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Archaeological microgravimetric prospection inside don church (Valencia, Spain)

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A B S T R A C T

The microgravimetric surveying technique is applicable to the detection of shallow subsurface structures if a lateral density contrast is presented, and thus, it is a valid technique for archaeological prospection. In this paper, this technique has been revealed to be an efficient tool for archaeological studies, such as those performed inside Don Church (18th century), located in the urban area of Alfafar town, Valencia (Spain), where a buried crypt, suggested by different boreholes drilled during the second restoration process in 1993, is expected. Details of the site's characteristics, topographic survey procedures, microgravimetric field operations, data collection and gravity reduction operations (where the inner building effect of walls, pillars and the altar is confirmed as one of the most important) are also presented. Finally, the results confirm the buried crypt.

1. Introduction

Gravity and microgravimetric studies have been widely and routinely used in geophysics, geodesy, geodynamics, geology, mineral and oil exploration and engineering applications (Burger, 1992; Sharma, 1997; Torge, 1989). Likewise, bibliographic references regarding the application of the microgravimetric technique in archaeological prospection are numerous; for example, microgravimetric and gravity gradient techniques are applied in Butler (1984) for the detection of subsurface cavities and tunnels; Friedrich et al. (1996) used microgravimetry to detect hidden cavities and cisterns in the Hagia Sophia's subsurface structure, confirming the accuracy and efficiency of this technique to investigate subsurface structures of historical buildings; Ranieri and Sambuelli (1996) evaluated the use of microgravity measurements to characterise density anomalies in surrounding tunnels; Yule et al. (1998) conducted a microgravimetric investigation to detect subsurface cavities or other anomalous conditions that could threaten the stability of switchyard structures; Beres et al. (2001), Styles et al. (2005) and Leucci and De Giorgi (2010) used microgravimetric surveys to map subsurface karstic features; Ebrahimzadeh (2004) used microgravity measurements to detect subsurface cavities or other anomalous conditions that threaten the stability of the foundation in the technical University of Tehran; Rodríguez et al. (2007) conducted a microgravimetric study in the Vall de Crist Carthusian Monestery (Castellón, Spain) to detect and map a shallow subsurface rainwater cistern, proving that the microgravimetric technique is an efficient tool for cultural heritage restoration studies; and finally, the microgravimetric technique has proven useful in urban areas to map well-defined structures, such as doline filled with urban debris (Mochales et al., 2008).

In this paper, we report a microgravimetric prospection study for archaeological purposes inside a historical building. The first part of the paper is devoted to the theoretical methodology and practical considerations to reduce, correct and process the microgravimetric observations. The second part presents the church and the microgravimetric maps related to the reductions, corrections and processing of the observations, which are followed by the final map of the local residual Bouguer anomalies. A microgravimetric inversion of a cross-section and analysis and discussion of the results ends this section. The paper ends with some conclusions about the utility of the technique, including practical considerations for a good microgravimetric survey and the archaeological benefits obtained in the Don Church prospection.

Therefore, this paper can be considered as a case study of microgravimetric technique applied to archaeological prospection. All the reductions and corrections to the gravimetric observations are applied (most of the references before did not include the complete sequence but only some of them), where we highlight the inner building effect as one of the most important in the reduction process when the propection is located inside a building.

2. Methodology

2.1. Survey details and field procedures

Data were collected with the Lacoste & Romberg D203 gravity meter. This gravity meter has electronic levels and is equipped with

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an electrostatic feedback system. The nominal sensitivity is approximately 1 μGal (1 μGal $= 1.10^{-8}$ ms^{-2}); however, its use in field conditions introduces accidental errors in the observations that should be appropriately minimised to achieve relative observations with an accuracy of 5–7 μGal. A list of error sources, their standard deviations and additional precautions to be adopted to minimise their impact can be found in Torge (1989) and Qianshen et al. (1996). These additional precautions include orientation of the instrument with respect to the magnetic field, the readings can only be taken 5 min after releasing the clamp, at least three readings should be performed for each station using only the feedback system, and hand carrying was employed during the survey to avoid vibration shock and to ensure careful operation.

In the case study presented, the gravity station grid was marked on the floor with chalk, and the nodes were used for gravity observations. The rules used for the station spacing and field operations with the Lacoste & Romberg are described in Qianshen et al. (1996).

A total-station surveying instrument was used to determine the horizontal and vertical positions of the station points in a local reference frame with an error better than 0.02 m. Microgravimetric surveys require effective and accurate consideration of the effects given by infrastructures, such as buildings (including which the microgravimetric survey is performed), as well as those given by topography near a gravity station. A local survey with the same total-station was performed for the sake of terrain and building corrections.

