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Subsoil Characterization by Electrical Resistivity Tomography around Rosières- la-Terre-des-Sablons site (Lunery, Region Centre, France)

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Abstract

This piece of work has applied Electrical Resistivity Tomography (ERT) with the aim of understanding Rosières-la Terre-des-Sablons site's subsoil. This site, placed in a Middle Cher Valley's fossil terrace has been dated in 0.8-1.1 My, fact that has been confirmed by the mode 1 lithic industry found in it.
Once distinguished one from each other the different resistivity values of the different materials present at the site, the subsoil could be characterized contributing to a better understanding of the geological formation of the site, as well as giving ideas of the strategies to follow in the future of the excavation. Test drillings have calibrated the results and showed the suitability of the method applied to the given problematic.

Keywords: applied geophysics, Electrical Resistivity Tomography, Lower Pleistocene, Middle Loire basin, Middle Cher valley, fluvial deposits.

Introduction

During the last decade, multidisciplinary studies on the stepped-terraces systems of the Middle Loire river basin (France) have been carried out, involving Quaternary geology, prehistory and geochronology. The Cher river (Centre region), one of the main Loire tributaries, has contributed to the study of Early Paleolithic with many sites in which lithic industries first pointed out the sites' antiquity. Electron spin resonance (ESR) confirmed then, up to 1.1 Ma for the eldest sites (Despriée *et al.*, 2007).

Whereas in roman or medieval archaeology geophysics is often used to solve structure problematics (such as the location of walls) in prehistoric archaeology its use is scarce. In fact, in prehistoric sites, even if geophysical studies have an archaeological application, its interpretation won't differ from a geological one.
This article presents the results of the geophysical prospection carried out at the open-air Early Paleolithic site of Rosières–la Terre-des-Sablons, being the work's main objective to get the most from the geoelectric method from an archaeological point of view. This interdisciplinary work intends to recognize the site's sedimentation process and to give relevant information that helps plannig the excavation surveys.

Regional setting

Rosières–la Terre-des-Sablons locality (Lunery district, Cher deparment, Region centre, France) is part of the "Sables de Rosières" formation and occupies a fossil terrace of the medium Cher basin, which is part of the medium Loire basin (see figure 1).
Between Châteauneuf-sur-Cher and Vierzon, the river Cher flows following tectonic structures. This sector called "Berry" conserves seven alluvial remnants thanks to the fact that they are tilted down blocks. The rest of the terraces were eroded, instead, bringing to ligth de jurassic limestone (Despriée *et al.*, 2007, 2009a) (fig. 1).

This site was exploited for over 40 years as an aggregates quarry to a depth of 25 m and it was later used as a dump. However, 3 alluvial complexes have been conserved, those corresponding to 3 tilted down blocks which have descended in a « piano key » way. The site occupies the third of these blocks, and, even though it has descended a total of 12 m, its limestone base keeps a large horizontality.

Unit 3 is a 2.20 m thick deposit made up, from the surface to the basement, of a layer of obliquely stratified sands (b), followed by a layer of medium to thick sands and gravels (a). This unit has a red brown patina due to the clayey matrix it is in, which contains numerous iron pisoliths (Voinchet *et al.*,2009) (fig.1).

