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Snapshots concerning the role of archaeology/archaeometry in the birth and progress of geophysical exploration

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FIRST SNAPSHOT

Following a series of tests made in the basement of the Ecole Nationale des Mines in Paris, Conrad Schlumberger carried out his first field test in September 1912, establishing the distribution of an electric potential at the ground surface when a direct current was injected through two electrodes (A and B in Fig. 1) (Schlumberger 1912). This test represented the true groundwork for the development of applied geophysics. Conrad Schlumberger had no specific interest in archaeology, since his aim was to describe the geological structure of the underground for mining applications. However, this initial experiment was carried out on an archaeological site: that of the Val Richer abbey in Normandy (France), which at the time was his family domain. This was the first Cistercian abbey in Normandy. It was founded in 1146 and stood until the French Revolution, at which time the religious wings of the buildings were destroyed and their stones sold, leaving only the abode and the barns untouched. In 1836, the property was purchased by François Guizot (historian, minister of state education and prime minister). His granddaughter, Marguerite de Witt, who was Conrad Schlumberger's mother, inherited the domain. Thus, the first experiment in geophysical exploration, which was not intended to be an archaeological survey, was in fact made on an archaeological site. Figure 1 shows a superposition of the 1912 voltage contours and the 2014 resistivity measurements.

SECOND SNAPSHOT

As electrical resistivity is known to be the ground's most variable physical property, it is logical to apply the DC resistivity method to archaeological prospection. However, the use of this technique is restricted by the need for a sufficiently good galvanic contact between the electrodes and the soil. As in mining prospection, researchers turned their attention towards electromagnetic induction (EMI)

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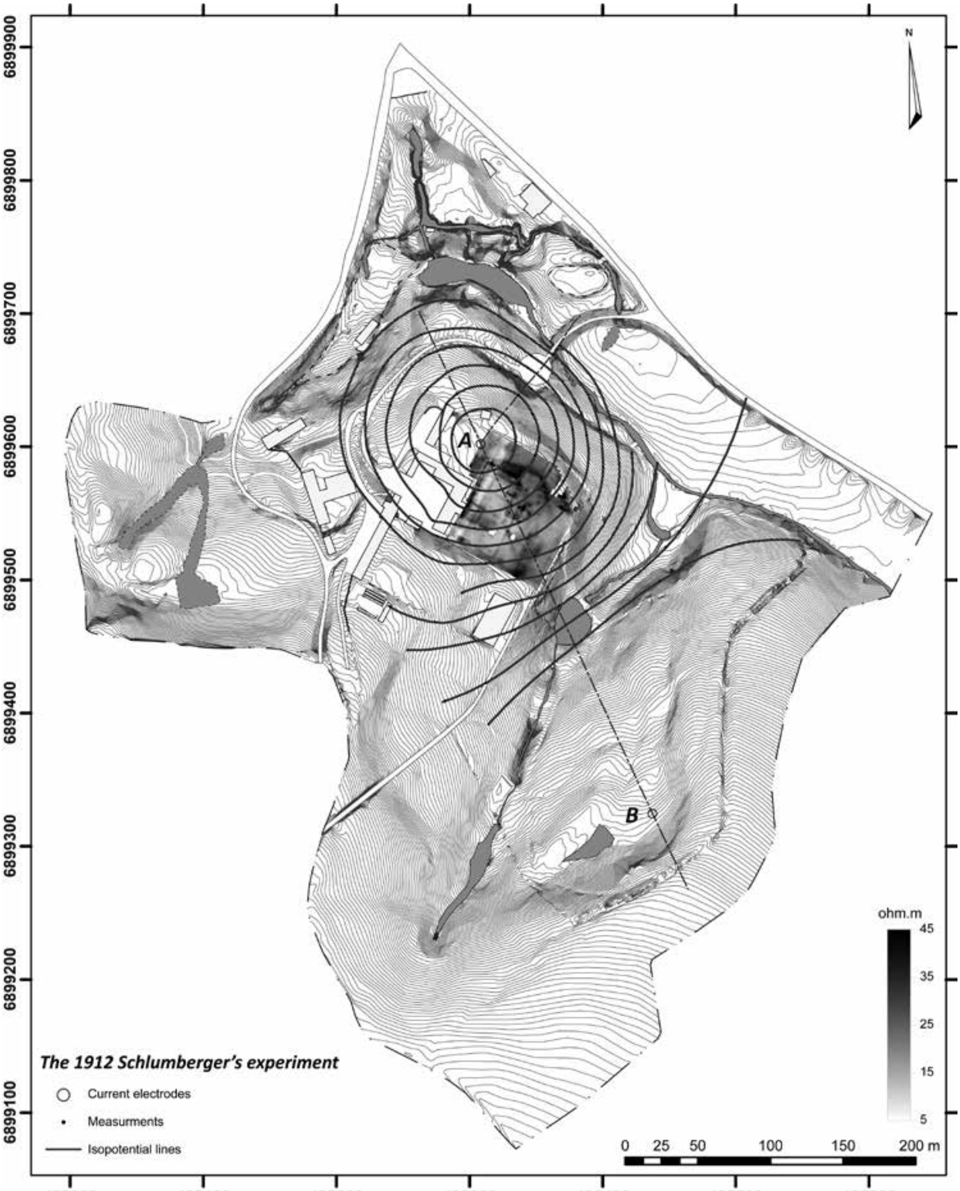

