Characterization of underground cellars in the Duero Basin by GNSS, LIDAR and GPR techniques

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1 Introduction

The underground cellars that appear in different parts of Spain are part of an agricultural landscape dispersed, sometimes damaged, others at risk of disappearing. This paper studies the measurement and display of a group of wineries located in Atauta (Soria), in the Duero River corridor. It is a unique architectural complex, facing rising, built on a smooth hillock as shown in Fig. 1. These constructions are excavated in the ground. The access to the cave or underground cellar has a shape of a narrow tube or down gallery. Immediately after, this space gets wider. There, wine is produced and stored [1]. Observation and detection of the underground cellar, both on the outside and underground, it is essential to make an inventory of the rural patrimony [2]. The geodetection is a noninvasive technique, adequate to accurately locate buried structures in the ground. Works undertaken include topographic work with the LIDAR techniques and integration with data obtained by GNSS and GPR.

Fig. 1 Underground cellars. Atauta (Soria)

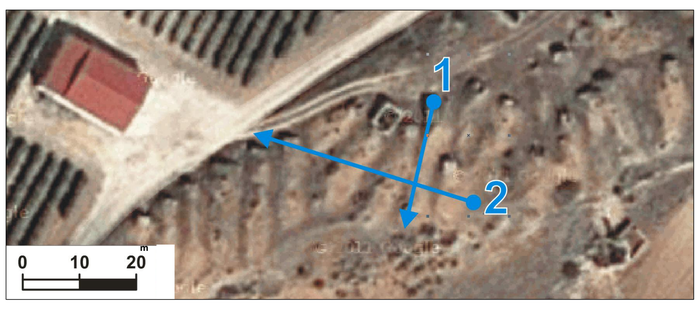


Fig. 2 Itineraries (1) and (2), both with GPR

2 Methods

Surface GPR prospecting and underground LIDAR scanning have been applied in order to jointly facilitate the determination and location of internal structures. Through their fitting with the GPR profile, we estimate the Radio Wave Velocity (RWV) in the ground, required for locating the GPR detections of the hollow parts and old hidden structures. The radar data were acquired using a Malå Ramac/GPR ProEx system equipped with unshielded antennae of 100 and 200 MHz, in order to compare the behaviour of different frequencies suitable for the area conditions and type of space [3]. Two profiles were done at each frequency, one along the selected cellar (itinerary 1, Fig 2), and the second transversal to the selected and adjoining cellars (itinerary 2, Fig 2).

The LIDAR used was a Faro Focus 3D unit. It was furnished with a telematic ambiguity unit and a range of 0.6 m - 120 m outdoor with low ambient light. Point clouds registered by LIDAR and GPR where linked using GNSS techniques [4]. GNSS techniques used in this study served a double purpose: to serve for geo reference all the survey, and further integrate the observations obtained using GPR techniques and LIDAR [5].

Equipment

- Malå Ramac/GPR ProEx with RTA 100 MHz and unshielded 200 MHz antennae.
- DGPS Leica 1200
- LiDAR Faro Focus 3D

Problem

Unknown Radio Wave Velocity (RWV).

- Depending on the existing substrate (Table 1) , RWV can take a value between 55 and 175 m/μs.
- Using wrong RWV, values of thickness obtained by GPR can be wrong.
- There is no easy way to measure RWV.

Material	Effective permittivity ε_{efr}	Conductivity σ (mS m^{-1})	Speed v (m μs^{-1})
Air	1	0	300
Distilled water	80 - 88	0´01	33
Fresh water	80 - 88	0´1 - 10	33
Saltwater (and marine)	80 - 88	4000	10
Snow polar	1´4 - 3	---	190 – 250
Polar ice	3 – 3´2	0´02 – 0´003	>168
Limestone dry - wet	4 - 16	10^{-5} - 25	75 - 150
Shale dry - wet	5 - 15	1 - 100	77 – 134
Granite Dry - wet	4 - 15	10^{-9} - 1	110 - 130
Dry sand - saturated	3 - 30	10^{-7} - 1	55 – 174
Dry Limo - saturated	5 - 30	1 -100	63 – 100
Dry clay - saturated	4 - 50	0´25 - >1000	60 – 170

Table 1. Typical values for different parameters of propagation media (modified from Ramak, 2003, Appendix 3).

3 Results

Fig. 3 shows the 100 MHz GPR transparent profile obtained from the itinerary 1, superimposed on the LIDAR profile. The inner profile of the winery detected by LIDAR is represented in blue (hidden cavities are not detected). The GPR detection is shown in yellow and the road level in white.

We can observe that the dome rests on the road level. Other detectable structures are the chimney pipe (in red), a wide cavity around it, and a discontinuity over the structure that supports the roof stairs. The coupling of the results from GPR and LIDAR lets us estimate a value of 130 m μs^{-1} for the RWV in the medium (soil and rock), which is appropriate for a reasonably dry limestone.

The radar detection profile does not match with the inner cavity detected by the LIDAR. This is due to the early GPR reflections in the hollow parts and old hidden structures, in addition to the limited resolution capability of the 100 MHz GPR, of ca. 50 cm.

A resonance effect appears in the staircase zone produced by multiple reflections between the stair treads and the ceiling.

Over the cellar roof there may be a layer of fractured rock, which can produce a GPR reflection some centimetres above the roof.