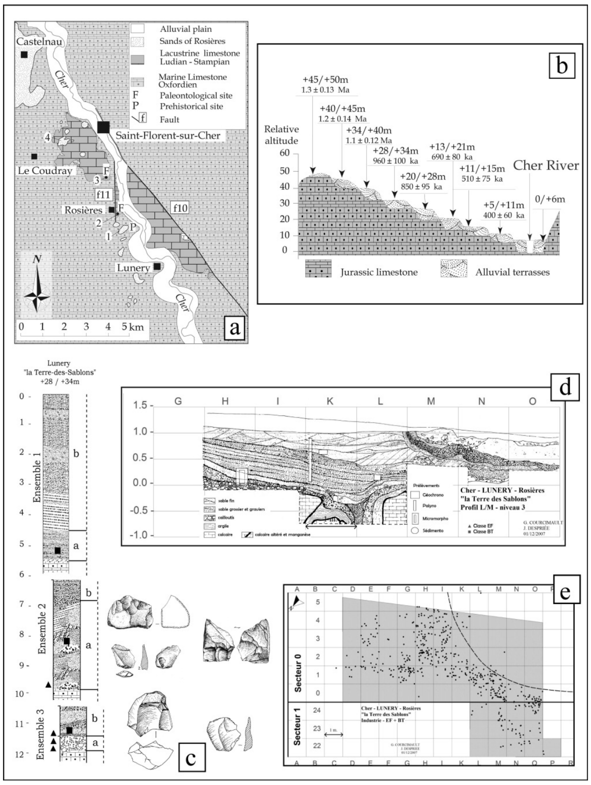

Fig.1. Cher River Valley, ''Berry Sector'', Lunery-Rosières, ''la Terre-des-Sablons'' site. a : location of outcrops of the ''Sables de Rosie` res'' formation ; b : cross-section of the Cher Valley and ESR ages of the stepped alluvial formations; c: stratigraphic logs of the three sandy units and position of the prehistoric levels (black triangles); d: stratigraphy of the cobbly channel bar and position of the artifacts; and e: distribution of the artifacts above the limestone floor. (Despriée *et al.,* 2009b).

This unit is dated by the ESR method in 0.8-1.1 My, contains three prehistoric excavation levels, where mode 1 lithical industry has been found (Despriée *et al*., 2007, 2009a). Dating and technology are so coherent.

It should be stressed that the site has numerous witness of glacial-interglacial process, such as cryoturbation, solifluxion, etc.

Materials and methods

All geophysic methods study the distribution of a particular subsoil property (Cantos, 1987). So, in order to choose the correct geophysical method, we should know the properties and depth of the object looked for, as this will determine the correct technique. Geophysical methods most used in archaeology are:

Gravimetric: it is used to find cavities.

Magnetic: it detects magnetic altered objects or soils (such as ceramics or hearths) (Martínez, 2006).

Seismic: it is based on the speed that acoustic waves propagate in the subsoil. It is the technique that reaches the higher depth of investigation.

Electromagnetic (at low frequency): it measures subsoil's resistivity and it is and it is useful for identifying structures in positive (such as walls) or in negative (such as fillers) (Thiesson, 2005).

Electric: it measures subsoil's resistivity. To understand this methodology, we have to go through the properties in which our study is based on.

First and essential is that geoelectric methods measure rocks electric resistivity ρ. Its unit is ohm.m (Orellana, 1982).

However, rocks and soils do not always present the same physic behaviour (fig. 2), they depend on porosity, fracturation, water content, clay content…). So, we cannot assign from the start a single resistivity value to each rock. That is why it is essential to study the site's geologic characteristics (Cantos, 1987; Orellana, 1982).

In order to establish an electric field we need two pairs of electrodes. A and B will inject the current, whereas M and N will measure the difference of potential between them. The bigger the distance is between the two pairs of electrodes, the deeper the electric current lines will arrive (fig. 3).

2D ERT (Electrical Resistivity Tomography), or panel, consists on planting on the soil the greater possible number of electrodes, along a straight line. They will all be connected to a device that will make all the possible combinations between them, in order to obtain resistivity values at different depths, but always over the same profile (Dahlin, 2001) (fig. 3).

Several parallel profiles are often done, as 2D ERT methods consider that subsoil may vary in a vertical and a horizontal way, so the combination fo several 2D ERT allows to describe the subsoil in a 3D way.

As for the geometric organization of these electrodes there are numerous combinations, i.e. arrays. Those used in this study are Wenner-Schlumberger and dipole-dipole(see figure 3). The first one is suitable for the study of horizontal and vertical structures, whereas the second is very sensitive to superficial heterogeneities. In this piece of work, we have mixed the data of both arrays in oder to have more information.

