GPR and Geoelectrical Surveys at a Patagonian Archaeological Site
Part I: Data Analysis

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Abstract

Geophysical methods have been used in archaeology for more than 50 years. Nevertheless in Argentina their implementation for archaeology is very recent. In this work we present a geophysical prospection carried out at Floridablanca archaeological site (18th Century) which is located at San Julián Bay (Patagonic Coast), Santa Curz Province, Argentina. Three geophysical methods were jointly applied for the first time in Argentina for archaeological prospection: ground penetrating radar (GPR), the resistivity method, and the electromagnetic induction method (EMI) to detect, characterize and determine the distribution of adobe (clay-brick) walls buried at a very shallow depth (no more than 1 m). The analysis of the data revealed a number of anomalies which, after correlating them with the archaeological excavations and the historical information available, could be associated to adobes or similar raw-material walls. These anomalies presented a periodic behaviour which should indicate that they belong to a main structure divided into substructures, each one separated by narrower walls.

Introduction

Geophysical methods have proved to be very useful for archaeological prospection. These methods have been used for detecting and mapping the characteristics of diverse types of archaeological buried structures for approximately fifty years (Imai *et al*, 1987; Goodman, 1994; Griffiths *et al*, 1994; Appel *et al*, 1997). Nevertheless in Argentina the implementation of geophysical methods for archaeology began during the 1990s (Carrara, 1996; Ponti *et al*, 1996).

In this work we present the implementation for the first time in Argentina of three geophysical methods – ground penetrating radar (GPR), geoelectrical method, and electromagnetic induction method (EMI)- at Floridablanca archaeological site (18th Century). This site is located at San Julián Bay, Santa Cruz Province, Argentina (49º 16´38´´S, 67º 51´ 22´´W) and corresponds to a Spanish colony settled for the colonization and defence of the Patagonian Atlantic Coast.

The site has an area of 10.000 m^2 defined by the presence of mounds under which archaeological buried structures were found in previous excavations (Senatore *et al*, 1999 and 2001). This work is focused on one sector of the site called North Wing I (NWI). According to the historical investigations, this sector corresponds to the settler's houses. Previous excavations showed the existence of three types of adobe walls: external, separation and internal walls. These walls were: 0.8 m, 0.44 m and 0.25 m wide respectively. The first ones were the external walls of the structure, the second ones separated one house from the consecutive one and the last ones were internal walls of the houses. In all cases the buried archaeological structures reached a depth of no more than 1 m. In figure 1 a house excavated in another sector of the site is shown. The adobe walls can clearly be seen. Though this house does not correspond to the sector that will be studied, a similar buried structure is expected to be found in the NWI sector.

Figure 1: a settler's house partly excavated in another sector of the site. The adobe walls can clearly be seen.

The objective of this geophysical survey was to detect buried adobe (clay-brick) walls and, as there is no historical information about the internal organization of the houses, to determine their distribution and characteristics. The results are shown in this paper and were correlated and interpreted using the archaeological and historical information available.

Method

As stated previously, the objective of the present work was not only to detect buried adobe walls but also to analyse their characteristics (depth, thickness) and distribution to provide the archaeological community with information about the internal organization of the houses buried in the NWI sector without excavating it completely.

In figure 2 all the profiles carried out on the NWI sector are shown. Profiles parallel and perpendicular to the major axis of the mound (marked with a rectangle) were carried out. Some of the parallel profiles were done on the mound and some outside it for the means of comparison. The GPR profiles are named with an F, geoelectrical profiles are named with the prefix AN, and EMI profiles are called line 1,2, etc.

