Neotektonik
Georisiken

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New data from the Nerja Cave, Southern Spain
geophysics, borehole camera and CO_2 measurements for karst investigations

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1 The site:

Figure 1: The Nerja Cave in southern Spain.

The Nerja Cave in Southern Spain is listed as UNESCO Cultural Heritage and counts as one of the most popular touristic sites on the Iberian Peninsula (Fig. 1). The cave reaches several hundreds of meters into the dolomitized marble and hosts paleolithic and post-paleolithic wall paintings (Fig. 2) as well as countless spelaeothems (Fig. 3).

CO_2 measurements:
During the last decades, systematic CO_2 measurements were conducted inside the galleries in order to monitor the gas concentration. Nearby drill holes with depths of up to 400 m were also probed. Here, CO_2 concentrations of up to 55,000 ppm were measured regularly. These values are much higher than the average and far beyond the concentrations inside the cave (525 ppmv). If cavities in the surroundings of the drill holes would be connected to the Nerja Cave system via the karstified marbles, the heritage site would not only have to be closed for the public, but would also suffer damages due to solution by H_2CO_3.

Figure 2: Rock paintings in the Nerja Cave.

Figure 3: Spelaeothems and calcite cristalls

2 Methods:

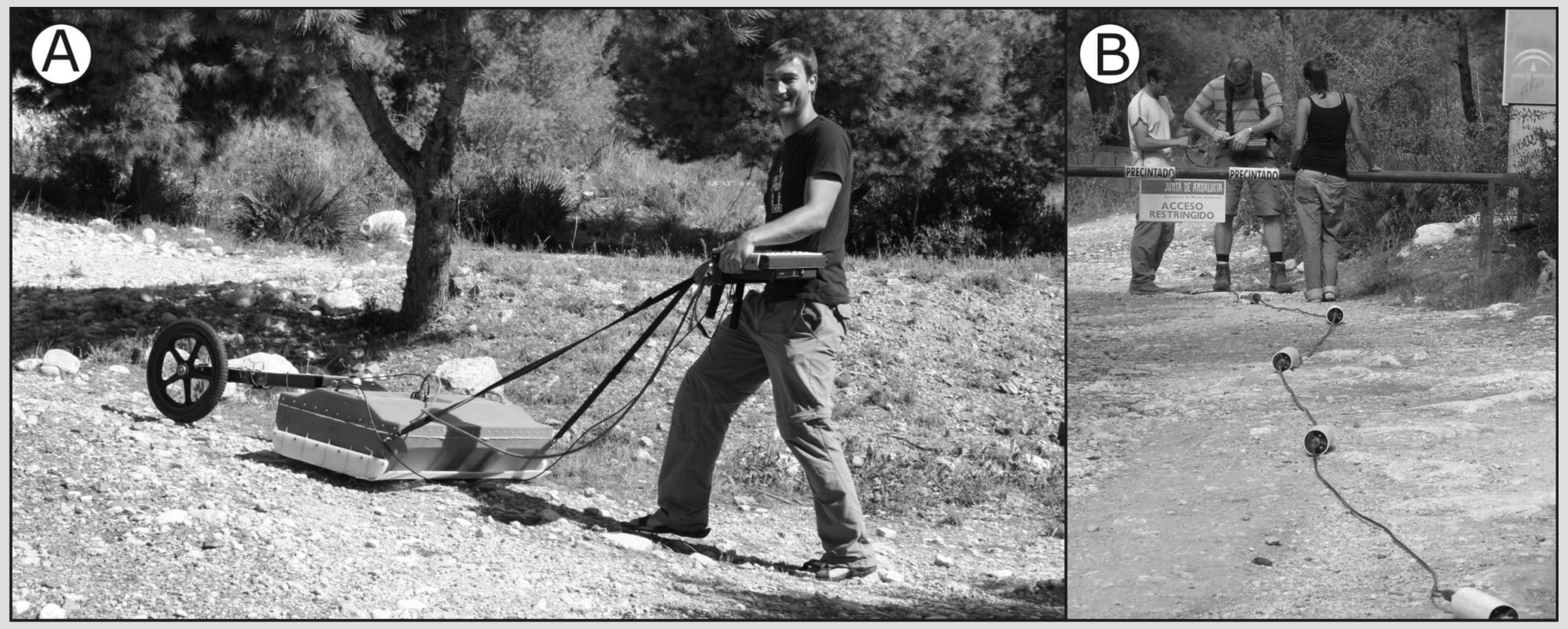

Figure 4: The GSSI ground penetrating radar equipment (A) and the Geometrics OhmMapper resisitivity system in use