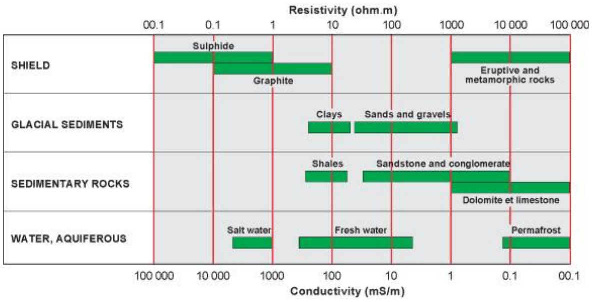

Fig.2. Resitivity of different formations (cours on line, 2009).

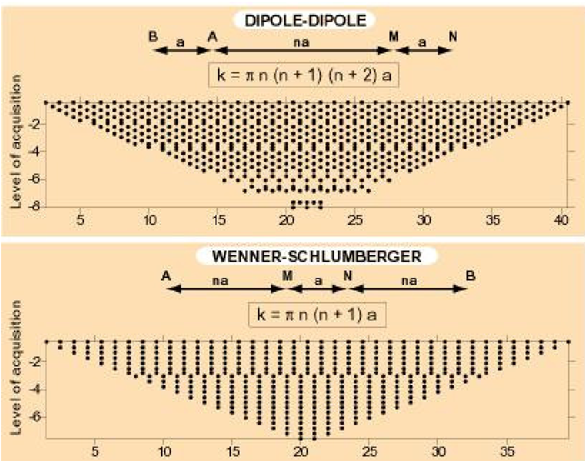

Fig.3. Schlumberger and Dipole-dipole acquisition points (cours on line, 2009).

Results

Results are obtained with the Res2Dinv software, which creates a subsoil's resistivity model, calculating the real thickness and resistivity values of each cell.

In order to interpret data, we should be able of differentiating the different resistivity values of the different rocks present at the site. This will help us "draw" the site's subsoil, specifically, the sediment-calcareous base contact. We should be also able of understanding the karstification dimensions.

Besides, it must be said that geophysics cannot exist without terrain's direct observation, so we have to be able of relating the visible structures with those shown in the results.

The aim will be to obtain the site's most accurate information, as well as the site's dynamics formation.

The profiles' layout at the site was therefore determined by two elements: one is related to the site's size, and the other one to the visible structures in surface, whose dimensions we wanted to study. To that end, it was necessary that profiles crossed these structures in a perpendicular way. Specifically, we are referring to a possible doline, and to a possible fault. Notice the axis along which the sediment changes from only sands, to sands and pebbles (therefore the hypothesis of a fault) (fig. 4).

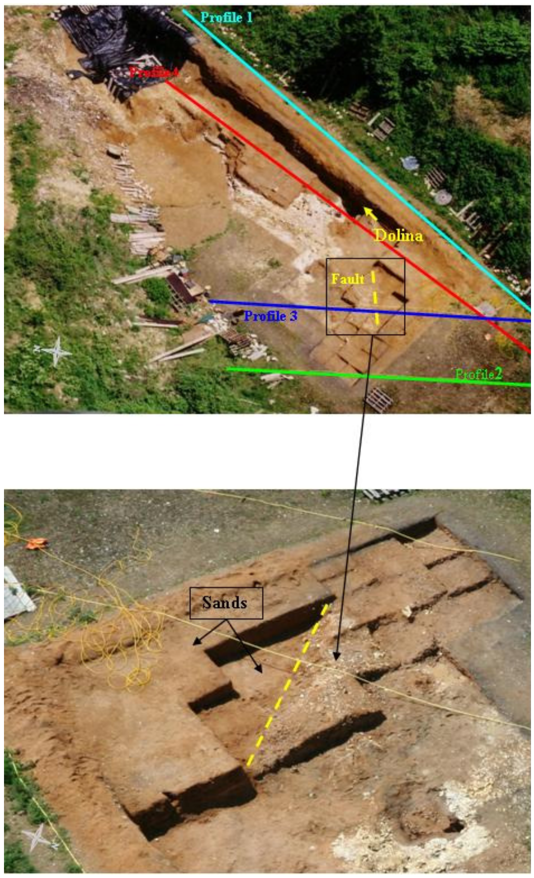

Fig. 4. Profiles layout.