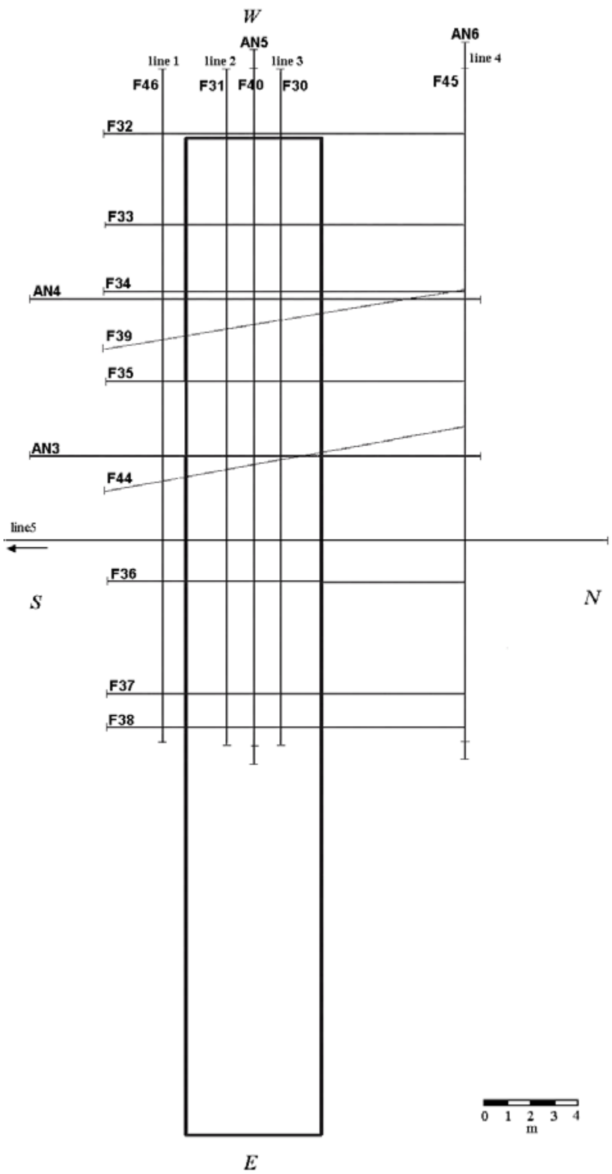

Figure 2: GPR, geoelectric and EMI profiles carried out on the NWI sector.

A 500 MHz antenna, that allowed us to get the resolution and the depth of penetration (up to 3 m) required (Conyers, 1999), was used in the GPR prospecting. Twelve scans per meter were taken for every profile. For the geoelectrical method the dipole-dipole configuration was chosen because of its high lateral resolution (Reynolds, 1998). Electrode apertures of 0.8 m were used. For the EMI lines a frequency range from 330-19900 Hz was used. For these frequencies a depth of penetration of more than 20 m was achieved (Won, *et a*l, 1996). Measurements were taken every 3 m. Though the resolution of the prospection was not enough to detect the archaeological structures, the deeper layers could be studied.

Data Analysis

In figure 3 GPR profile F40, and geoelectrical profile AN5, both parallel to the major axis of the elevation and done along the same line, are shown simultaneously. In F40 some anomalies can be clearly distinguished along the whole profile (the anomalies are pointed with white arrows). All these anomalies present a low contrast with the surrounding medium, they have the same shape, and they are found at the same shallow depth though some of them are stronger than the rest. The difference in the strength of the anomalies could be because of the presence of different type of buried structures. One interesting feature of this radargram is that the anomalies present a rather periodic distribution: the separation between strong anomalies is 7 m and the weaker anomalies are at 3 m to the left of them throughout all the line. This behaviour is repeated on the other parallel profiles done on the mound (F30 and F31). On the other hand, no anomalies were found in the profiles carried out outside the NWI sector (F45 and F46). This means that under the mound that defines the NWI sector there are buried shallow structures distributed in a periodic way, that are not present outside the mound. These structures may be the buried adobe walls.

