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Urban Archaeo-Geophysics in Cusco. The Case Studies of Paraninfo and Casa Concha

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Abstract

The detection of archaeological heritage buried in urban areas represents today one of the most complex challenges of the cultural heritage sciences. The inter and trans disciplinary integration of archeology and geophysics can provide a significant contribution to open new perspectives and approaches addressed at improving the knowledge of the history of cities and locate the areas to be protected. The high complexity for the identification and interpretation of geophysical characteristics in the urban subsoil makes it necessary to develop *ad hoc* procedures to be implemented and validated in significant case studies. This work shows the results of an interdisciplinary project in Cusco (Peru), the capital of the Inca Empire, where the georadar method has been applied in urban areas of the city, in particular in courtyards of important historical palaces. This follows a published work on georadar based investigations of the main square of the city

I. INTRODUCTION

Many places in the world preserve in their subsoil ancient archaeological structures which represent their identity and history. In the case of urban areas with long history, there are an even greater number of possible buried archaeological structures which unfortunately can be threatened by insensitive urban planning and the construction of modern infrastructures. In order to improve the knowledge about archaeological remains buried under modern cities and preserve them, non-invasive geophysics techniques combined with archaeological evidence and historical documentation can be powerful means. Nevertheless, in urban areas, the identification and interpretation of geophysical characteristics is very complex because of the co-presence and mixture of ancient fabric (of archaeological and historical interest) and current or recent pipes and channels.

For these reasons, "urban geophysics" is developing as a new study discipline focused on the geophysical exploration of the urban subsoil to investigate and characterize the properties of urbanized environments and provide effective solutions.

The “Urban archeology” developed in Europe and North America in the last decades of the twentieth century in response to rapid urban development and its impact on archeology [1-3]. To date, urban archeology represents a cognitive tool for a complete and diachronic analysis of social, cultural and political events that occurred in ancient cities over time and can provide a methodological approach and a complete interpretative analysis together with integration with the applied geophysics [4-10]. In fact, urban geophysics has great potential if applied to archeology since it can be used to improve the planning and design of urban development and infrastructure and to protect buried archaeological remains , as in the case of Cusco, the capital of the Inca empire. To date, the interpretation of geophysical investigations remains very complex and difficult due to the presence of modern underground services that can heavily influence the discrimination between natural and artificial stratifications [11]. Despite this, the integration of different geophysical techniques together with the archaeological knowledge of the places can lead to satisfactory results regarding the identification of ancient buried structures [9-11].

II. URBAN ARCHAEO-GEOPHYSICS IN CUSCO

Cusco was the ancient capital of the Inca Empire, which after the Spanish conquest, was partially rebuilt on the foundations and structures of the pre-existing Inca buildings and monuments. Recent excavations, carried out for the maintenance of the underground services along the roads leading to the Plaza de Armas, brought to light important structures of the Inca civilization (Fig. 1).

Fig. 1. Archaeological findings in Calle Mantas, near Plaza de Armas (courtesy of ANDINA/Percy Hurtado Santillán).

Although the construction features of the found walls are attributable to the Inca period, fragments of pre-Inca pottery also emerged from the excavations [12]. Preliminary geophysical investigations, conducted in the Plaza de Armas, suggest the hypothesis that the entire nucleus of the ancient city of Cusco was built over an ancient Inca and pre-Inca site [11]. In order to improve the current knowledge about this very important issue, additional geophysical investigations were carried out to explore the archaeologically sensitive areas located in the subsoil of the city. This paper describes and discusses the GPR survey performed in two courtyards of two historic buildings, Paraninfo and Casa Concha, both located near the Plaza de Armas (Fig 2).

Fig. 2. Location of georadar surveys carried out in the center of Cusco.

GPR prospections were conducted in the framework of the bilateral project between the Universidad Nacional de San Antonio Abad del Cusco (UNSAAC) and the National Research Council of Italy (CNR). The research project was aimed at assessing the potentiality of the GPR to detect buried structures of archaeological interest, discriminate them from modern underground utilities, and to produce an archaeo-geophysical map. This is mandatory to preserve the archaeological vestiges and support the management and maintenance of underground services in the urban area of Cusco.

III. GPR INVESTIGATIONS

III.1 GPR data acquisition and processing

In this study, we used the GPR method which is based on the detection of variations in the electromagnetic properties (EM) of the subsoil and subsequently these data were exploited to identify the archaeological characteristics and distinguish them from the subsoil pipes. The GPR prospecting was carried out with the time domain, IDS manufactured, TH DUAL-F HI-Mode GPR system equipped with a single fold dual frequency antenna, allocated into a shielding box, whose nominal central frequencies are 200 MHz and 600 MHz. The data were collected in two directions through the acquisition of radargrams located according to a grid that included parallel lines equidistant every 0,5 m. in two perpendicular directions, using 512 samples per trace, two-way time (TWT) of 70 ns for 600 MHz antenna and TWT of 130 ns for 200 MHz antenna.

In particular, the Paraninfo courtyard is represented by a 27.5 x 25 m rectangle with a fountain in the center (Fig.3).

The Casa Concha courtyard is a rectangle of 20x 15m area with a small fountain in the center and an open-air excavated area on the side showing ancient walls. (Fig.4).

Raw data were processed to improve the signal to noise ratio and facilitate the interpretation using the standard two-dimensional processing techniques available in the GPR Slice software [13]. The processing phases were: i) amplitude normalization; ii) the filtering of the dewow to eliminate a possible low frequency part of the signal; iii) background removal; iiii) band-pass filter; v) application of the energy gain function; vi) Kirchhoff 2D velocity migration including a quantitatively estimated velocity using the diffraction hyperbolas generated by the objects located in the subsoil (em velocity = 0.090 mns^{-1}); vii) B-Scans interpolation for the reconstruction of a 3D model.

