Integrated archaeological and engineering geophysical investigation of the castle ruin Mödling (Austria)

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Abstract
An extensive multi-method investigation of a castle ruin has been conducted that extends the spectrum of geophysical methods used in archaeological prospection. For complex sites like a castle ruin, the incorporation of seismic and geoelectrical methods can facilitate the interpretation of ground penetrating radargrams, particularly in the existence of bedrock.

Keywords
electrical resistivity tomography; ground penetrating radar; multi-method; refraction seismic tomography

Introduction

After its prime in the 12th century, with being the residency of a collateral line of the Babenbergers, the castle Mödling has ever since been in decline. It was stripped of its ashlar stones at the end of the 18th century, and rebuilt as a romantic castle ruin by Johann I. of Liechtenstein. In an effort to restore the initial foundation walls in the 1970s, the area was subjected to significant disruptions leaving the present-day castle ruin in shambles.

We present results from an integrated investigation applying archaeological and engineering geophysical prospecting methods to uncover what is left behind of the old foundations of the original Babenberger castle. The geophysical measurements had two main objectives: (1) delineate unknown foundations or other remnants of the past history of the castle ruin and (2) detect the depth to the bedrock and provide a basis to differentiate between loosened bedrock and toppled building materials/rubble.

Materials and methods

The geophysical measurements included (i) refractions seismic tomography, (ii) electrical resistivity tomography (ERT) and (iii) ground penetrating radar (GPR) profiles. Measurement at a total of 6 RST profiles were conducted with between 40 to 120 30 Hz vertical geophones with 1 m spacing in each profile. The seismic wave field was recorded with Geode seismographs (by Geometrics) for 512 ms with a sampling rate of 0.25 ms. A 5 kg sledgehammer was used as the seismic source and shots were made at each geophone to ensure adequate coverage along the profile.

To support the interpretation of the seismic results two ERT profiles were measured with 80 and 120 electrodes in each profile and applying an electrode spacing of 0.5 m. The data were collected with an ABEM Terrameter LS2 using a pulse length of 0.5 s and a dipole-dipole electrode configuration. Furthermore, GPR profiles were collected with a Mala GroundExplorer GX 160 MHz antenna.

The areal GPR measurements were performed with a Sensors&Software PulseEkkoPro 500 MHz antenna with 3 antenna pairs mounted in parallel to permit a faster coverage of the area. Where applicable, we also computed depth slices for the 160 MHz data. Figure 1 presents