Once the RWV is characterized using the data of itinerary (1), domes of near cellars have been detected using 200 MHz GPR itinerary (2). Those cellar domes are at less than 2 m depth (Fig. 4 a and b)

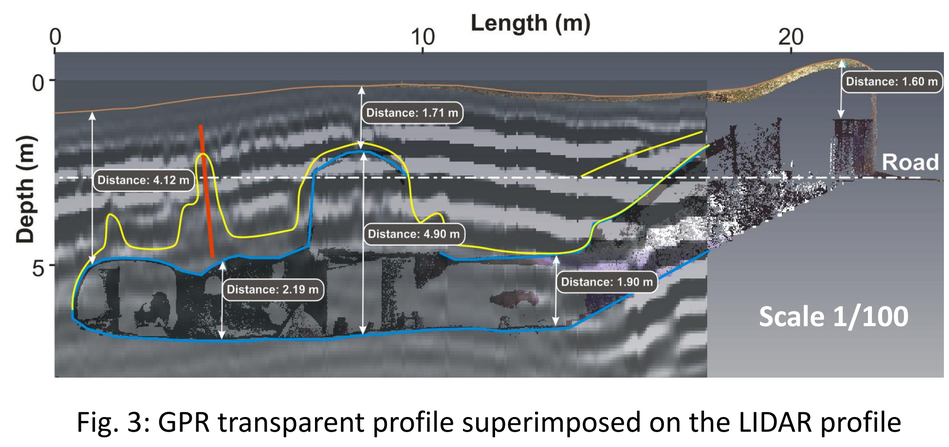
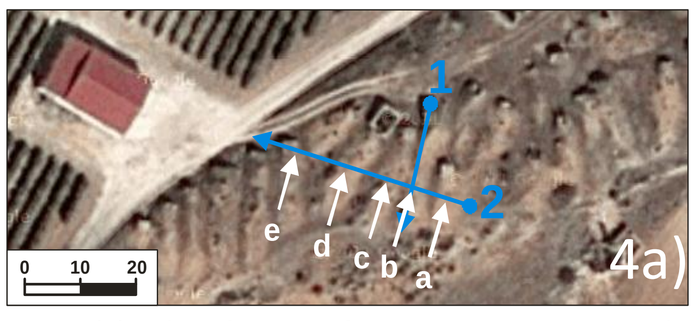


Fig. 3: GPR transparent profile superimposed on the LIDAR profile

Solution

One profile is done joining outside GPR and inside LIDAR measurements. LIDAR gives real positions, so RWV can be tuned in GPR detecting. This RWV will be also used for the rest of profiles (LiDAR measurement in blue; in yellow GPR some detections of cavities and structures over the cellar).



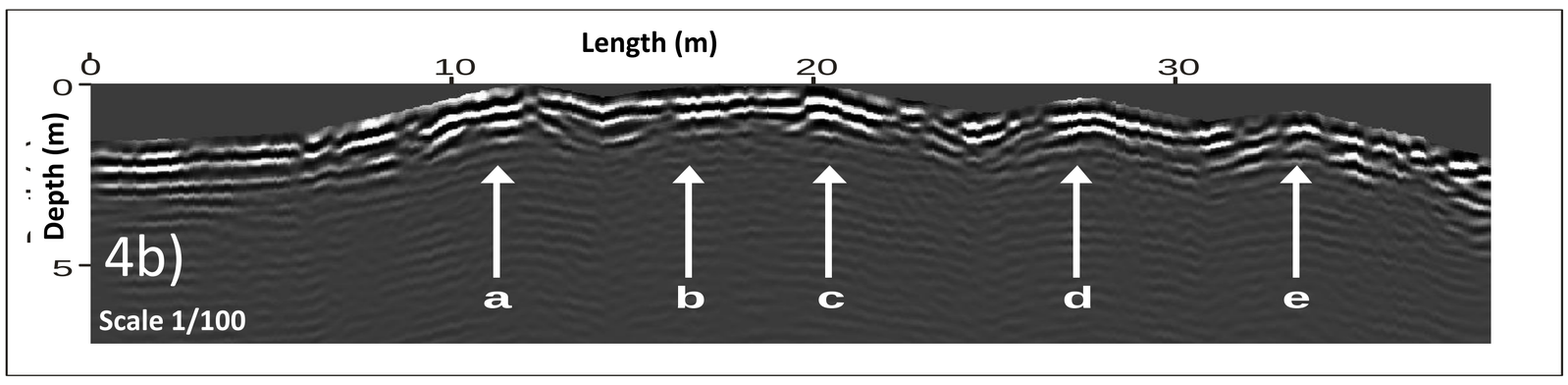


Fig. 4 (a) : Identification of structures on transversal itinerary. (b): Radargram showing the different domes

4. Conclusions

The use of Geographic Information Technology allows better geovisualization of the rural heritage, as shown on this article.

Using 200 MHz GPR the penetration depth was scarce, while with 100 MHz we have obtained successfully results. It has detected the different cave-domes, the cave-ceiling and most of the cave-floors. It is also possible to detect the presence of other structures, as the entrance beam, the chimney or other close entrances.

The joint use of LIDAR and GPR techniques has revealed a faster method than conventional techniques, such as total station or photogrammetry. Also the RWV estimate is faster and more accurate than using only GPR. The accuracy obtained is centimetric, and GNSS technique makes feasible the combined use of LIDAR and GPR maintaining the accuracy and the survey speed.

The techniques described in this article are suitable to use on other natural cavities, archaeological cavities or multipurpose constructed underground spaces.

This project can help the underground cellars to be declared as Cultural Interest by the Comisión de Patrimonio Cultural de Castilla y León - Junta de Castilla y León (Heritage Department of the Regional Government of Castilla y León).

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