Profile 1 results offer a large conductivity area where the dolina was seen in surface, showing a depth of at least 5 m (fig. 5).

Panel 4 shows the horizontality of the limestone basement (thanks to the already existing test drillings that has calibrated our results, we know that the contact between the sediments and the limestone is in between 90-100 ohm.m) (fig. 5). This panel shows also the possible doline, with more than 5 m depth of conductive sediments.

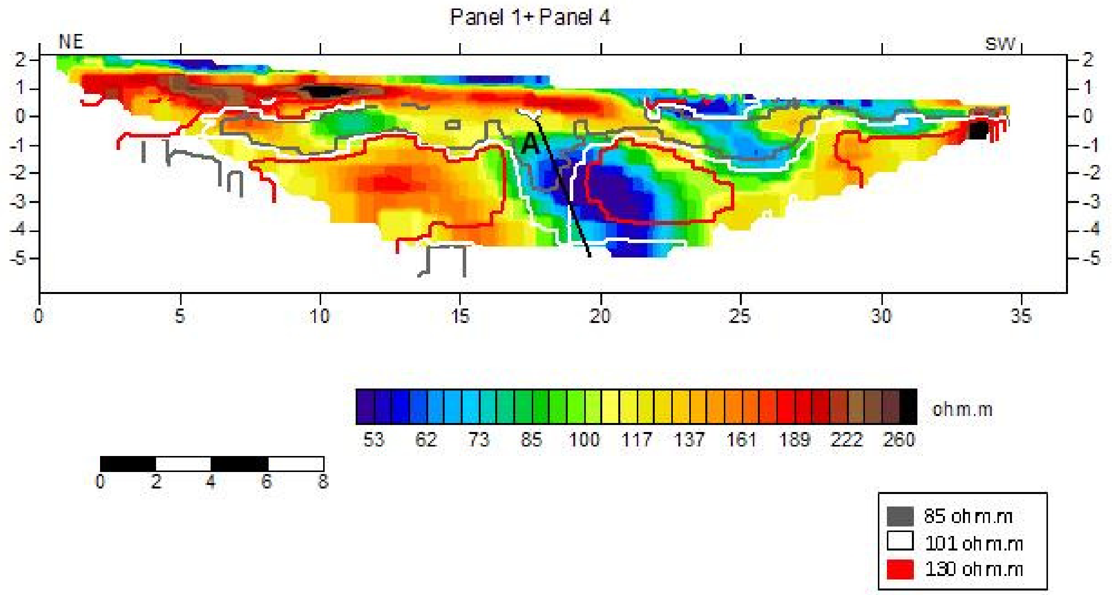

Fig.5. Panel 1+ Panel 4. A: marks the filling direction

Since these two profiles were parallels, we have overlapped both profiles. The result is that the low resistivity area matches up, even if it seems to have a N-S direction (fig. 5).

Profile 3, that crossed the possible fault, was not able to validate this hypothesis. In fact, at the « fault's » level, a horizontal orientation of the subsoil is shown. Nevertheless, we notice a large pit filled of conductive materials (fig. 6). Unfortunately, this part of the excavation does not have any control element (in other words, it is not excavated), so we do not know if it is part of the terrain karstification, or if it is rather a non in situ area (specially if we bear in mind that this was the place were the lorries passed when the quarry operated).