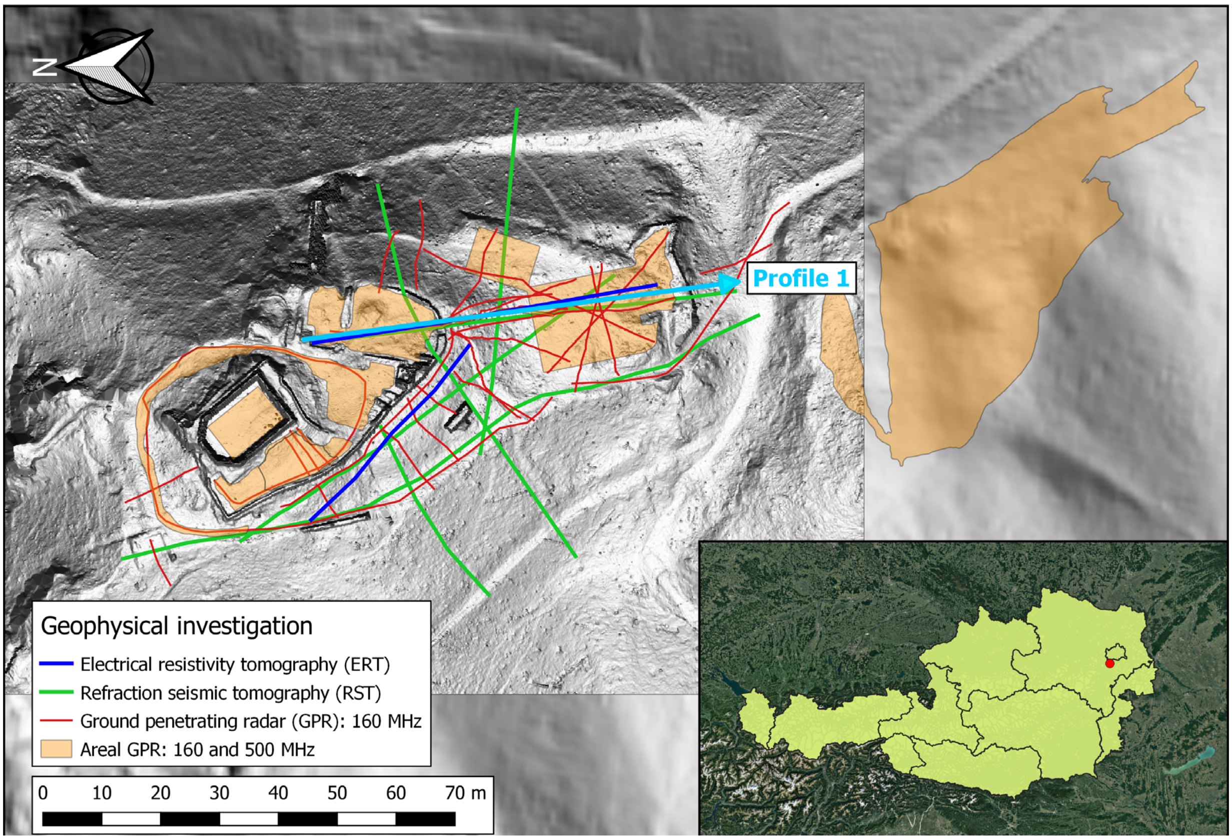

Fig. 1: Overview of the applied geophysical methods and their location as well as areas where the density GPR data permitted to obtain areal information. LIDAR data provided by Land Niederösterreich – data.noe.gv.at and LIKWID (likwid.at).

an overview of the study area and the location of the individual geophysical profiles as well as the zones of areal GPR information.

Results

Figure 2 presents the geophysical imaging results for the profile 1, which covers large parts of the investigated area (c.f. Fig 1). The RST imaging results in general show an increase in P-wave velocity (V_p) with depth ranging from 200 to 3400 m/s. Low velocity zones (V_p < 600 m/s) can be observed in shallow depths down to 3-5 m, particularly between 10 and 40 m along the profile. Such areas can be considered weakly compacted and are probably comprised of loose building material or fine-grained topsoil. Below, the velocity increases to values between 1200 and 2200 m/s and are indicative of fractured bedrock.

In comparison, the ERT imaging results show more heterogeneity in shallow depths (1-3 m), i.e., a sequence of low and high resistivity anomalies, particularly in the first 15 m of the profile. Given the abnormally high resistivity of the anomalies (> 5000 Ωm) we interpret the features as buried walls surrounded by fine-grained deposits. The discrepancy between the ERT and RST imaging results in the first 15 m of the profile can be explained by both the lower spacing used for the ERT measurements and the ability of the ERT method to resolve near-surface small scale anomalies – whereas the RST tends to provide smoother images, due to the larger smoothing factor applied in the inversion. Nevertheless, both methods show a depression between 20 to 35 m along the profile, which can also be observed in the radargram (Fig. 2C) as a reflective layer. Moreover, the high resistivity anomaly at approx. 10 m along the profile also corresponds to an area with increased P-wave velocity (> 1000 m/s) as well as a highly reflective feature in the radargram. A comparison with the LIDAR scan in Figure 1 shows an east-west oriented wall at approx. 10 m along the profile 1, therefore sustaining our interpretation. The linear patterns in the radargram between 0 to 10 m along the profile are air reflections from larger walls.