Figure 5: The FORA 47 borehole camera with the field computer

Figure 6: Live streaming of camera videos to the laptop

GPR (Fig. 4A):
- GSSI 100 MHz and 270 MHz antennas
- SIR-3000 with survey wheel
- GPS device

Geoelectrics (Fig. 4B):
- OhmMapper (Geometrics)
- capacitive-coupled system (CCR)
- 5 receivers with 5 m spacing

Borehole camera (Figs. 5, 6):
- FORA 47 borehole television camera
- 360° horizontal rotation
- 220° vertical rotation
- up to 100 m depth
- LED light source
- high-resolution images
- live video streaming

3 Results: georadar geoelectrics borehole camera

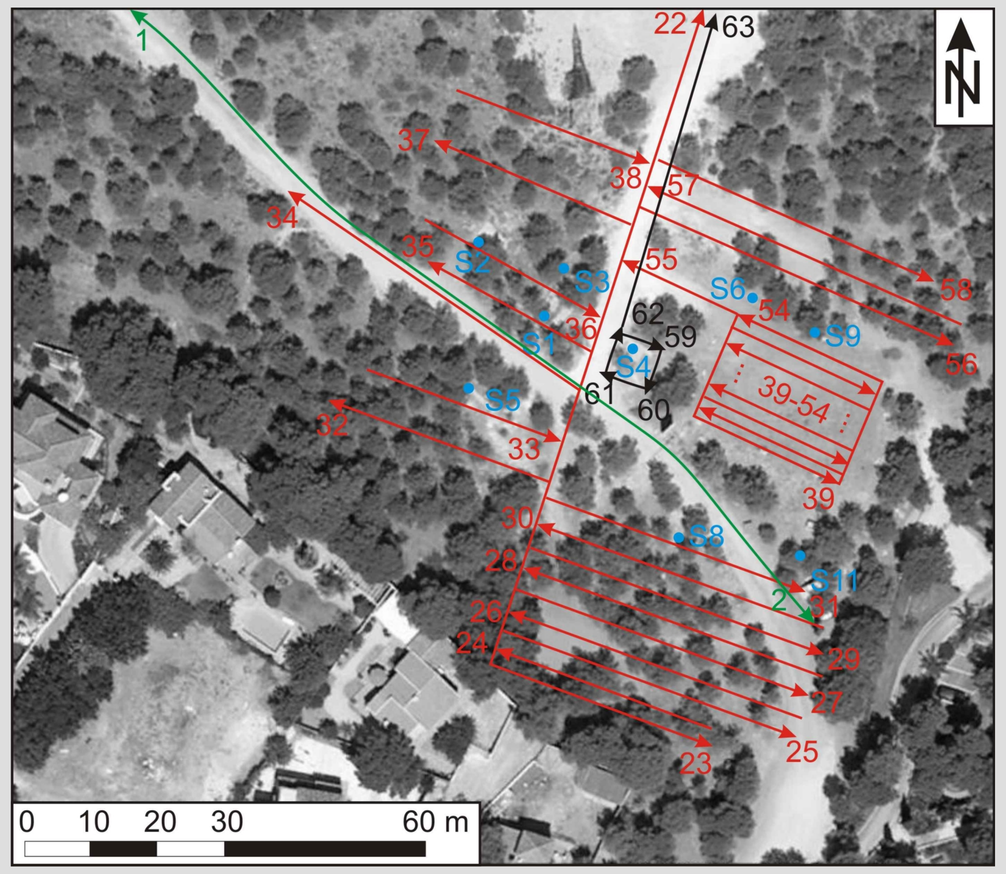

Figure 7: Location of GPR profiles (red), Geoelectrics profiles (green) and the drillings (blue)

We found formerly unknown cavities with diameters of several metres in some cases, most of them in depths of 6 to 13 metres (Figs. 7, 10) with all methods applied. Spelaeothems were present in some cavities. GPR could prove these findings and trace the cavities between the drill holes (Fig. 8). Since the maximum resolution of the GPR system is in the order of 0.3 m, smaller hollows must necessarily remain undiscovered.