2.2. Gravity corrections and reductions

Corrections to microgravimetric observations are needed to compensate gravity variations due to natural causes (earth tides or atmospheric variations), instrumental causes (drift), observational

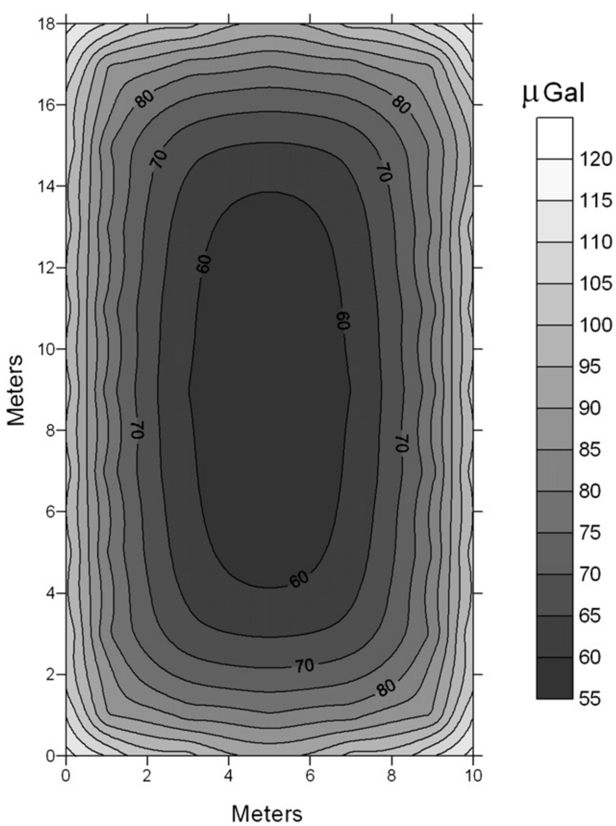

Fig. 1. Example of the influence of rectangular building on microgravimetric observations; for explanations see the text.

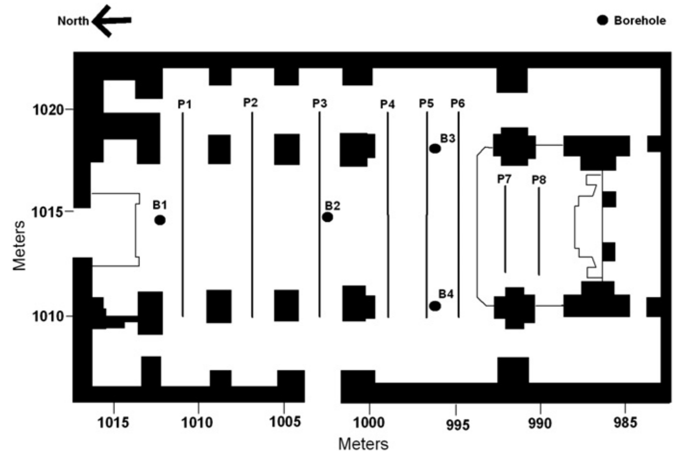

Fig. 2. Ground plan of Don Church including the profiles (P1 to P8) used for the microgravimetric observations. Black points represent the location of a borehole.

causes (instrumental height) or geographical situation causes (variations in latitude or corrections for terrain and buildings). In the following, these corrections are presented in the same order as they are applied to the raw microgravimetric data. They are well known since many decades and are applied in a standard way, so a short description is only need.

2.2.1. Tidal effects and correction

To predict the tide component, version 3.32 of Professor Wenzel's ETERNA software package with Hartmann–Wenzel Earth tide catalogue was used (Wenzel, 1999). Parameters for amplitude and phase-difference for the principal tidal waves were fixed to zero and 1.164, respectively (Boedecker, 1988).

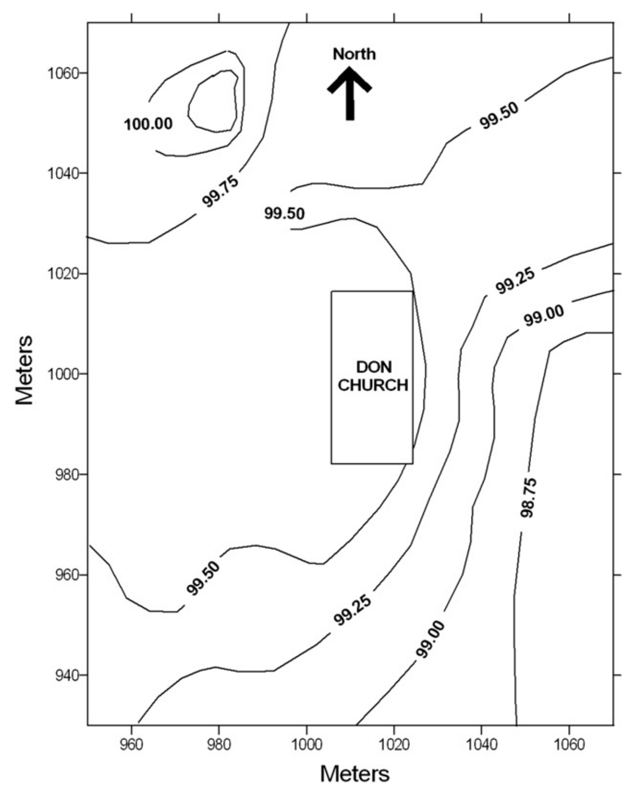

Fig. 3. Plot of the digital elevation model.