collapse processes, and yield petrophysical models that can be applied predictively to natural hazards and groundwater or hydrocarbon exploitation in paleokarst settings.