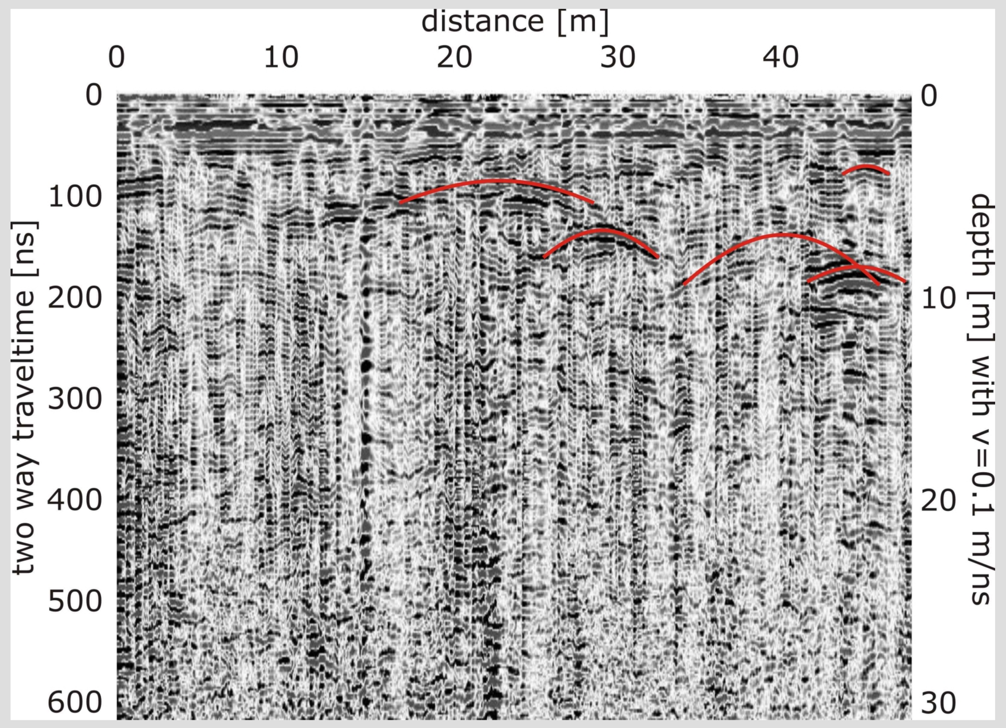

Figure 8: Georadar profile 28 (100 MHz antenna) can count as typical for the GPR data, see Fig. 7 for location. The penetration depth is high and cavities appear as diffraction hyperolas (red). A hyperbola analysis allowed calculating depths from the two way traveltimes.The interpretation of the single radargrams led to the cavity map in Fig. 10.

The mobile CCR system (OhmMapper) represents a relatively new technique that is not commonly used for karst investigations. Hence, the CCR system was applied despite its low resolution and limited penetration depths. The data (Fig. 9) show good coherence with GPR and optical imaging results (Fig. 11, 12), and it is possible to detect bigger cavities reliably as high-resistivity anomalies.

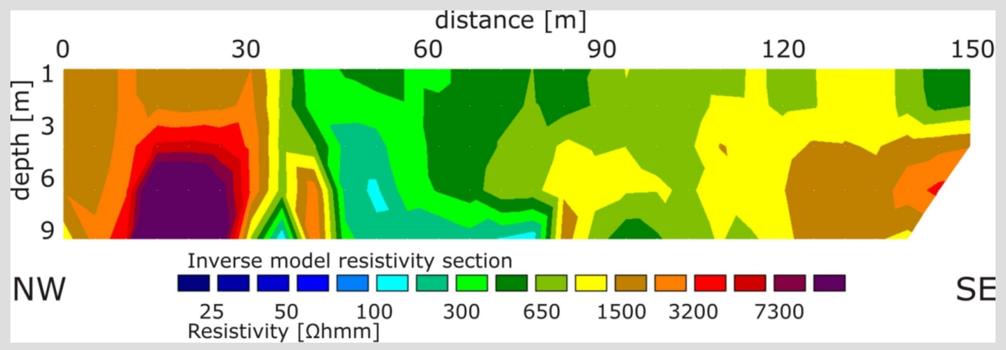

Figure 9: Geoelectrics profile 1 (OhmMapper), see Fig. 7 for location. Background resistivity values are relatively high due to the marble bedrock, but the cavity is clearly visible as a high-resistivity anomaly in the north-western part of the profile.