Fig. 1. Val Richer (Calvados, France). Superposition of the terrain elevation, building position, 1912 voltage contours drawn by Conrad Schlumberger and 2014 resistivity map (topographic survey: J.-B. Vincent; geophysical survey: G. Hulin, A. Tabbagh)

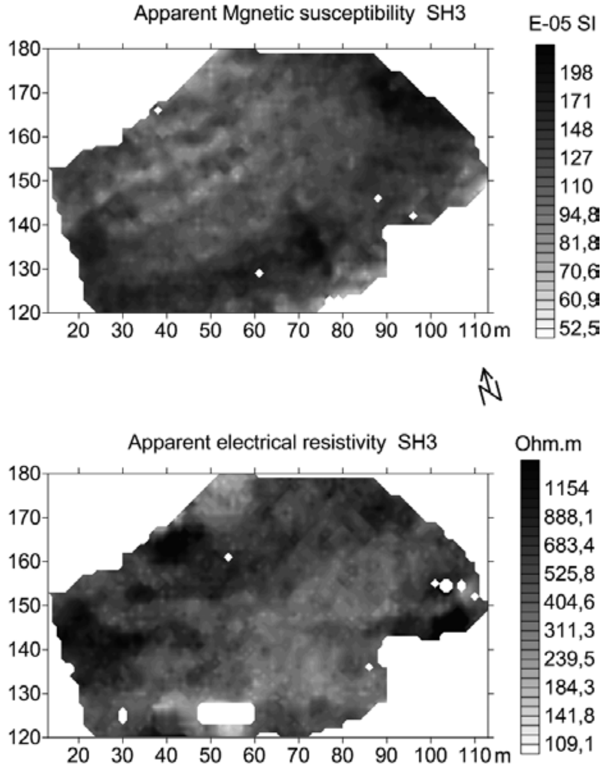

Fig. 2. Camp de Bierre (Merri, Orne, France) Late Bronze Age site. Apparent resistivity and apparent susceptibility maps measured using the SH3 instrument (1.5 m coil separation, PARA coil orientation)

techniques in order to overcome this limitation, and using Wait's theoretical formulas (1958), Scollar (1962) defined the characteristics of a matched apparatus. When EMI instruments were tested on archaeological sites using both frequency domain (FDEM) and time domain (TDEM) devices, a correlation was observed with the magnetic measurements but not with the resistivity measurements; the ground's magnetic properties were found to dominate the responses (Tite and Mullins 1969; Colani and Aitken 1966). In the case of FDEM instruments, it was recognized that electrical conductivity measurements can be made by taking the phase of the secondary field into account: for a commonly encountered range of soil conductivities and instruments with metric dimensions, the induction number can be much smaller than unity if the frequency is lower than 100 kHz (the induction number, $\sigma\mu\omega L^2$, is the product of conductivity, magnetic permeability, angular frequency and characteristic geometric dimension of the device). The conductivity response is thus in-phase quadrature, and the in-phase magnetic susceptibility can be determined from the in-phase response. The SH3 instrument (Parchas and Tabbagh 1978) successfully performed these two simultaneous measurements (Fig. 2). Later, exploration geophysicists working in mining prospection recognized the presence and significance of the magnetic component of EM responses, which allowed signifi-