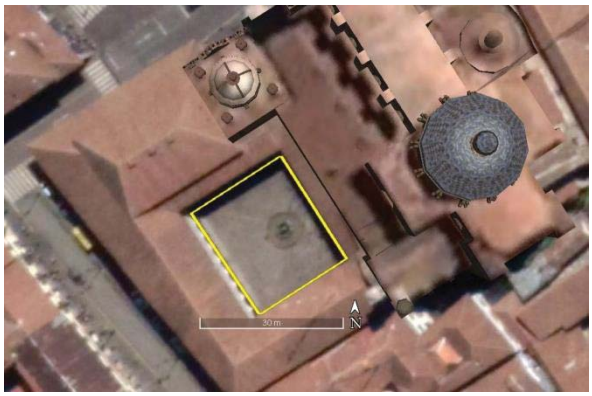

Fig. 3. Paraninfo - Localization of the area investigated with the GPR

Fig. 4. Casa Concha - Localization of the area investigated with the GPR

III.2 GPR result interpretation

The interpretation was made comparing the GPR amplitude maps with the 2D-radargrams, suitably georeferenced on the available digital cartography.

Paraninfo: The maps obtained processing the data at 600MHz frequency show several interesting reflections particularly in two areas (marked with a red dotted background in Fig. 5). From 2D images it is possible to discriminate linear anomalies as underground services, while areas with strong anomalies are found from 0.6m and up to over 1.2m depth (Fig.5b, c). The analysis of the radargrams in these most interesting areas, showed a continuous reflection, thus indicating the presence of probable buried archaeological structures (Fig. 5, radargrams 1-4), clearly discriminated from the recent pipes and channels characterized by small reflections .

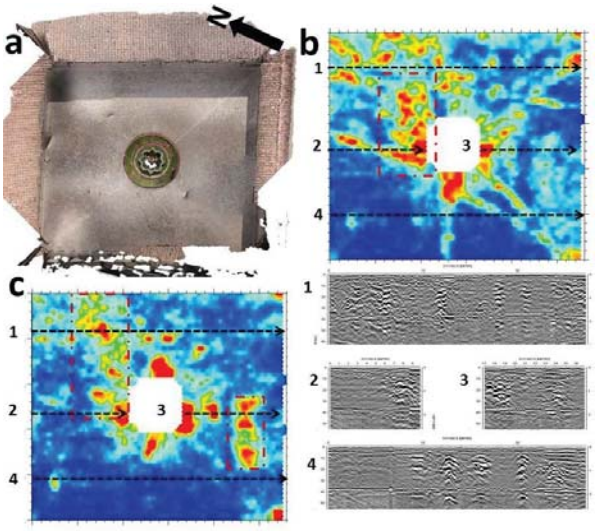

Fig. 5. Paraninfo – a) investigated area; b) horizontal slice acquired at 600MH at the depth of 0.6m; c) horizontal slice acquired at 600MH at the depth of 1,2m; d) with number 1-4 Radargrams 200 MHz with location on maps with black dotted lines; the most interesting anomalies, for archaeological purposes, are indicated with dashed red lines

Casa Concha: The maps obtained from data processing at 600MHz and 200MHz frequency show different reflections at low depths (0.5m) ascribable to recent pipes and channels as can be seen in fig.6. At depths greater than 1m there are instead highly reflective areas indicating the probable presence of archaeological structures buried in continuity with the structures visible from the open-air excavation located near these areas.

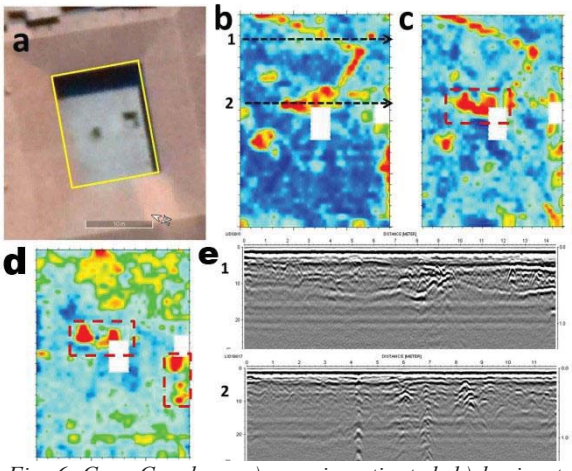

Fig. 6. Casa Concha – a) area investigated; b) horizontal slice acquired at 600MHz at the depth of 0,5m; c) horizontal slice acquired at 200MHz at the depth of 0,5m; d) horizontal slice acquired at 200MHz at the depth of 1,2m; e) with number 1-2 the radargrams acquired at the frequency of 200 MHz (their location is showed in b with black dotted lines); the main archaeogeophysical anomalies are indicated with dashed red lines

IV. DISCUSSION AND CONCLUSIONS

The geophysical surveys carried out in Cusco demonstrate the great potential of the GPR method in the imaging of complex stratigraphy up to 2 m deep, characterized by the presence of ancient walls, along with modern aqueducts, sewer pipes and other structures connected to underground services. On the basis of the direct data observed by some archaeological excavations, a model of anthropogenic stratigraphy of Cusco was hypothesized to simulate the reflection of the waves and discriminate the buried ancient walls from the modern pipes. Two test areas, located inside monumental buildings, were investigated. The approach herein proposed enabled us to identify GPR anomalies related to the presence of both ancient walls and modern underground utilities. In particular, the anomalies related to the walls are reasonably related to the Inca period because perfectly aligned with the emerging walls previously excavated on Calle Mantas (Fig. 1).

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