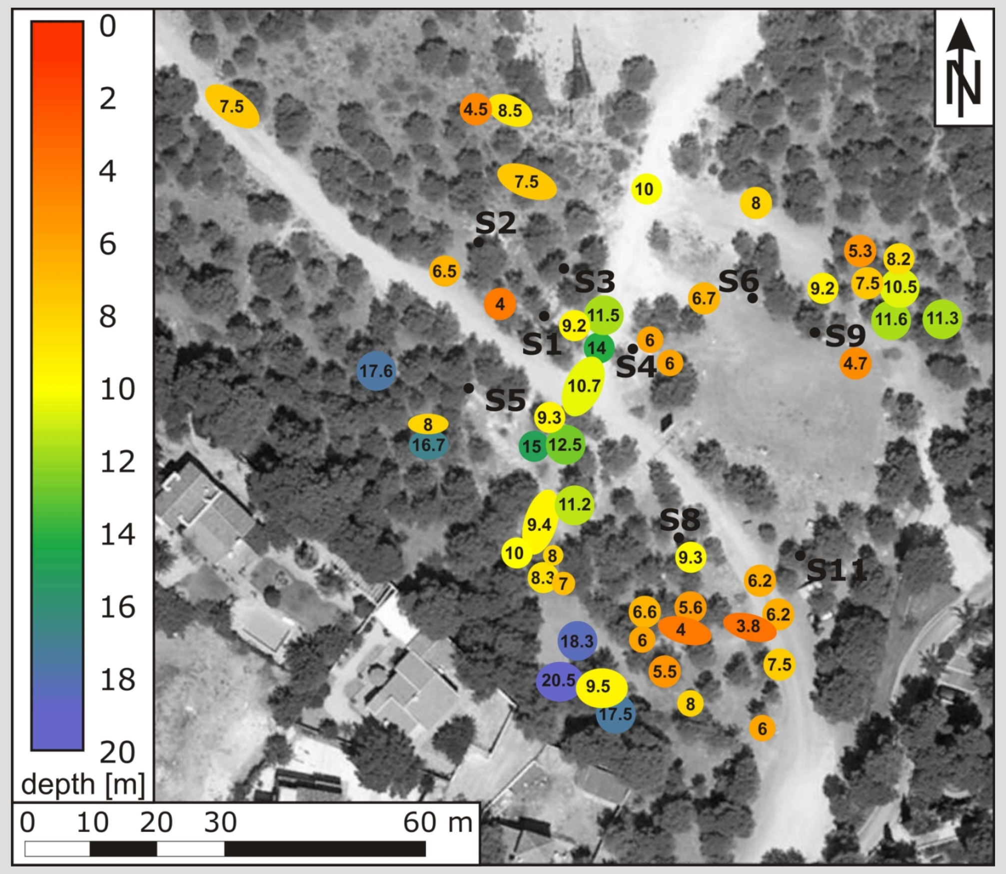

Figure 10: Map of all cavities in the study area discovered by geophysical methods (georadar and geolectrics) with their depth below surface. Note that some cavities seem to belong together.

