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Development and collapse of karstic cavities in folded marbles: Geomorphological and geophysical evidences in Nerja Cave (southern Spain)

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ABSTRACT

Karstic evolution leads to the growth and collapse of cavities by the interaction between geological structures and the hydrogeological framework. Nerja Cave developed within marbles belonging to the Alpujarride complex of the Internal Zones in the Betic Cordillera of Spain. The residual gravity anomaly map of the karstified areas –surrounding the known Nerja Cave– may indicate a likely elongated parallel cave system, *N-S* oriented, unknown up to present, and formed by both small shallow and large deep caves below a nearby hill located northwestwards to the known cave. At the east hillside, a moderate gravity anomaly minimum and geomorphological evidence (vertical walls and sunken terrains) suggest the presence of an old collapsed cave. At the west hillside, a marked gravity minimum is associated with a strongly folded marble layer without evidence of collapse. An electrical resistivity tomography (ERT) profile across the hill –in the *E-W* direction– supports an interpretation of several voids, two of the bigger ones located on either side of the hill. The combination of geomorphological, ERT and gravity forward modelling indicate the location of unknown caves, one of them partially collapsed. These caves, located at a higher topographic level than the known Nerja Cave, may represent an early stage of cave development, and suggest the preferred dissolution of some layers in the folded marbles. This field example provides new insights on the interaction of structure in the karstic evolution that determines the cavity stability.

1. Introduction

Karstic structural features depend on several factors including fracture abundance, opening and orientation, topography, precipitation and temperature, which in turn determine the groundwater hydrodynamics. The structures may remain gravitationally unstable, causing subsidence with gradual settling or sudden changes like sinking or collapses (Waltham et al., 2005). The development of a karstic cave can cause large rock blocks to collapse into the cave, modifying its shape, although the roof remains stable (Martínez-Moreno et al., 2016a). Surface features are related to the high degree of cave development; the fact that it remains gravitationally unstable can cause roof collapses. These processes creates changes in the topography and/or cave openings to the outside, generally surrounded by vertical walls at the perimeter.

The most effective cave detection procedure relies on a combination of geomorphological and geophysical methods (Martínez-Moreno et al., 2014). Geomorphology indicates likely boundaries of partially collapsed caves and possible openings through recognition of the subsidence area, including the magnitude of sinking when vertical walls remain after the collapse (Galve et al., 2009). Geophysical methods are used to verify the surface evidences and to constrain the features in-depth (Martínez-Moreno et al., 2013). The methods that typically offer most accurate results –even in partial collapses– are electrical and gravity methods, owing to the high physical property contrast between the unaltered host rock versus cavity voids and/or collapse deposits.

The detection and determination of unexplored voids in karst systems are very important in two senses: tourism and hazard. Caves can be a significant economic factor for the surrounding population and voids should be detected before the construction of anthropic structures to avoid future collapses of those structures (Martínez-Moreno et al., 2016b).

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