The comprehensive archaeological-geophysical inter-

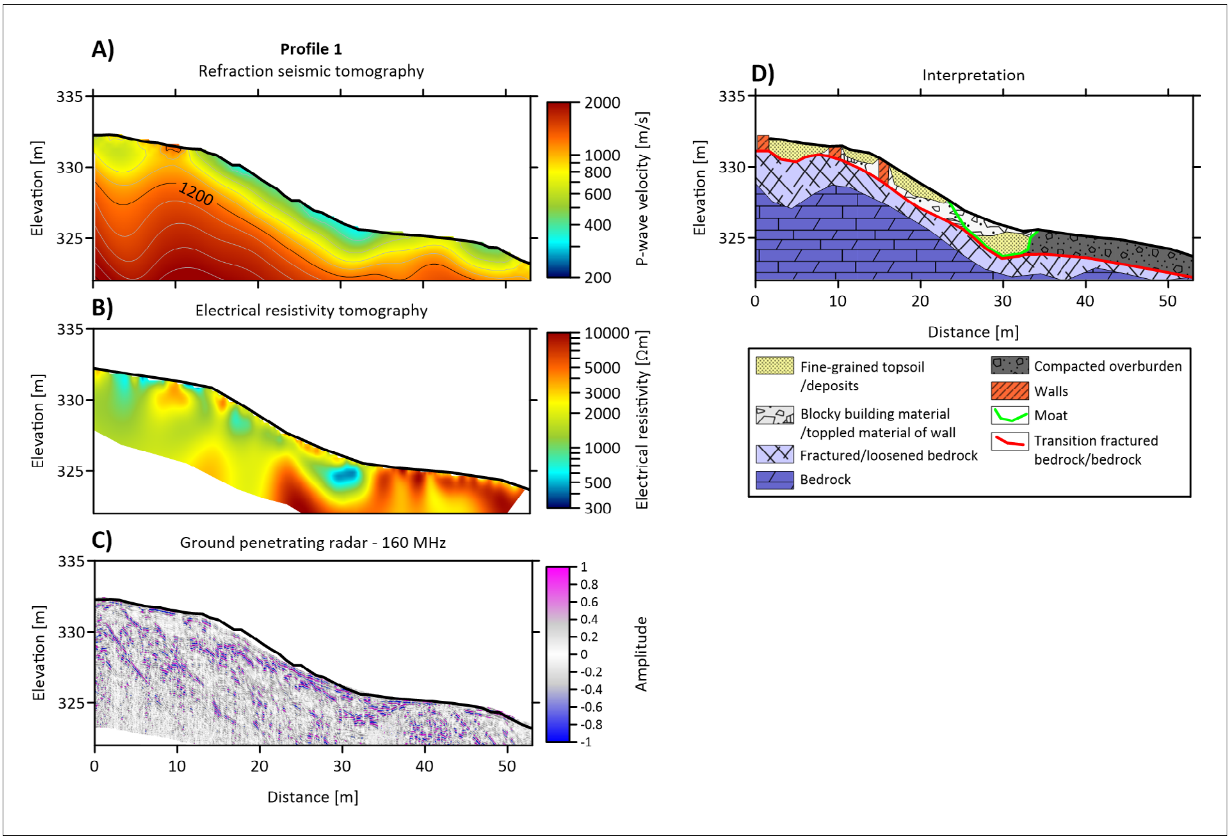

Fig. 2: Geophysical imaging results for the profile 1 (cf. Fig. 1): A) refractions seismic tomography, B) electrical resistivity, C) ground penetrating radar and D) archaeological-geophysical interpretation.

pretation presented in Figure 2D can be summarized in the following: (buried) walls in shallow depths at 0, 10, 16 m along the profile sit on top of non-fractured and fractured bedrock. Above the bedrock sits a layer of fine-grained deposits intermixed with blocky building material or larger stones of toppled walls. Of particular interest is the depression between 25 and 34 m along the profile. We interpret this as a moat, which was first backfilled with fine-grained sediments and then, with the ongoing deterioration of the castle ruin, toppled material of the castle walls. For complex sites such as a castle ruin, that consist of a sequence of various intermingled temporal layers, an integrated investigation in which ERT and RST are used as complementing methods to GPR could be a step forward for an improved interpretation.

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