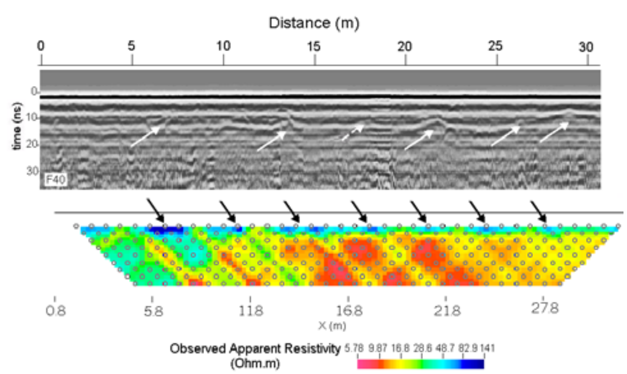

Figure 3 : GPR profile F40 and Resistivity profile AN5 done on the same line. The white arrows mark the GPR anomalies and the black arrows mark the apparent resistivity anomalies.

In the geoelectrical pseudosection AN5 there are also shallow anomalies that manifest themselves with high values of apparent resistiviy. These anomalies coincide with the GPR anomalies in most of the cases. Like in the GPR profiles, no anomalies were found in the resistivity profile done outside the mound (AN6), where the pseudosection presented a rather uniform behavior. In this way there is a correspondence between the GPR anomalies and the geoelectric ones.

In figure 4 GPR profile F39 and resistivity profile AN4, both perpendicular to the mound's major axis are shown. In F39, the slopes of the elevation can clearly be seen. There is an anomaly at approximately 5 m, that is wider and better defined than the ones shown in figure 2 but has the same shape and depth of the anomalies found in F40. There seems to be an anomaly at 11 m. This anomaly is not so clear as the first one because it is under the slope of the elevation. This behavior is also found in most of the other perpendicular profiles. These anomalies, as they are wider and better defined than the ones found in the parallel profiles, could be the external walls of the houses.

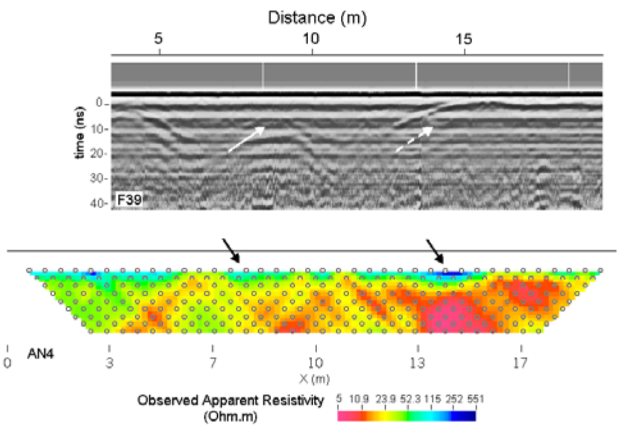

Figure 4 : GPR profile F39 and Resistivity profile AN4 done perpendicular to the mound. The white arrows mark the GPR anomalies and the black arrows mark the apparent resistivity anomalies.

As in the previous case, the geoelectric anomalies coincide with the GPR ones. The fact that the descending slope of the elevation presents higher values of apparent resistivity than the ascending one supports the idea that there is a buried structure under it.

In figure 5 a scheme of the mound that defines the NWI sector, with all the GPR profiles and all the anomalies found is shown.

There is a correspondence between all the GPR profiles. The possible separation and internal walls are grouped. The periodic distribution of the anomalies can clearly be seen. The external walls of the structure can also be distinguish along the perpendicular lines. All these anomalies coincide in most of the cases with the geoelectric anomalies, as it was shown above.