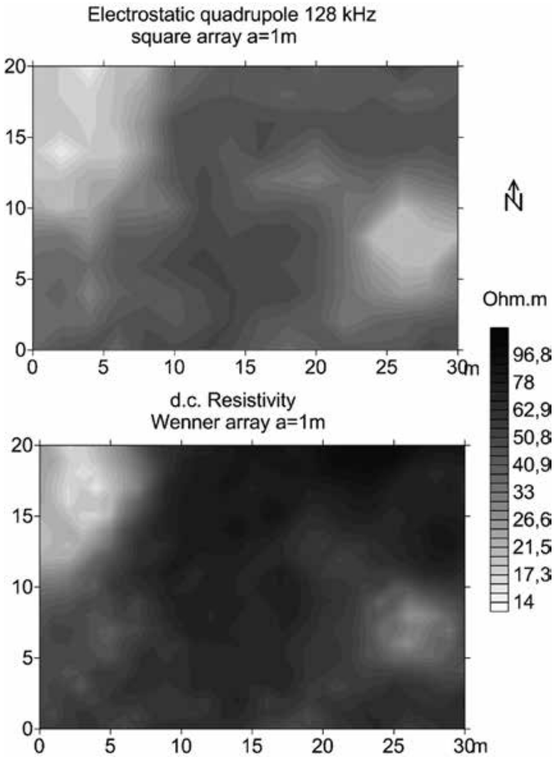

Fig. 3. Garchy (Nièvre, France) test site. Comparison between the resistivity map obtained with a 1 m square array, using the direct current resistivity method, and the resistivity map obtained with an electrostatic quadrupole of the same geometry at a frequency of 128 kHz

cant improvements to be achieved in the interpretation of both FDEM and TDEM signals (Buselli 1982; Beard and Nyquist 1988).

Instruments of this class are thus able to simultaneously measure and map two independent properties: electrical resistivity and magnetic susceptibility. They also open new paths for a joint interpretation of these susceptibility maps and the earth magnetic field variations recorded using the magnetic method.

THIRD SNAPSHOT

Although the EMI instruments provide a solution to the galvanic contact limitation, they fail to produce good results in contexts of high ground resistivity, and suffer from major disturbances in the presence of any metal. Other solution(s) thus merit consideration. An electric field can be produced directly by an open capacitor, of which the first plate carries an electrostatic charge +Q and the second plate has an electrostatic charge –Q. However, when such a field source is placed near the ground surface, a series of questions arises: what is the field distribution inside the ground, which property(ies): electrical conductivity, σ, and/or dielectric permittivity, ε, intervene, what are the roles played by the clearance above the ground's surface and the frequency? To answer these questions, theoretical approaches were adopted based on the image method (quasi-static assumption) and Maxwell's equations, and a quadrupole device was built, comprising two open capacitors, of which the first generated an electric field, and the other was used to measure the resulting voltage difference. The results of the first experiments made in 1988 are presented in Fig. 3 (Grard and Tabbagh 1991). Both experiments and theory allowed us to establish that when the induction number remains low and the displacement currents negligible, $\sigma >> \varepsilon\omega$, the results and the interpretation process are the same as for the direct current resistivity method. This electrostatic method (also called capacitive resistivity) opens up considerable possibilities for the surveying of urban areas, as illustrated by the results obtained during the Heptastadium research project carried out in Alexandria, Egypt (Hesse *et al.* 1998; 2002).

Beside these snapshots, other innovations, for example the introduction of vertical pseudo-gradient measurements in magnetic prospection (Tite and Aitken 1962), could be raised to demonstrate the influential contribution of archaeological prospection to the progress of applied geophysics.

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