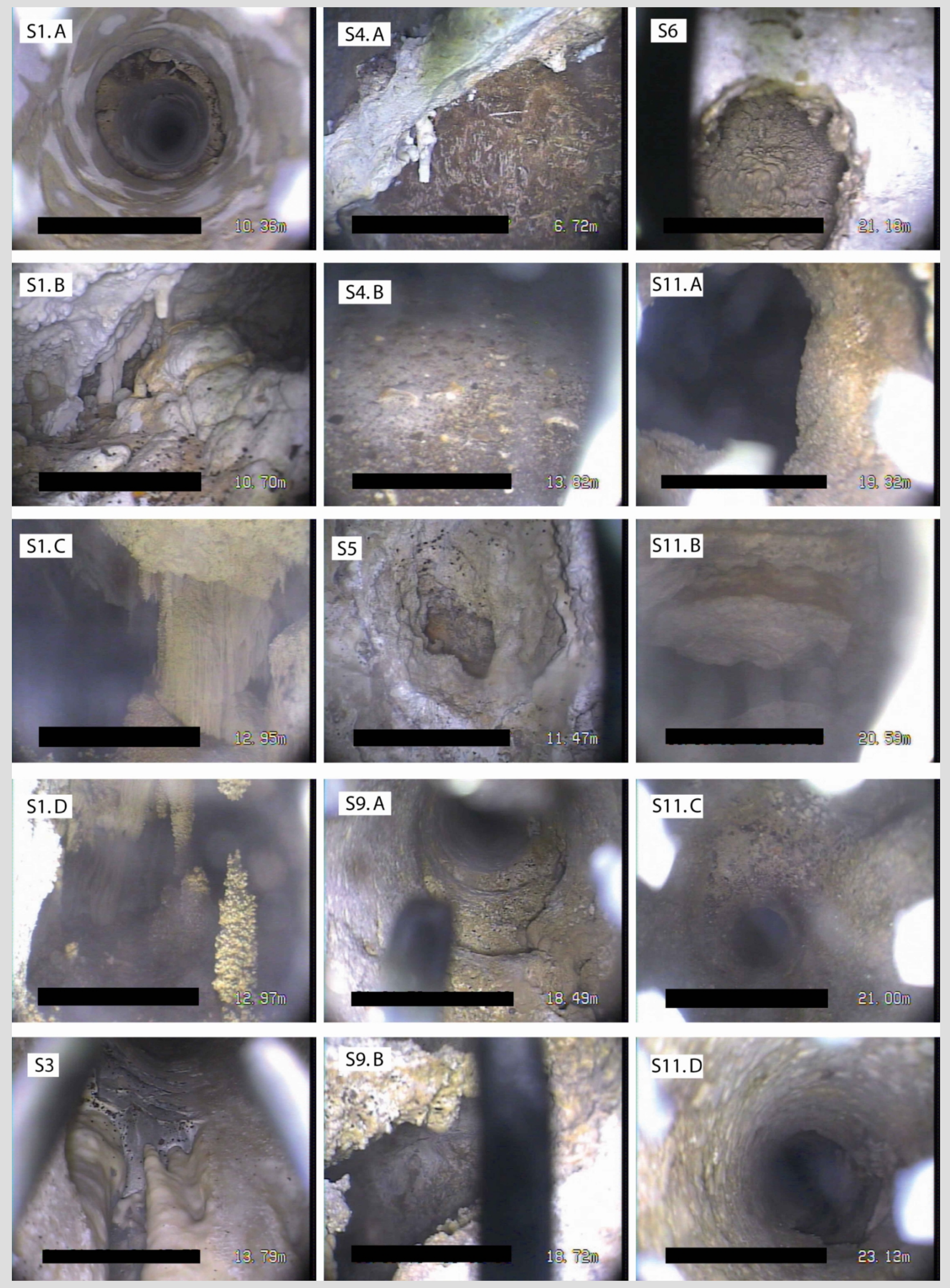

Figure 11: Images from the borehole camera, see Fig. 7 for borehole locations. Note the large stalagmites in S1.

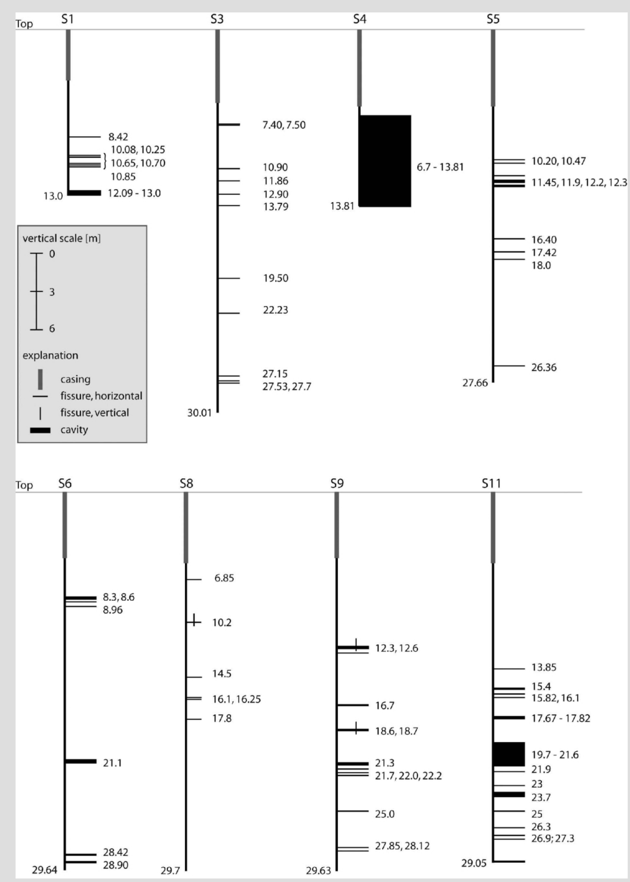

Figure 17: Depths of cavities discovered in the boreholes. Note the clustering in depths around 10 m.

We could determine several cavities with extraordinary high CO_2 contents (>55,000 ppm) in the surroundings of the cave, but (luckily) found no hints for a direct and highly permeable connection to the heritage site.

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