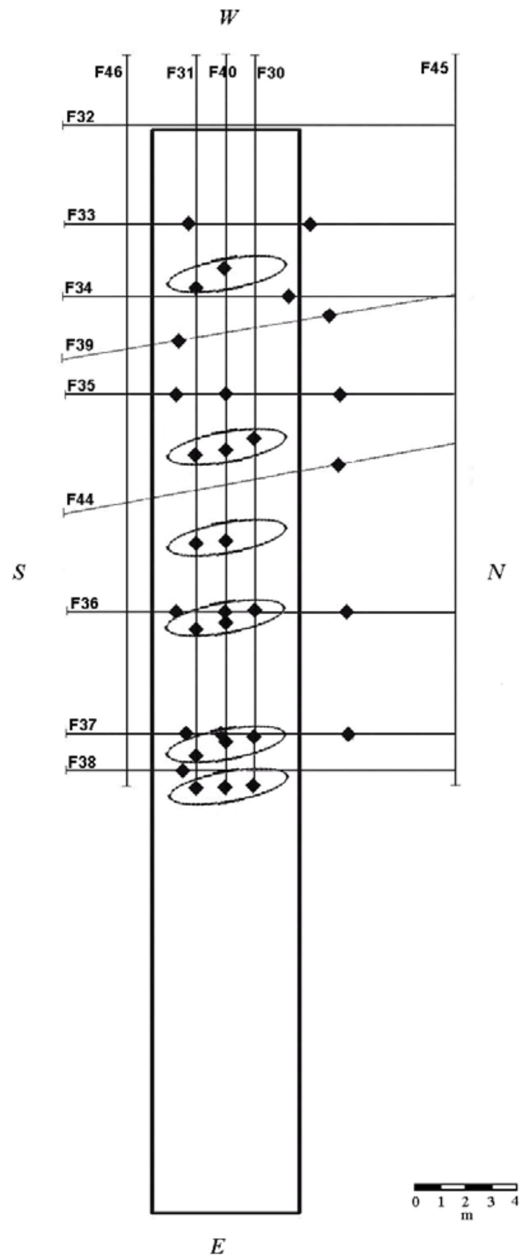

Figure 5: Scheme of all the GPR anomalies. The separation and internal walls are grouped. The external walls can be seen in the perpendicular profiles

Inversion Models

In figure 6 the electrical tomographies obtained by the inversion of the apparent resistivity data corresponding to the resistivity method are shown for profiles AN5 and AN6. These profiles are both parallel to the mound's axis, but the first one was done on the mound and the second one outside it. The inversion was carried out using the the DCIP2D inversion code developed by the University of British Columbia (UBC) and based on the work of Oldenburgh *et al*. (1993) and Oldenburgh and Li (1994).

These electrical tomographies confirm the results exposed previously. That is, there are shallow, more resistive buried structures present under profile AN5 that are clearly not found under AN6 and so there are shallow buried archaeological structures only under the NWI mound. Nevertheless both models present the same behavior for the deeper depths, from 1.5 m. There is a very conductive layer, a clay soil according to previous excavations, interrupted by a more resistive layer at a depth between 2 and 4 m. There is also a more resistive lens at the beginning of both profiles, up to 10 m approximately reaching a depth of 5 m in AN5.

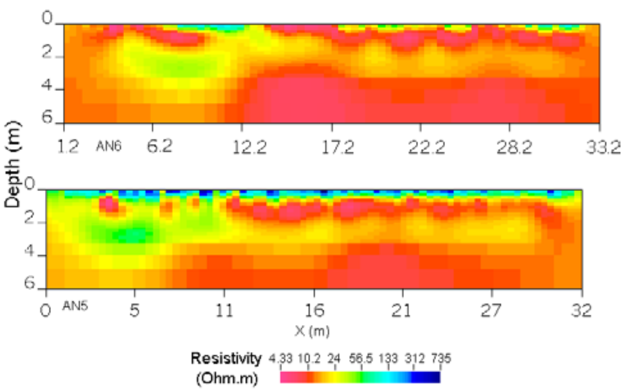

Figure 6: Electrical tomographies obtained from the inversion of the AN5 and AN6 profiles.