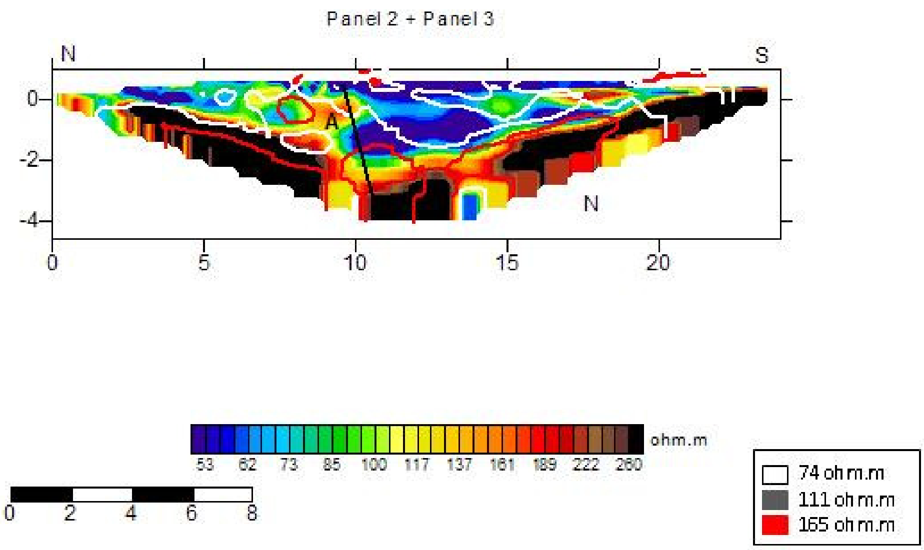

Fig. 6. Panel 2 + Panel 3

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Panel 2, parallel to number 3, presents a structure that, if it had been over the possible fault, we could have interpreted as a graben (fig. 6). This profile crossed past over the fault's prologation, were the contact between those sediments is not visible in surface.

As before, we have overlapped both profiles and the possible filled depressions, and they do match up (fig. 6). However, as said before, this is a non excavated area, so there are no control elements that help a better interpretation.

Discussion

In order to check the results, we made some simple but efective manual test drillings. Regarding the doline, as its excavation did not find its bottom, a 2 m long metallic bar was introduced in the subsoil. Neither this touched the bottom. So, if we attend to the panel results, it will be correct to estimate that this « channel » may be, at least, 5 m deep.

The "fault", that the panels did not notice, was also rejected when the test drillings were done: at both sides of the contact between only sands and pebbles and sands, the limestone base was found at the same depth. So, the new hypothesis is that this might rather be sediments that descended in a block by solifluxion, what fits with the other glacial-interglacial witness.

The other areas filled of conductive sediments could not be verified as they are supposedly located beneath a very packed soil, where a hand test drilling is impossible. However, we extended the nearest existing test drilling. This, found the limestone base at more or less the same depth at which it is found in the rest of the site, but as it was not exactly over the profile's edge, we cannot rule out the hypothesis. In any case, we have to bear in mind that this was the area were the quarry lorries passed, and so this anomaly might have an anthropic origin.

Conclusions

A detailed geological and sedimentological observation was crucial in order to interpret which resistivities correspond to each material. In this particular case, only by directly observing the limestone state, we have been able to attribute to it so low resistivity values.

It has also been a good decision to carry out manual test drillings, which have allowed to calibrate and to verify hypothesis. Without both things it would have been almost impossible to have a correct idea of subsoil's structures.

This confirms, that the used method is adequate, as in prehistoric archaeology there are no materials sensitive of being found by other geophysical methods. Indeed, it is a geological study, applied for the better understanding of a site.

In short, we have now an idea of the oganization of the site's subsoil. Karstification should have had place before the basement deposition, as this appears in horizontal layers.
Finally, it has to be mention that an interaction between geophysics and archaeology is necessary, so that the initial approach is correct and results can be exploited to the maximum.

Acknowledgements

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