



# Geophysical Investigation of Recently Formed Collapse in Latvia

Pēteris Džeriņš, Jānis Karušs, and Jurijs Ješkins

## Abstract

In December 2020, a sinkhole appeared in Latvia, nearby Skaistkalne's vicinity, where active karst processes occur. It is the most active karst region in Latvia, with an average density of approximately 13 sinkholes per km<sup>2</sup> (Paukstys & Narbutas Paukstys B., & Narbutas V. (1996). Gypsum karst of the baltic republics. *International Journal of Speleology*, 25. 10.5028/1827-806X.25.3.21). This region is in the southern part of Latvia (on the border with Lithuania), and it is part of the Gypsum Karst Region of the Baltic States that continues south and is well pronounced in the territory of Lithuania. However, this recent collapse formed more than 6 km from the officially known karst area (SGS Ministry of Environmental Protection and Regional Development. (1997). State geological survey. Karst area map of Latvia, scale 1:200 000 (in text: SGS 1997).). UAV was used to prepare the Digital Elevation Model (DEM) of the surrounding area to evaluate the collapse's volume precisely. In addition, the Electrical Resistivity Tomography (ERT) method was used to investigate ground conditions under the collapse. Results show a low-resistivity zone under the collapse at 30 m depth, which coincides with the boundary between clastic sediments on top and carbonate sediments (dolomites) at the bottom. The results of this study could be used to understand the origin of this sinkhole better and subsequently used to assess possible karst risk outside the officially known karst area of Latvia.

## Keywords

Sinkhole formation · Carbonate karst · Geophysics · Electrical resistivity tomography

## 1 Introduction

Karst processes in Latvia are related to carbonate rocks or gypsum dissolution. The present climate does not favor the evolution of the karst process in carbonates. Therefore currently, only the active gypsum karst process takes place. However, paleokarst features have been reported in carbonate rocks in Latvia, nearby Daugava valley. These features are mostly filled with secondary material—sand, clay, or dolomite powder. In some areas, surface features of karst processes such as sinkholes, karst shafts, land subsidence, lakes, and dolines are present (Paukstys, Narbutas 1996).

The relevant sinkhole is formed approximately 200 m from the coast of the Memele river, which is known to recharge from the karst aquifer (Delina et al., 2012). The geological section here consists of Quaternary and Upper Devonian sediments. The upper 8 m are formed by glacial till and sandy gravel, followed by a 24 m thick Upper Devonian marlstone and sandstone layer. Below carbonatic Devonian sediments are found—mostly dolomite with marl, gypsum, and dolomitic marl interlayers.

This study aims to investigate the geological setting of the nearby area surrounding the recent collapse and to understand its origin better.

## 2 Materials and Methods

The cause of the collapse was investigated using Electrical Resistivity Tomography (ERT) frequently applied to a shallow subsurface investigations (Drahor, 2019; Karušs et al., 2021; Lamsters et al., 2020). ERT survey was carried out using a multichannel Syscal Pro Switch (IRIS Instruments)

P. Džeriņš (✉) · J. Karušs · J. Ješkins  
Faculty of Geography and Earth Sciences, University of Latvia,  
Jelgavas Str. 1, Riga LV-1004, Latvia  
e-mail: [peteris.dzerins@lu.lv](mailto:peteris.dzerins@lu.lv)

device. Measurements were performed using 72 stainless steel electrodes and Wenner and Dipole–dipole electrode configurations. Data were gathered using two different electrode spacings—1 and 2 m. Results were visualized by combining separate profiles into a 3D resistivity model. ERT data processing was done using RES2DINV and RES3DINV (Geotomo Software). In addition, aerial photographs of the surrounding area were taken from unmanned aerial vehicle (UAV) and used to produce an orthophoto map and DEM.

### 3 Results

The collapse area is 72 m<sup>2</sup>, and the approximate volume is 134 m<sup>3</sup> based on a Digital Elevation Model (DEM). ERT results show a low-resistivity zone under the collapse that is traceable until the maximum Depth of Investigation (DOI), which is 27 m, and possibly continues deeper (see Fig. 1). DOI coincides with the geological boundary between Devonian clastic sediments (sandstone, marlstone) on top and Devonian more carbonatic sediments (dolomite) at the bottom. A high resistivity zone directly below the ground surface is interpreted as Quaternary sediments (glacial till, sand, gravel), which typically have high resistivity values, followed by a thick low resistivity layer corresponding to Upper Devonian clastic sediments. In the ERT profile, at approximately 20 m depth, the resistivity increases again, which is interpreted as the boundary between Upper Devonian clastic and carbonatic sediments. However, under the collapse, at 25 m depth, depression of low resistivity in the surrounding higher resistivity layer was found. It could be explained by the downward movement of the overlying low-resistivity material.