In figure 7 a) and b) the inversion of the EMI profiles line 2 and line 4, parallel and perpendicular to the mound's major axis respectively are shown. The inversion of the data was done using the EM1DFM code (Farquharson *et al*, 2000) . An anomalous zone, of a depth of no more than 3 m, and a more conductive layer bellow it can be distinguish for line 2. According to previous excavations the highly conductive layer is associated to a clay soil. There are also some resistive intrusions in this conductive layer, probably due to gravels and sand. The shallow resistive layer could be the result of the combination of buried structures together with the accumulation of materials sediment over them. In this way, even though the walls cannot be resolved (measurements were taken every 3 m), their presence may be deduced from these shallow resistive values.

In figure 7 b) (line 5) two resistive zones can be seen. Their position coincide with the position of the GPR and geoelectric anomalies shown above. So these resistive zones stand for the presence of shallow buried structures. As in the parallel profile, there is a very conductive layer bellow these resistive zones, with resistive intrusions.

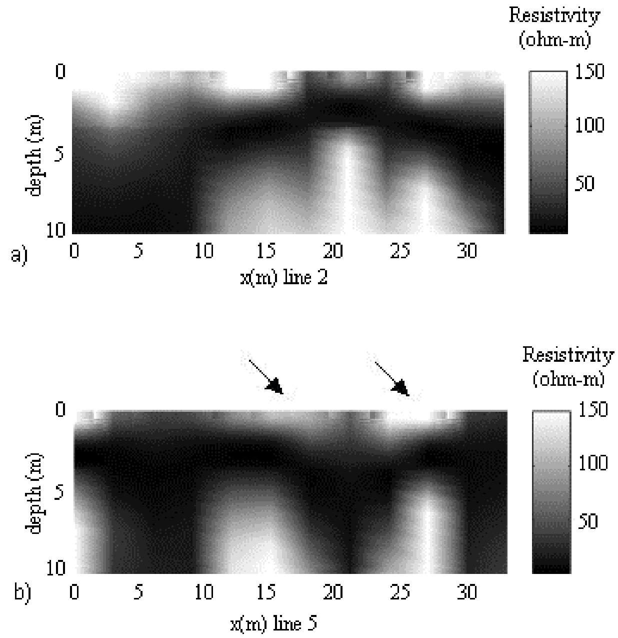

Figure 7: inversion of Emi profiles a) line 2 parallel to the mound and b) line 5 perpendicular to it.

Discussion

Three geophysical methods were applied for the first time in Argentina for archaeological prospection. The geoelectric, the GPR, and the EMI methods were carried out in the Floridablanca archaeological site to detect, characterize and determine the distribution of adobe buried walls that corresponded to the houses of the settlers of the site.

From the presence of a periodic distribution of equally shaped anomalies found at the same depth in the parallel GPR profiles, it can be said that underlying the NWI's mound there are buried adobe walls with those characteristics. From the different strength of the anomalies it can be deduced that these anomalies correspond to different types of adobe walls, thinner and wider walls. These walls would correspond to the internal and separation walls of the houses respectively. Consecutive stronger anomalies (separation walls) are separated 7 m through the whole profile. On the other hand the thinner anomalies are separated approximately 2 o 3 m from the stronger anomalies.

The anomalies found in the perpendicular GPR profiles present the same characteristics that the ones found in the parallel ones. As these anomalies are wider and better defined than the ones found in the parallel profiles, they are associated with the external walls of the houses. According to the separation found between the anomalies it can be said that the external walls are separated 6 m apart.Similar observations can be made from the geoelectrical data and their inversion. This correspondence between the geoelectrical and the GPR data analysis make these conclusions still more reliable.

These results were also confirmed by the EMI profiles analysis, which provided important information about the medium in which the archaeological structures of interest are embedded up to a depth of 20 m.In this way, the adobe walls were detected and characterized. The internal distribution of the houses could be established from these results providing the archaeological community with important information without excavating the whole zone.

Acknowledgements

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