Results show that dissolution processes must have introduced the origin of the collapse in carbonate layers,

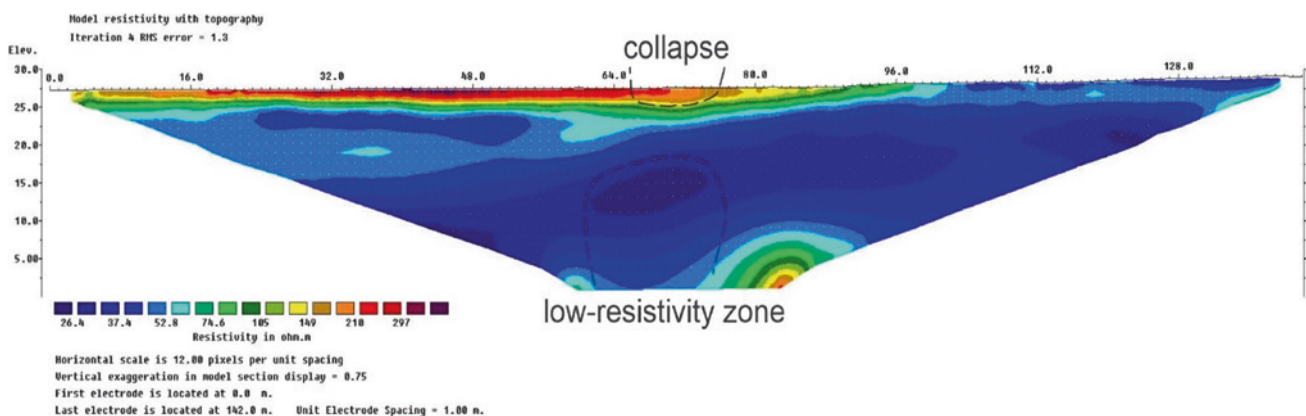
followed by the upwards progression of the void in overlying clastic sediments.

### 4 Discussion

To map karst risk zones for geotechnical purposes, some relationship between geological setting, underground void size, and sinkhole formation risk can be used. Waltham's (2016) estimations show that the stable thickness of rock cover above the underground void for gypsum and weak limestone should be approximately the same as the width of the cavity itself. Although our investigations don't provide insight into the size of the underground cavity, the limiting factor for vertical dimension usually is the thickness of dolomite and gypsum layers (here, less than ten continuous meters). Comparably thick Devonian cover over this void (24 m) suggests that such a relationship between void size and stable rock cover might not be appropriate in this geological setting. Instead, the authors hypothesize that relative proximity to the Memele river significantly impacts underground dissolution processes and subsequent formation of the collapse. However, this should be further investigated using, for example, hydrogeological methods.

As this is ongoing research, for a better understanding of the geological setting under the collapse, ERT measurements could be complemented with other geophysical methods, such as seismics. In continuation of this study, it is planned to use the seismic reflection method to specify boundaries between layers—seismic data could be used to improve the ERT model.

Since UAV was used to capture sinkhole dimensions soon after its formation, repeated measurements over a more extended period could be taken to visualize slope development over time.



**Fig. 1** ERT profile along the collapse. This profile was performed using Wenner electrode array and 2 m electrode spacing

## 5 Conclusions

A recently formed sinkhole outside of an active karst area of Latvia was investigated using UAV and ERT measurements to understand its origin better. Based on photogrammetry results, the collapse area is 72 m<sup>2</sup>, and the approximate volume is 134 m<sup>3</sup>.

ERT results show a low-resistivity zone up to 27 m depth (limited by DOI) that most probably continues deeper. This suggests that dissolution processes must have introduced the origin of the collapse in carbonate layers, followed by the upwards progression of the void in overlaying clastic sediments. However, additional geophysical investigations are planned in this location. For example, a different ERT profile should be performed with broader electrode spacing to reach DOI, where the extent of the low-resistivity zone in the vertical dimension could be seen. Also, additional geophysical methods (for example, seismic reflection) could be used to improve the ERT model.

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